GEO ExPro

GEOSCIENCE & TECHNOLOGY EXPLAINED Vol. 3, No. 3 - 2006

www.geoexpro.com

Photo: Halfdan Carstens

Svalbard:
Visiting the Festningen Section

ExPROFILE

Iman Hill

The Seychelles:
Billions of barrels to be found?

Technology Explained:
Quantum Leap for Seismic

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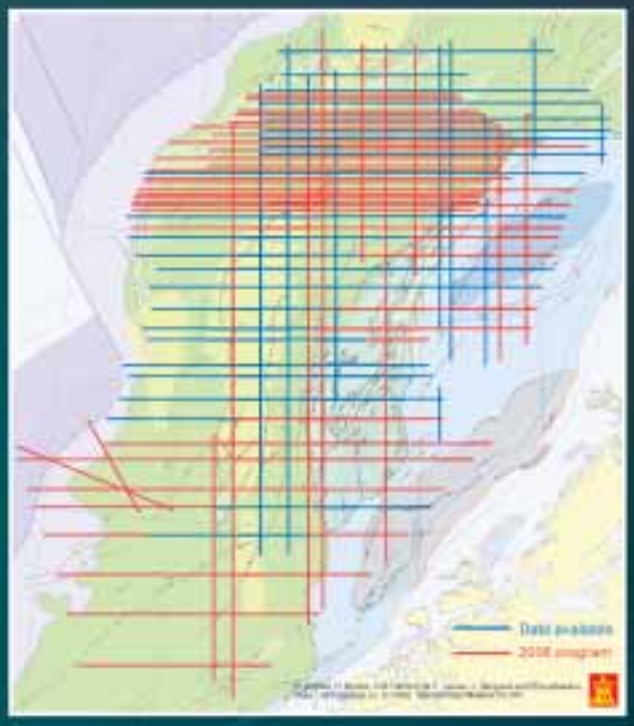

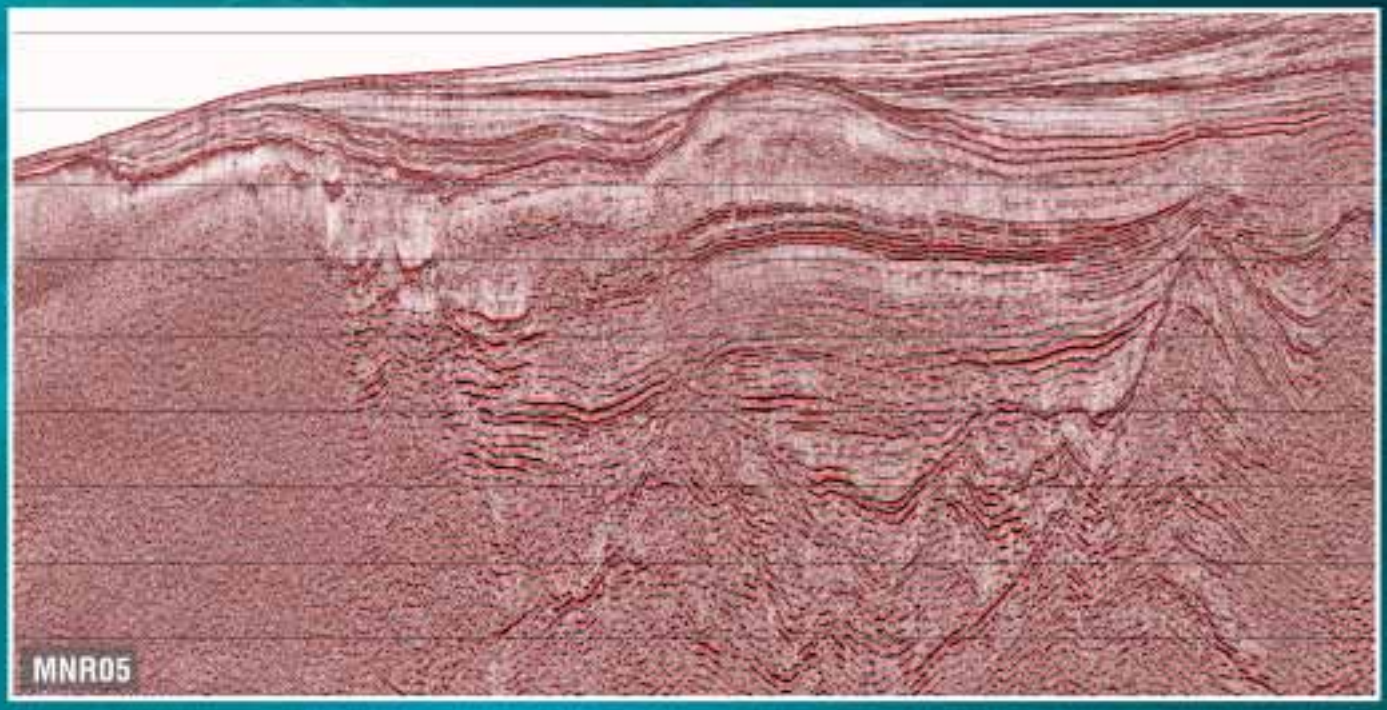

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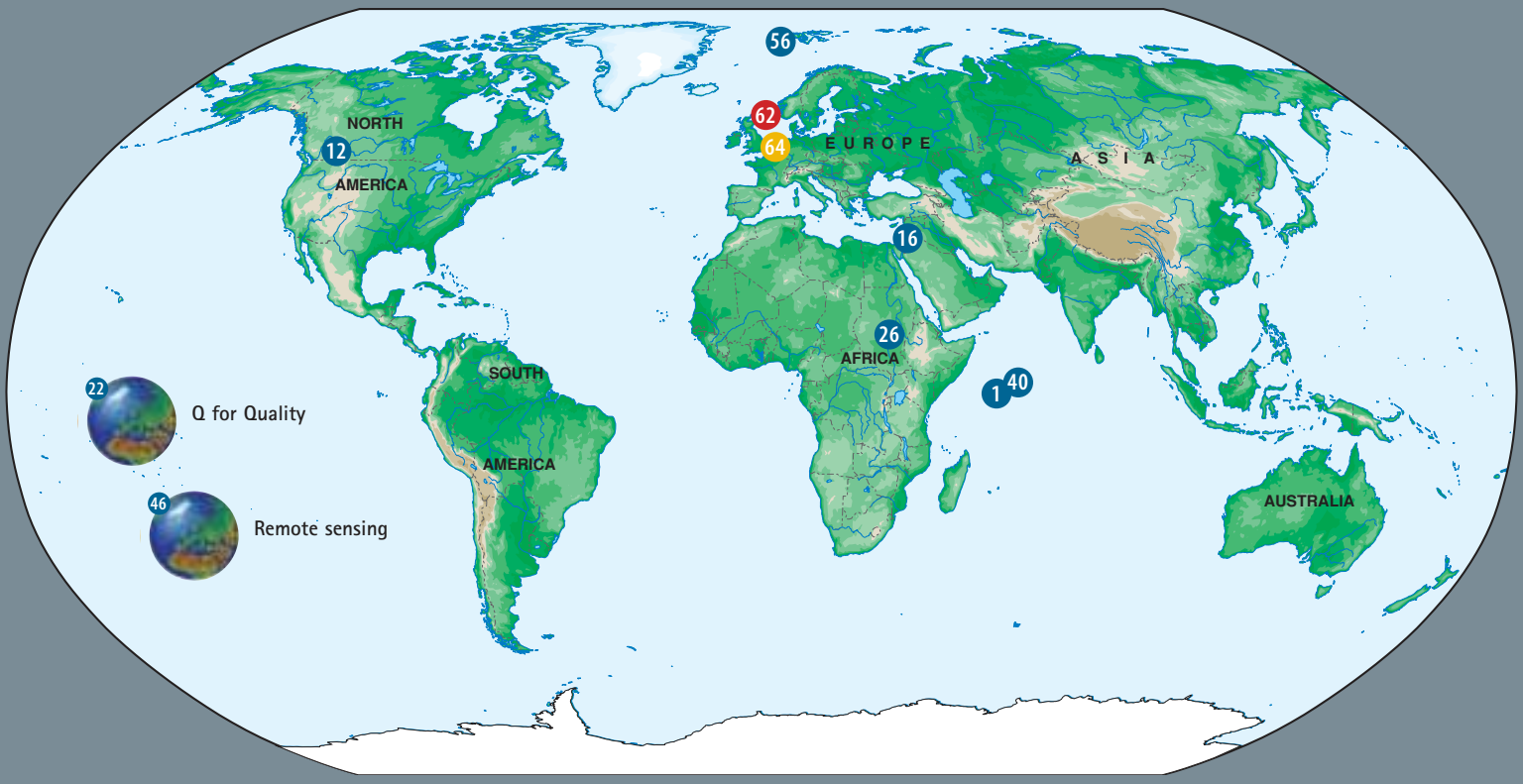
GEOSCIENCE & TECHNOLOGY EXPLAINED Vol. 3, No. 3 - 2006

Coloumns

Features

Eager to Explore
The Syrian authorities are now actively encouraging international oil companies to acquire acreage and drill for oil and gas. Later this year, an offshore licensing round will also be announced.

Q for Quality
The Q-Marine technology was developed in the Oslo Technology Centre, and their staff is proud of having been crucial in the development of seismic technology that has given oil companies value for money.



Logging without drilling

For 75 years the industry's benchmark hydrocarbon indicator has been subsurface resistivity. But, until now, this important formation property could only be acquired by logging wells after drilling had commenced. Without resistivity data to guide exploration decisions, only one in every four exploration wells has been an economic success.

emgs developed seabed logging to find offshore hydrocarbons by remotely measuring reservoir-scale resistivity contrasts. Today, subsurface resistivity can be found without drilling.

As rig and seismic-vessel utilisation reach record levels and a limited number of oilfield professionals strive to meet exploration goals, operators have been quick to adopt seabed logging to focus their finite resources on pursuing the best prospects. Recent announcements have confirmed several major discoveries in Europe and Southeast Asia that were predicted by the technique before drilling. Some licensing authorities now require successful bidders to conduct seabed logging over selected blocks, and will accept drill-or-drop decisions based on seabed-logging surveys.

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How much oil?

Read this carefully (adapted from 'BP Statistical Review of World Energy'): "Proven reserves is the estimated quantities of oil which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under current economic and operating conditions."

Note in particular the last few words: **"under current economic and operating conditions"**.

The ongoing discussion about "peak oil" (see also page 66) is about how much oil is left to be produced, i.e. the world oil reserves, and the actual price of oil. The big difference under the **current economic conditions** is that the price of oil has quadrupled compared to only a few years ago.

It is my allegation that the definition referred to above should increase the world's oil and gas reserves considerably compared to many of today's conservative estimates. There are – at least – four reasons for this. First, small fields that were previously considered uneconomic are now highly profitable. Second, larger fields that were previously considered uneconomic are now healthy investments because new and innovative technology have made it possible to recover the oil. Third, improved oil recovery has the potential to increase the output from many large and giant fields. Fourth, vast deposits of unconventional oil (heavy oil, oil sands, shale oil) are turning profitable because the price of the product is now higher than the cost of producing it.

Photo: Halfdan Carstens

The proof of the above statements, to name a few examples, lies in the interest of the oil companies to invest in the development of small fields, ultradeep water, the Canadian oil sands and the huge deposits of oil shales in Utah, Colorado and Wyoming of the United States.

Why then are the official estimates of the world's oil reserves not being changed in line with the new regime?

In my mind, the time is now right – based on the higher oil prices – to revise our estimates of the world's oil reserves. I am very curious to know who will have the courage to make a new and radically higher estimate than some of today's low numbers.

I am eagerly waiting for the BP report on world energy for 2005.

Halfdan Carstens
Editor in Chief

Photo: Eddie Belle

A Frontier Province

The Seychelles constitutes a frontier geological province with respect to hydrocarbon exploration. The data acquired so far suggests that the sedimentary basins contain all necessary ingredients to make this huge area an oil province.

The government of the Seychelles has recognised the importance the discovery of petroleum would have on the economic objectives and has put in place the required structure to facilitate exploration and eventual production within its maritime boundaries.

Granitic rocks exposed on the islands – as illustrated on the front cover photo – give no clue as to the presence of oil and gas. Plate reconstructions do, however, confirm that the Seychelles platform area is a drowned microfragment of Gondwanaland, a supercontinent that lay to the south of the Tethys Ocean 225 million years ago. At this time the Seychelles is understood to have been conjugate to both Northern Madagascar and India where billons of barrels have been discovered.

Plate reconstructions nicely show the geological closeness of the proven petroleum systems to both India and Madagascar making the Seychelles an attractive objective.

Photo: Eddie Belle

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Trading assets on the web

Terry Jackson, with EZDataRoom ("easy data room"), is eager to demonstrate the new software that the company claims will make asset divestments much more time and cost efficient. "The problem with the traditional data room method is two-fold: a) the time allowed to review the legal, commercial and technical data, usually about 2-days, is not long when you consider the millions of dollars at stake and b) the cost of hosting a string of 2-day data rooms mounts up very fast when everything is taken into account. The industry needs a better way," he says.

"A project in EZDataRoom extends the data review period to as long as the seller wants, be it weeks or months. EZDataRoom can virtually eliminate the traditional data room saving considerable time and costs for the hosting company," says Terry Jackson. He goes on to stress that "face to face meetings between sellers and buyers are still vital. They cannot be replaced since it is important for relationship building and getting the 'deal' concepts across".

"EZDataRoom is an online service for companies wishing to farm-out or sell oil and gas assets. With this software everything can be included in one centralised site and viewed remotely via the Internet without ever downloading a file. Nobody has ever done anything similar to this before," Jackson explains. "Our charges are also substantially lower than other suppliers of online data rooms," he claims.

EZDataRoom was launched in January 2005. As usual the oil industry, being very conservative, took five months to get the first project off the ground. Things have changed, however, and they are now selling by recommendation.

Jackson says that a typical scenario is developing for EZDataRoom. The face-to-face meetings are still happening and the interested parties are being shown that all the information is available online. The review is being carried out, not in the seller's office, but from the interested parties office online over the Internet where a multi-discipline team can dip in and out of the data room over an extended period. Feedback indicates that serious investors study a prospect for longer, ask questions and request downloads whilst the other companies drop out saving time and resources for the selling company.

Asked how EZDataRoom was different, Jackson answered: "It's the unique features of the software. With EZDataRoom you do not need to download a file to view it. Not only is this a good security feature but it also means that incredibility large files can be viewed virtually instantly. For example, a 3D seismic in segy format is large but with EZDataRoom a user can view and manipulate the file live and interactively. They can change a host of viewing parameters, generate cross lines on the fly and even print remotely, if permission has been granted. The same can be done for well logs. In addition office documents such as Word, Excel, PowerPoint, PDF files plus a wide range of graphics files are handled, without reformatting, in the same way. The remote users do not need any special software or plug-ins, the whole thing works using a standard web browser. It's efficient, convenient and powerful."

Another key feature is the online Presentation and Conferencing tools included with the software. This enables the seller to give live presentations of anything within the data room to anyone wherever they are located in the world. The conference facilities enable online queries to be sorted out with both participants looking at the same data. This cuts down on travelling and wasted time.

"EZDataRoom is not meant as a complete replacement for traditional data rooms. Instead, it is a compliment to this relationship building process by providing a more convenient and longer review period for potential trading partners," Jackson says.

"This is a new way of doing asset deals. We use technology to provide a useful service that benefits both buyers and sellers whilst saving a lot of travelling time," concludes Terry Jackson.

ABBREVIATIONS

Numbers
(U.S. and scientific community)

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

Liquids
barrel = bbl = 159 litre
bopd: bbls of oil per day
bcpd: bbls of condensate per day
bwpd: bbls of water per day

Gas
mmscfg: million ft^3 gas
mmscmg: million m^3 gas

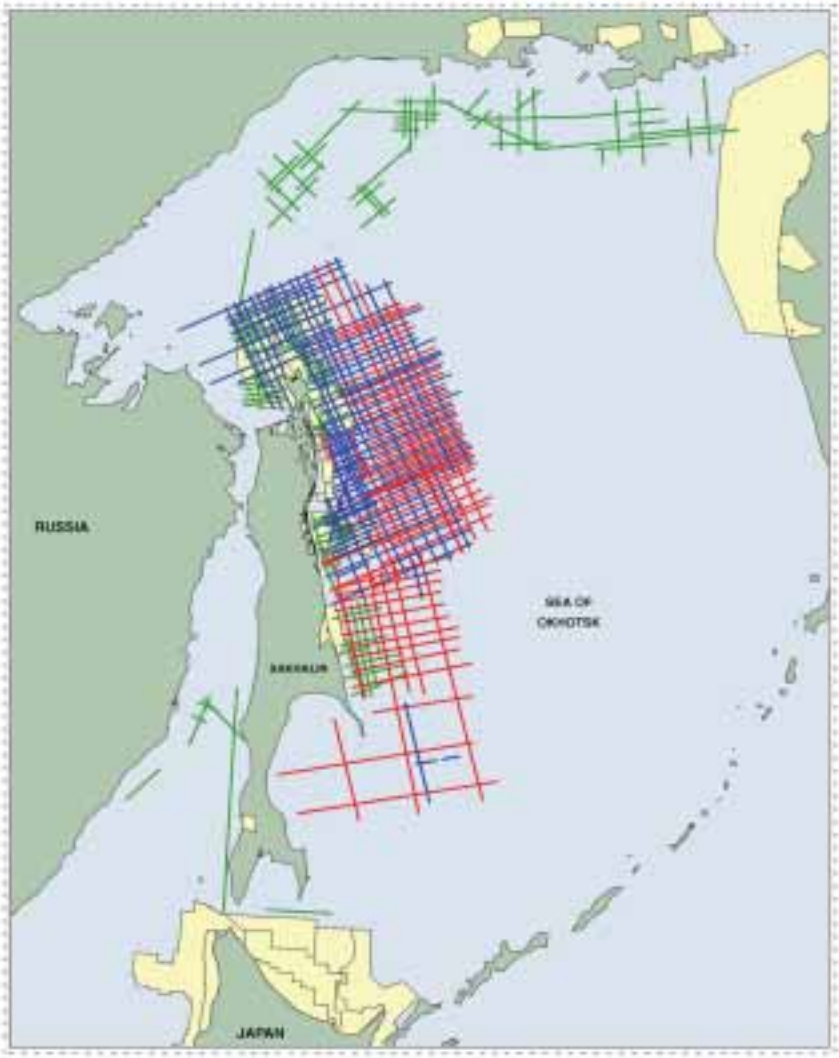
NGL
Natural gas liquids (NGL) include propane, butane, pentane, hexane and heptane, but not methane and ethane.

Reserves and resources
STOOIP:
Stock Tank Oil Originally in Place

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

Balanced Rock. Sculpturing in the Arches National Park, Utah, USA. The softer Dewey Bridge Member mudstone below weathers more quickly than the hard, resistant Slick Rock Member above.

EXPLORATION IN THE SEA OF OKHOTSK ?



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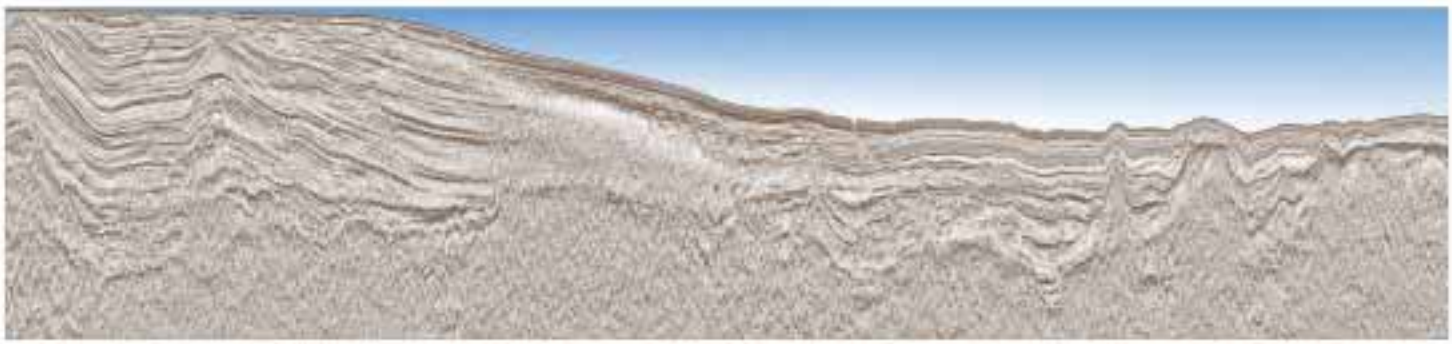

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New Orleans, a city of past and present history

New Orleans is one of the most unique cities in the United States and one with a fascinating culture and history. Many different influences - Cajun, Creole, and southern U.S., in particular - combined with the most European ambience of any major U.S. city to produce an original, unmistakable and world-famous mixture of culture, food, music, and architecture.

Today, our perception of legendary New Orleans is tempered with our questions, many unanswered, regarding how significantly the city has recovered from devastating hurricanes last August. It can definitely be reported that the part of the city that contains the convention center and the major logistical venues associated with a major event such as SEG's Annual Meeting (the hotels, restaurants and French Quarter) have recovered nicely and are functioning as professionally as ever.

The SEG Executive Committee recently held a regularly scheduled meeting in New Orleans to conduct its routine business and to see first hand how things were progressing. The results of this tour of the French Quarter, Warehouse District, convention center and many of the hotels to be used during the annual meeting revealed business as usual. All of the hotels were open. The number of rescue workers staying in the hotels is going down and the number of tourists is going up.

The convention center has been completely refurbished from top to bottom and resumed holding meetings in April. The city assures us that they will be ready for SEG in October, and there appears to be solid evidence supporting this confidence.

We are glad to report that our early indications forecast a meeting of similar dimensions to recent SEG conventions. The technical program received over 800 submissions, almost identical to same number submitted for the 75th anniversary convention in Houston in 2005. The Applied Science Program will include a presentation by one of the world's leading astronomers - Richard Binzel, professor of Planetary Science in the Department of Earth, Atmospheric and Planetary Sciences at MIT and a widely recognized expert on Pluto and the asteroids.

The Society of Exploration Geophysicists is an international organization with over 25,000 members who live and/or work in well over 100 countries. SEG's annual meeting has long been the world's leading showplace for state-of-the-art geophysical instrumentation, and booth sales indicate the exhibition flow with again be overflowing with examples of the equipment that makes geophysics one of the world's most "high-tech" industries.

In conclusion, all systems are "go" for our meeting in New Orleans in October. We anticipate the registration, the quality of the technical program, and the number of exhibiting companies will be similar to the levels of recent, highly successful, SEG annual meetings. It is a position that, frankly, we did not anticipate a few months ago when it seemed unlikely that New Orleans could possibly rebuild its infrastructure in time to support a meeting of our size. But New Orleans has managed this minor miracle and we are excited to be part of re-establishing this unique place as one of the world's great cities.

Stephen Emery
Society of Exploration Geophysicists

NGF MEMBERS!

Members of NGF (Norsk Geologisk Forening/ The Geological Society of Norway) are offered a free subscription of GEO ExPro 2006 as part of their membership. If you would like to register, please write an e-mail to halfdan.carstrens@geoexpro.com.
If you want to register as a member of NGF, check www.geologi.no.

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ACTIVITIES

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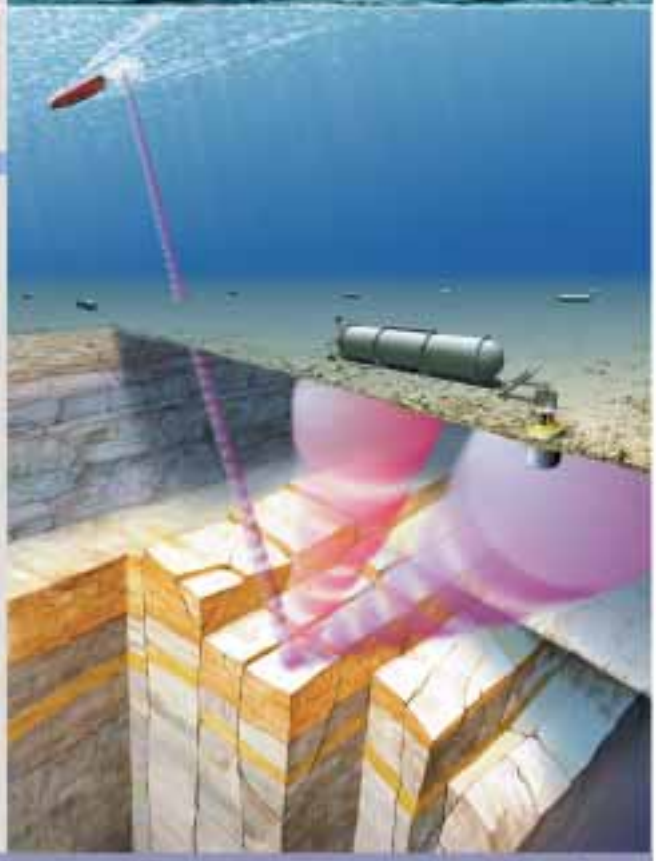
- Survey Design
- 4C Acquisitions
- Processing
- Interpretation



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SeaBird to acquire SeaBed

SeaBird Exploration Limited (SeaBird), a global provider of 2D and 3D seismic data and associated products and services to the oil and gas industry, has reached an agreement to acquire **SeaBed** Geophysical AS.

SeaBed is a geophysical company that specializes in seabed seismic. Main concept is to deploy geophone sensor nodes into the seabed and acquire high quality multi-component data. SeaBed can provide all aspects of seabed seismic; feasibility studies and pre-survey planning, data acquisition, on site QC, minor data processing and interpretation.

The objective of SeaBed is to provide services to the oil industry in order to reduce the economic risks in the exploration phase and reduce uncertainties related to reservoir description, fluid-flow and reservoir management. With the industry's strong demands for a reduction in field development and operating costs, improved technology and techniques are absolutely necessary. The concept of acquiring high quality pressure and shear wave data on the seabed will have a great impact by reducing costs and giving higher production on existing and new fields.

SeaBed's strategy has been to develop innovative and cost efficient solutions that can meet each client's specific needs and requirements. The flexibility available in the use of this highly target oriented data acquisition method make it well suited for application in exploration prospecting, reservoir description and reservoir monitoring. The company has developed solutions for the seabed acquisition of 2D, 3D as well as 4D multimode pressure and shear wave data.

SeaBird Exploration Limited specializes in high quality operations within the high end of the source vessel and 2D market, as well as in the shallow water 2D/3D market. Main focus for the company is proprietary seismic surveys (contract seismic). SeaBird does not have a multi-client data library. SeaBird operates a seismic fleet of 4 vessels with two additional vessels under conversion with expected completion during the first half of 2006.

"We have been keeping an eye on the company for years and felt that the time to do something was right. SeaBird shot the successful SeaBed survey on the Cantarell field for Pemex in 2004 (**GEO ExPro No. 2, 2004**), so we know them very well. We are excited to get into the Ocean Bottom Seismic (OBS) market, and are confident that this will grow into a profitable addition to our range of services," says Mr. Tim Isden, Chairman of SBX.

"It is positive to have an owner that has ambition and industry understanding as well as access to vessel capacity in a very tight market," says SeaBed founder and inventor Eivind Berg. He is also pleased to get an owner that supplements the copmpany on QHSE, operational experience and business development.

Increased capacity for multi component seabed data acquisition

The timing looks good for RXT: "As for the towed streamer market there is an excess of demand over supply for multi component seabed seismic which has resulted in a number of programs being delayed from 2006 to 2007" says Chris Walker, VP of Geophysics for RXT and continues; "The ocean bottom cable market, especially 4C, is focused more towards production than exploration so we anticipate that with the superior imaging capabilities of the VectorSeis Ocean OBC system and the increased cost-effectiveness of our operations, demand will continue to be strong even if the current exploration driven activity "boom" comes to an end."

On Friday April 28th Reservoir Exploration Technology (RXT) took over their new OBC vessel Ocean Pearl during a ceremony in Stavanger. This will be the first time multi component data will be acquired with only one vessel with both cable/buoy handling and the seismic source operated from the Ocean Pearl. The vessel is configured to deploy/recover the VSO cables and buoys as well as dual 4000+ cu. in. seismic sources. It is equipped to handle 12 cables – double that of any other OBC vessel. The new vessel, built in 1997, is owned by the Shipman group and has been converted from a cable-laying vessel by Rosenberg Shipyard.

Until now RXT has been operating their first crew in the Gulf of Mexico, a dual vessel operation comprising a shooting vessel - the m/v Beulah Chouest - and a cable/buoy handler - the M/V Bourbon. Their GOM operations started in June 2004.

The vessel-rigging boom currently experienced in the towed streamer market is not found in the seabed seismic segment. With the new vessels coming this year and the ones planned for 2007 and 2008 an increase in the order of 30% is expected in the global towed streamer fleet. For seabed seismic, Ocean Pearl appears to represent the only new capacity currently being introduced. WesternGeco is an important player in the multi component market promoting their Q-Seabed technology. PGS, on the other hand, recently decided to pull out of the seabed market and converted their vessels for towed streamer operations. Node based ocean bottom seismic acquisition is offered by Fairfield and SeaBed Geophysical. RXT, however, has already secured funding for their third crew, which is planned to be in operations in Q1 2007.

For the North West European market RXT has announced that they have been awarded a contract for acquisition of 4C seismic data for BP on their Clair Field west of Shetland and that they have received a letter of intent from Statoil for acquisition of 4C seismic data on the Norwegian Continental Shelf. This will keep Ocean Pearl busy through the 2006 North Sea season.

Doing it alone

In 1988 Mark Sun looked into the future and asked himself a question. "Is this what I want to do with the rest of my life – and is this the best way to do it?"

The inspiration for this life-changing moment was the realisation that the interpretive software tools that he was using as a young explorationist with Suncorp in Calgary did not work as well as he thought they should. Investigating why the software did not seem to make sense or even undertake many common tasks, he realised that programs written by non-explorationists would never fully satisfy the needs of the interpreter.

A keen 'hacker' in his youth, Mark felt he could produce a better product. As he puts it "I wanted to do something more creative with my life, working when, where and how I liked. Why not make life easier for other geoscientists while I'm about it?" So in 1989 he sold his house and bought a workstation with the proceeds. He moved from Calgary back to his parents' basement in Vancouver and set about developing his product. Two years later he sold his first commercial workstation, and both he and his product have been developing ever since.

Real Time Interpretation

Mark's innovative product is the EarthWorks Exploration System, which combines the power of an interpretive workstation with real time processing technology. It includes all the features needed for full prospect analysis, from picking horizons and simple mapping, to complex zero offset modelling and fault association and visualisation. The system usually uses two monitors, with seismic data on one and the mapping application on the other. As the seismic is picked, filtered or manipulated on one screen, the map can be seen on the other screen, automatically re-gridding, contouring or re-imaging the data.

"It is an intuitive, menu driven system," Mark explains. "It allows the interpreter to adjust filters and apply tools 'on the fly' to bring out geological character. You can overlay different seismic data versions to see changes over time, or drag things around and change the character of a feature whilst looking at it. This is instant real-time analysis at the click of the mouse. I call it 'what-if interpretation'."

An important feature of the EarthWorks system that geoscientists particularly profit from is the ability to bring in pre-stack data. Mark explains this feature "Traditionally, interpreters use stacked data, where the seismic traces have been averaged to a common depth point (CDP) for each shot. But if there is any error in the processing the seismic will have the wrong character. By bringing in pre-stack data we can compare it on screen with the processed lines and see the nature of the data. It is also very important with AVO analysis and the identification of gas. The job of the geophysicist is to recommend where and where not to drill, and the more we can see, the better our information and the greater the risk reduction."

Independent and rapidly evolving product

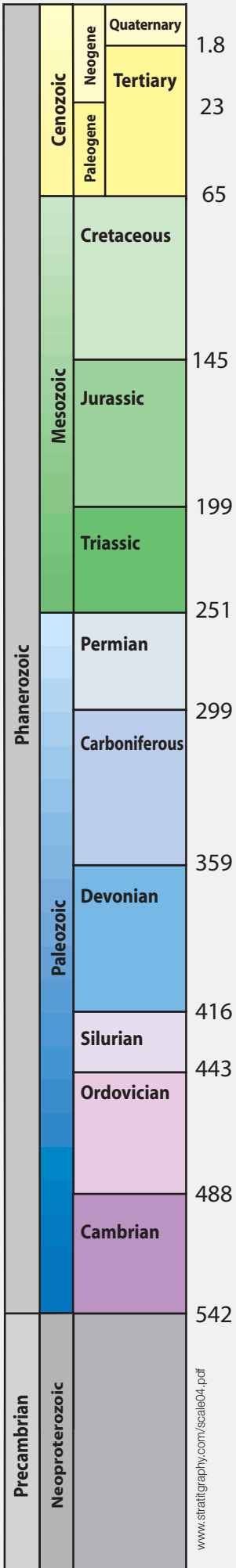
Independence is an important feature of Mark Sun's business. "Most products in the industry are hooked into the major applications, so the geophysicist has to learn individual products to solve various problems, plus spend a lot of time transferring data from one product to the next. With EarthWorks, everything is in one system, and because the system has been designed by interpreters, it is very easy for other interpreters to learn to use."

Mark Sun takes prides in the fact that the product is constantly evolving to meet customer requirements. "Having only one main software developer - myself - means we can easily update the product and add new features in a very short space of time," he says.

Mark decided early that he would design his product on "whatever hardware gave the best performance." The system is built on an operating system called OpenVMS, powered by a 64-bit HP Alpha processor, simply because this gives the most power and the fastest response. As he points out: "Many oil companies are trying to become PC-based, because PCs are cheap. But this gives short term savings. With the speed and power of a product like EarthWorks, an interpreter can save literally months of interpretation time"

Emphasis on independence also means that although his company, Genetek, is gradually growing, Mark has no intention of expanding any faster. "I want to develop the product so that it continues to solve problems for geoscientists – not because I have some venture capitalists breathing down my neck."

Jane Whaley



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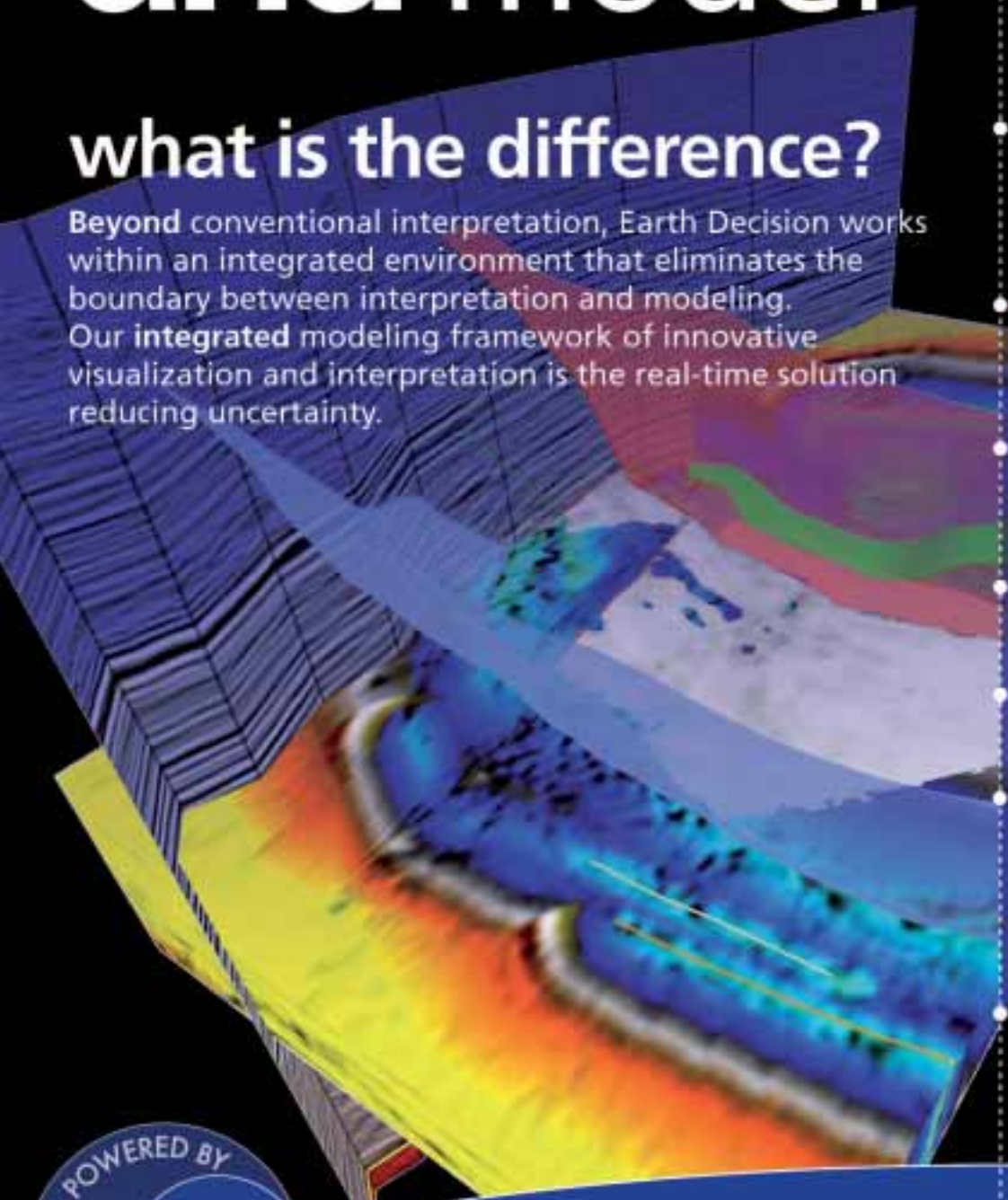

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Do you prefer chess or poker?

How much does human bias affect geological models and can we account for the uncertainty it introduces?

Dr. Clare Bond at the AAPG in Houston in April inviting geoscientists to participate in the Odin Project, an initiative to study how people use their 'prior knowledge' and concepts to interpret seismic data.

"If you put several geoscientists in front of the same dataset, you will get as many different interpretations as there are geoscientists," says Dr. Clare Bond with Midland Valley Exploration. She is using the opportunity at conferences and workshops to get geoscientists to interpret the same seismic section and answer questions about their background knowledge and personality. "Seismic data is inherently fuzzy due to the limited resolution, making it an ideal data source for assessing variations in data interpretation by individuals. These interpretations are based on differing assumptions, bias and experience. We call this 'concept uncertainty'," she says.

The Odin Project, a joint initiative between the University of Glasgow and Midland Valley Exploration, looks at how people use their 'prior knowledge' and concepts to interpret. The project uses seismic data as the experimental medium.

In order to quantify the range in interpretations of a single data set by professionals, more than 200 geoscientists from industry and academia have been asked to interpret the same seismic section. The aim is to assess the impact that such interpretations have on structural models and, ultimately, on prospectivety. An important aspect of the experiment is to know 'exactly' what the seismic section represents that people are asked to interpret – a 'Catch 22' scenario if using 'real' seismic, where the 'true' answer is unknown. The data set was therefore created using a structural modeling and restoration program in order to produce a known geological scenario. Synthetic seismic was 'shot' across the model to produce an image for interpretation.

Both statisticians and psychologists are involved in the analysis of the data. In addition to questions about technical education, background and experience, participants are asked personality type questions like; "Do you make your own decisions regardless of what other people say?", "Do you prefer chess or poker?", or "Do you read the manual or find your own way?"

The results of the initial Odin experiment will be published later this year. Already, however, some observations and preliminary conclusions are available. Initial findings suggest that people's previous experience affects both their approach and the outcome of their interpretation. The range of interpretations is huge, with only 43% of interpreters getting the tectonic setting of the seismic section correct. Interpretation styles vary from those that draw straight lines to pick discontinuities or concentrate on faults, to those that follow seismic reflections to pick horizons. These differing interpretational styles have resulted in interpretations of the single data set that can be divided into a number of tectonic regimes ranging from salt to inversion tectonics.

So far the results show that those that have worked predominantly in a particular tectonic regime have in many cases brought their experience from that regime to play in their interpretation.

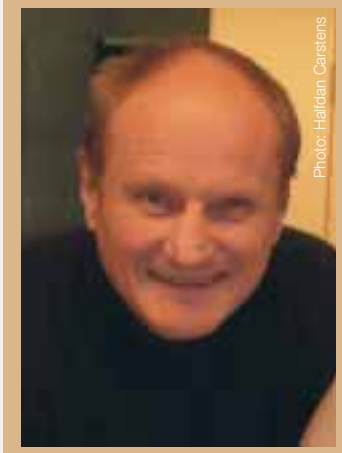
"Interestingly, length of experience alone is not a crucial factor in achieving a correct interpretation, and in many of the interpretations you can see how individuals have applied their background experience and knowledge even when there is little or no fit to the data. Understanding when use of 'prior knowledge' becomes a hindrance rather than an aid is important for optimising interpretational accuracy and minimising uncertainty. How we deal with this variability in geological interpretation of a single dataset and the processes we use to validate our geological models is clearly an important consideration when assessing productivity of petroleum reservoirs. Its important not to get hung up on the "right" and "wrong" interpretation but to understand the range and reasons for differences in the interpretation outcome and how to use this to manage risk and uncertainty." Clare explains.

emgs wins award

Electromagnetic Geoservices AS (**emgs**) has received the prestigious 2006 Hart's E&P Meritorious Engineering Award in the "exploration system" category for its seabed logging survey method (GEO ExPro No. 1/2004).

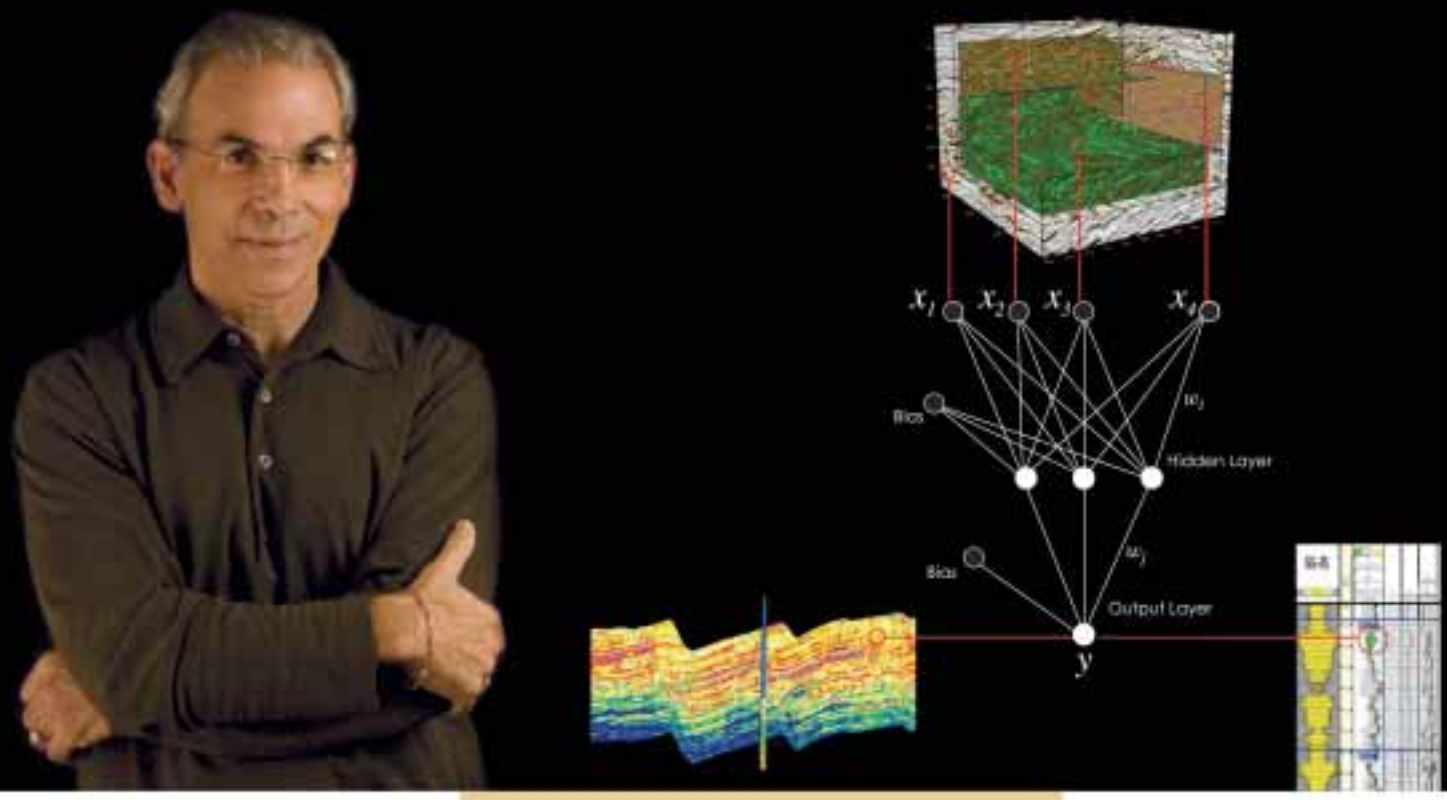
Svein Ellingsrud, vice president Research &Development, emgs, accepted the award at the Offshore Technology Conference (OTC). Thanking the panel of industry leaders who made the award, Ellingsrud noted that the commercialization of seabed logging has brought the industry a completely new type of remote-sensing survey, which is changing the face of offshore exploration.

"Identifying hydrocarbon reservoirs before drilling is improving exploration efficiency and profitability for a rapidly increasing number of operators. Recognition of our contribution by leading industry figures, in the form of this prestigious Hart's award, means a lot to everyone at emgs. The award endorses the industry's acceptance of seabed logging as a valuable offshore exploration tool," he said.



Svein Ellingsrud, VP E&P, excepted the Hart's E&P award on behalf of emgs.

THE PARADIGM CHALLENGE SERIES • #1



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C. = false acoustic boundary
D. = point scatterer
E. = all of the above

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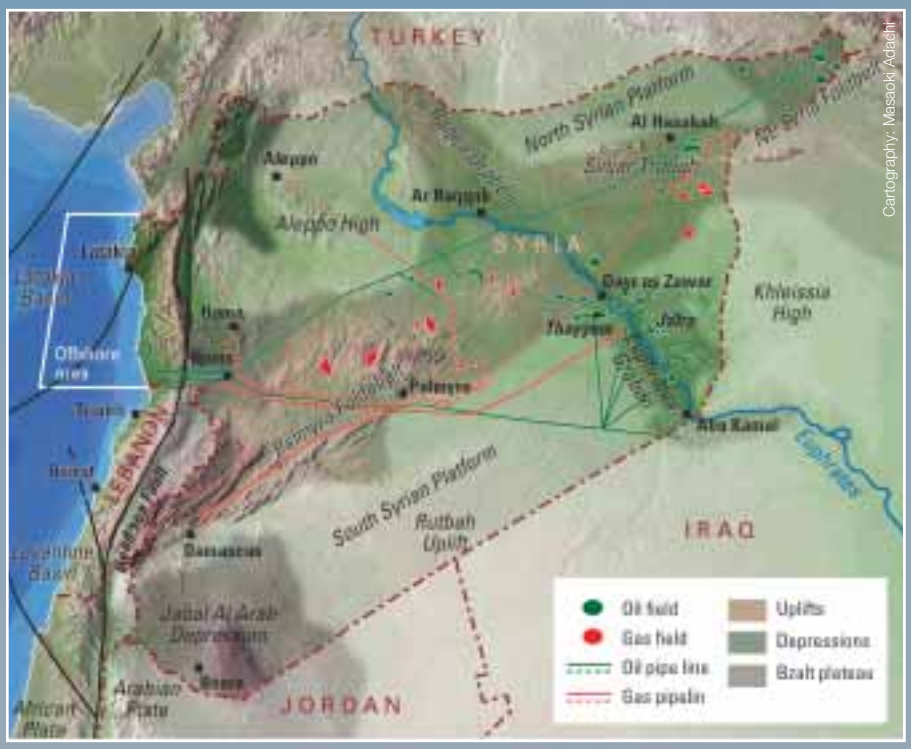
Encouraging Exploration

In the barren landscape of the Syrian desert you may find an occasional drilling rig exploring for hydrocarbons. In the years to come several more rigs are expected to enter, as the Syrian authorities are now actively encouraging international oil companies to acquire acreage and drill for oil and gas. The next frontier, however, is the offshore, where no wells have yet been sunk.

Photo: Halfdan Carstens

Altogether close to 300 exploration, appraisal and development wells have been drilled onshore Syria. The Syrian Petroleum Company has drilled more than half of them.

Photo: Halfdan Carstens



Oil and gas exploration and production has hitherto been concentrated within three geological provinces: The Palmyra Foldbelt northeast of Damascus, the Euphrates Graben along the river Euphrates, and the Sinjar area, including the Sinjar Trough and the Syria Foldbelt, close to both Iraq and Turkey in the northeastern part of the country. The Euphrates Graben is the main producing area. The coastal basins cover approximately 8,500 km^2. The geology of the sedimentary basins is poorly known as the very first commercial seismic survey was acquired in 2005 (www.inseis.com).

Facts about

Syria Arab Republic

Area: 185,000 km^2
Coastline: 193 km
Population: 19,000,000
Independence: 17 April 1946
GDP – per capita: USD 3,400
Source: The World Factbook

To date, exploration and production of hydrocarbons have taken place only in the onshore sedimentary basins. While exploration was previously largely concentrated to the deep sedimentary basins, new search for hydrocarbons has now also moved onto the platforms. The Syrian Petroleum Company is currently evaluating bids from last year's blocks offering and is now in the process of negotiating several contracts. However, approximately 65,000 km^2 is still open for licensing onshore. It was only last year that the first move towards exploring the offshore acreage was made when InSeis acquired 5000km of 2D data. Following this, an offshore licensing round is expected to be announced late this year.

Halfdan Carstens

As an oil- and gas-producing nation, Syria is certainly dwarfed by its neighbours to the east and south, including Iraq, Iran and Saudi Arabia. Nevertheless, Syria has a healthy oil production of some 500,000 bopd and gas production is steadily on the rise to meet domestic demands.

With a soaring population that is approaching 20 million people, Syria has a need to boost the production and increase the oil and gas reserves. The authorities are therefore now actively encouraging international oil companies to explore onshore. Onshore licensing rounds are being arranged with regular intervals with basic information easily available on the home page of the Syrian Petroleum Company (SPC): www.spc-sy.com.

A recently acquired seismic survey lays the corner-stone for offshore licensing. For the first time, exploration is thus moving offshore this year. The plan is to announce an offshore licensing round at the end of the year. This will open up an entirely new geological province to the oil industry.

The quest for oil

"We are eager to attract the international oil companies to carry out exploration, and this is why we are now inviting the industry to bid for acreage in licensing rounds that include blocks all over the country," says Deputy General Director and Technical Manager of SPC, Mr Omar Al-Hamad.

"This is the reason why we have made it much simpler to operate in Syria," he says. "There is no need to have an agent. Moreover, there is no requirement for upfront payments, and the system is now totally transparent," he emphasizes. This change in attitude seems to be favourable, as SPC has lately said that the latest exploration round was very successful. Altogether 13 companies made 23 bids for 9 blocks on offer. Companies from Asia, Europe, Middle East and the Americas were bidding.

The authorities are very concerned that the companies that enter Syria have the right qualifications. This is why they have adopted a system of pre-qualification. "The oil companies need to prove that they have the technical expertise. It is by no means sufficient to have the right money to invest," Al-Hamad says.

"Overall, the conditions for the international players are much better now than they use to be," he adds.

Onshore geology

Syria is part of the northern Arabian Platform that has been proximal to active plate boundaries during most of the Phanerozoic (see page 12 for Geological Time Scale). Active transform and convergent plate boundaries still surround the country, and Syria is close to the collision zone where the Arabian Plate runs into the Eurasian Plate with a speed of almost two cm per year. The convergent movements are accommodated in the Zagros fold and thrust belt in Iran and Iraq, resulting in significant shortening.

The Arabian Plate is bounded to the west and separated from the African Plate by the Dead Sea Fault System. The fault accommodates the differential northward movement between the plates caused by the opening of the Red Sea further south.

Photo: Halfdan Carstens

"Gas is now equally important as oil, partly because it is being used to replace oil in power generation" says Mr Omar Al-Hamad, Deputy General Director of SPC. "That is why we need to find more gas," he says.

The offshore acreage thus belongs to the African Plate.

Within this tectonic framework Syria can be divided into three tectonic zones (compare map on previous page): The Palmyride area, the Euphrates Fault System and the Sinjar area in northeast Syria.

The Palmyride is a Late Paleozoic/Mesozoic depocentre trending northeast across central Syria where the present topography is created by compression in the Tertiary.

The northwest-trending Euphrates Fault System, including the Euphrates Graben and the Raqqa Graben, extends fully across Syria from the Turkish border in the northwest to the Iraqi border in the southeast. It is an aborted intracontinental rift of Late Cretaceous age that has subsequently been hidden by Cenozoic burial. Approximately 100 km wide, the system comprises an extensive network of grabens and half grabens extending some 160 km. The graben is relatively unexpressed topographically because of little tectonic reactivation in the Tertiary. The Euphrates depression is a Neogenic depression, and this is also why the river Euphrates follows the graben. Proven recoverable reserves in the Euphrates area are estimated at well over 2 billion barrels of light, sweet oil.

The Abd el Aziz/Sinjar area (including the Sinjar Trough and the Synjar Foldbelt) is an anticlinorium controlled mainly by a

Photo: Halfdan Carstens

Miocene to recent black basalts cover a huge depression with more than 5,000m of sediments in southwestern Syria and northern Jordan (compare map on page 17). This basalt has been used extensively as building stones in the past and is found in ruins far to the north of Damascus.

The river Euphrates provide water for agriculture in southeast Syria. Within the same area and in the same depression some of Syria's largest oil fields are found, including Thayyem.

Photo: Halfdan Carstens

Adnan Al-Asmi, exploration manager of SPC.

major south-dipping reverse fault It is thought that the Abd el Aziz was a sedimentary basin in the Mesozoic which inverted in the Neogene, and may have been the northwestern edge of the larger Sinjar trough which existed at that time. South of Abd el Aziz, and to the north of the Euphrates, is a series of structural highs, controlled by deeply penetrating faults.

In addition to these tectonic zones, there are several stable platforms: the North Syrian Platform, the South Syrian Platform and the Aleppo High. Another important feature is the Jabal Al Arab depression that is covered by extensive basalts (the Drouz Basalt Plateau). Two dry wells have been drilled in this basin.

Dwindling oil reserves – increased gas production

The Syrian oil production peaked in 1995 with 635,000 bopd. Since then it has fallen steadily, albeit not dramatic, and in 2004 the average production was 536,000 bopd, down approximately 5% from the year before, according to the BP Statistical Review of World Energy. In comparison, Saudi Arabia, the world's leading oil producer, produced more than ten million bopd in 2004, while Yemen and Oman produced 429,000 and 785,000 bopd, respectively.

The reason for the decline is probably related to dwindling reserves of Euphrates fields that began producing in the 1980´s. Technological challenges that have not yet been overcome may also be to blame. While the production decreases, the consumption increases, partly due to the population growth that is now about 2.3%. This may cause Syria to become a net oil importer in the foreseeable future.

The main producing oil company in Syria is Al Furat Petroleum Co. (AFPC) with a production of approximately 280,000 bopd (al-Furat meaning the Euphrates). AFPC is a joint venture between the Syrian Petroleum Company (SPC), Shell and Petrocanada that started operating in 1985.

AFPC's main asset is the Thayyem oil field, which was the first field discovered in the Euphrates play in 1985, and remains one of the most prolific fields. Primary production is from the Lower Cretaceous Rutba sandstones, the most prolific reservoir in the graben, charged by Upper Cretaceous source rocks, with additional reserves in Miocene carbonates.

SPC ranks second as an oil producer in Syria with Total in the third place. SPC's operated fields include Karatchuk, which is Syria's first discovery.

The BP estimate of the recoverable proven reserves of oil in Syria is 3.2 billion barrels (509 million m^3), which is less than half a percent of the total Middle East reserves. This gives a R/P ratio (reserves/production) of only 16 years, meaning that it is important for Syria to find additional reserves.

Photo: Halfdan Carstens

Associated gas is now being pumped from the Deir ez-Zour region to western Syria through a 450km pipeline buried in the desert. The gas was previously flared, but following the completion of a gas gathering system and a major gas processing plant, it is now being used for production of electricity.

Gas reserves are also small compared with other Middle East countries, only 0,37 trillion m^3 (13.1 Tcf).

Undiscovered resources are estimated by USGS in a 2000 study. In their study it is concluded that the Syrian onshore basins may contain an additional 1.2 billion barrels of oil, 4.8 Tcf of gas and 313 million barrels of natural gas liquids.

As for gas, Syria in 2004 produced 5.2 billion m^3 or 14 million m^3 per day, which is the highest production rate ever, and it has tripled in ten years.

Syria plans to increase gas production as part of a strategy to substitute natural gas for oil in power generation in order to free up as much oil as possible for export.

Exploration efforts

"Syrian authorities are determined to boost both production and reserves and reverse the decline in oil production. The only means of doing this is by intensifying the exploration efforts and undertake improved oil recovery projects," says Adnan Al-Asmi, Exploration Manager of SPC.

"These efforts include the licensing of new blocks onshore in several sedimentary basins and an offshore licensing round that is expected late this year or early next year."

"More than 800 structures have been identified to date, almost half of them has been tested by the drill-bit and between 150-200 discoveries have been made," Adnan Al-Asmi adds.

Syria has therefore opened up new blocks for oil and gas exploration. The first round closed in 2001 on five areas. A second round closed in 2002 that involved eleven blocks. A third, also including eleven blocks, was announced late 2002.

"We have two other major projects ongoing. One is to boost production by Enhanced Oil Recovery. Chinese CNPC and Canadian companies are carrying out this. Also, we are looking into developing tar sands, but there is a need to develop new technology," Adnan Al-Asmi says.

Improving terms

Syria, along with many other countries with an oil industry, is eager to find more oil and gas and boost production by inviting new companies to take part in the boom and applying new technology. The authorities have therefore eased the terms and claim that it is now much easier to operate than it used to be.

Al Jafra/Tabyyeh oil field

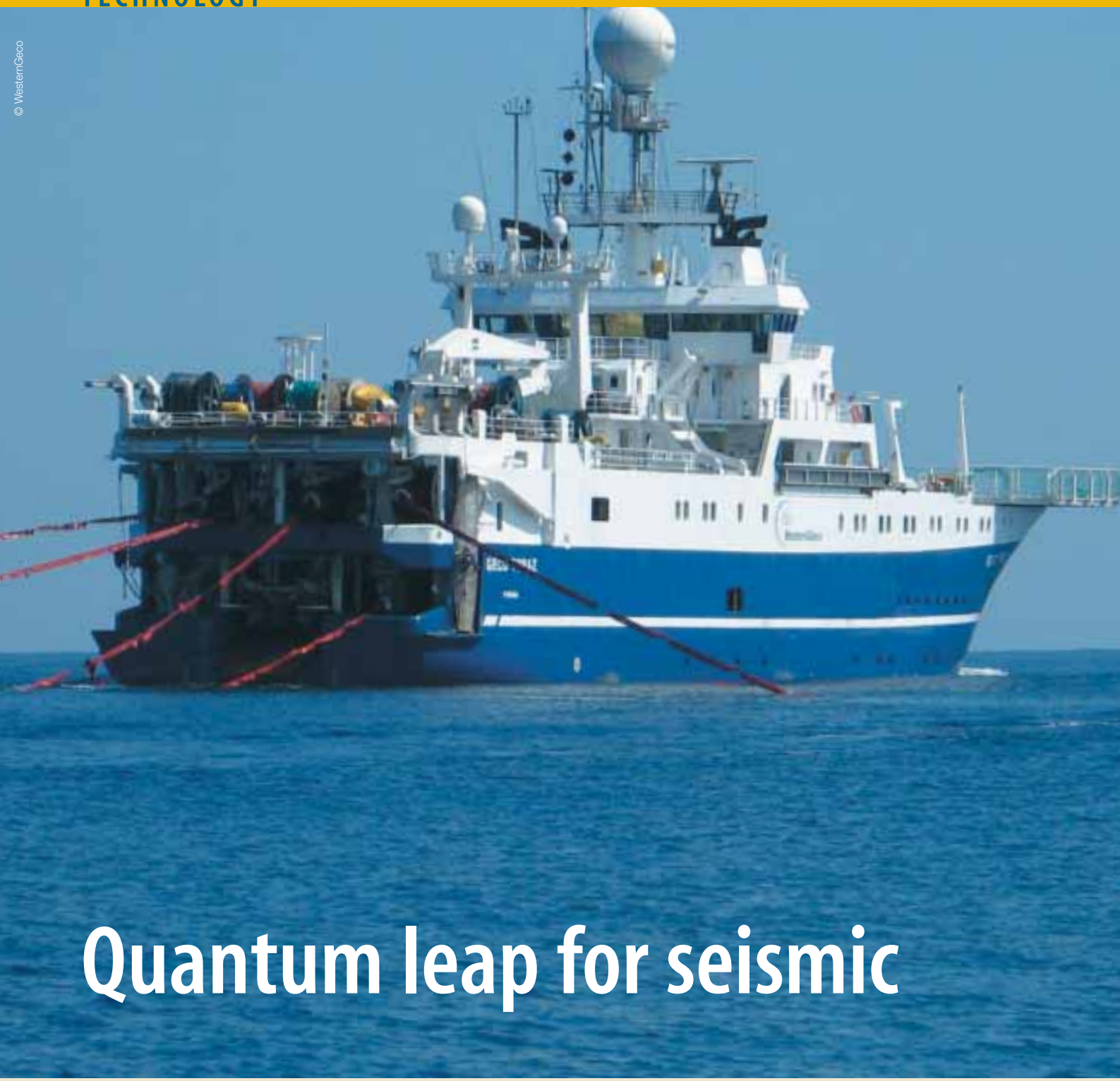
The Jafra oil field is located very close to Dayr as Zawar along the Euphrates and is not very distant from Iraq. The field is operated by a joint venture between SPC and Total E&P Syrie, Dayr es Zawar Petroleum Company (DEZPC). The field was discovered in the late 1980's and started producing in 1991.

There are a total of eight fields in the area, and the combined production is now 35.000 bopd, down from 60,000 bopd when the field was opened. The fields originally had 600 million bbls of oil *in place*. Roughly 80% of the reserves have been produced, thereby demonstrating the need to discover additional reserves to maintain the production level.

Drilling rig working on the Tabieyh field, approximately 15km away from the city of Jafra.

"DEZPC is using low toxic oil based mud, which is very expensive and increases the well cost with 3 million dollars for 10-12 wells," explains drilling supervisor John Williams.

Geologist Mahmoud Al Bittar studying his own account of the lithology.



Quantum leap for seismic

The introduction of Q-Marine* technology a few years ago has given WesternGeco a competitive edge, the company claims. In the Oslo Technology Centre they are proud of having been crucial in the development of seismic technology that, beyond any doubt, has given some oil companies value for money.

WesternGeco, now owned in full by Schlumberger, is in the process of upgrading their fleet to Q-Marine Technology. The development of this technology, including improvements of both the source and receivers, was done in the WesternGeco Oslo Technology Centre that was founded in the early days of Geco in the 1970's.

Photo: Halfdan Carstens

Morten Svendsen (left) was Product Champion for WesernGeco when developing the Q-Marine system between 1997 and 2001. Morten is now Chief Geophysicist Marine, while Ottar Kristiansen is Product Development Manager, Marine Acquisition Systems, in the Oslo Technology Center. This centre is responsible for the development of all aspects of acquisition of marine, land and seabed seismic data.

Halfdan Carstens

"We distinguish between conventional seismic and Q-Marine seismic," says Morten Svendsen, Chief Geophysicist Marine with WesternGeco. "While conventional seismic has been crucial in exploration for many, many years, Q-Marine technology provides the possibility of, not only locating, but also managing offshore reservoirs throughout the life of the field."

For almost five years, Svendsen participated in the development of Q-Marine single sensor seismic system, and he strongly believes that introducing the new technology was a quantum leap forward, not only for WesternGeco, but also for the entire seismic industry. "Q-Marine applications now allow the petroleum industry to look beyond exploration and fully apply seismic technology in reservoir management," he says.

"Until the Q-Marine system was introduced, there were several *evolutionary* improvements of seismic acquisition technology since digital recording was introduced in the early 1980s, but the first really *revolutionary* concept change and data quality improvements came with Q-Marine technology," Svendsen claims.

Centre of Excellence

Morten Svendsen and his colleague Ottar Kristiansen are based in Asker outside Oslo, Norway, in what is known as the WesternGeco Oslo Technology Centre, one of several Schlumberger technology centres around the world. This centre has great ambitions being responsible for developing seismic acquisition systems for marine, land and seabed seismic.

"This is an exciting place to work. We are in a position to follow projects from idea inception until they are classified as commercial products. This includes design, testing, prototyping, manufacturing and commercialization. Also, we get project responsibility at an early stage, which is good," says Ottar Kristiansen, Product Development Manager of Marine Acquisition Systems in WesternGeco.

The centre is also an interesting workplace from another viewpoint. "More than 340 employees belong to it, and they come from all over the world. With 32 nationalities present, of which non-Norwegians represent 40 per cent of the staff, we have a wonderful opportunity to get acquainted with people from other cultures," Kristiansen says. "Also, because they all come from different universities and have different

* Mark of WesternGeco


Photo: Halfdan Carstens

The WesternGeco Oslo Technology Centre includes an in-house training centre for seismic crews. It operates in much the same way as airplane pilot training centres. Crewmembers are exposed to real-life situations with small and big problems causing intermittent periods of stress. In fact, airline pilots are used as consultants when training the engineers because of their unique experience in dealing with stress. The screen gives a view of the scenery behind the seismic vessel, as observed by the operator, while the small monitors show the same information as would be displayed on the ship. With background noise and simulation of real events, capable of causing problems when acquiring data, such as, for example, other vessels unexpectedly crossing their course, the training facility duplicates real-world situations.

experiences, we get exposed to various ways of handling the challenges that we are presented every day."

Q-Marine

"Q-Marine technology results from many years of detailed work analysing the key sources of noise and error when acquiring seismic," Svendsen says. He lists four main components that impact quality and repeatability of the data.

"To start with the signal, we have introduced a digital source controller system that measures the source output from each shot and enables removal of the variations in the signature of the airgun source. Seismic data quality naturally improves significantly when the signal is consistent."

"Secondly, with conventional seismic acquisition, signals from hydrophones within a group are wired together and summed into one trace, resulting in signal perturbations and smear. With single-sensor recording, however, all signals are recorded and sophisticated new types of filters can be applied. This reduces noise and gains resolution."

The other two improvements are related to receiver positioning.

"New steering devices enable precise depth control and horizontal streamer positioning, thereby providing feather correction and controlled streamer separation. With up to 12 cables being towed in different types of weather and strong currents, it is easy to appreciate the necessity of having full control. In several 4D projects, the streamers have been steered as close as 40 meters to fixed platforms, something unheard of with conventional seismic acquisition technology."

"Finally, a new acoustic positioning system improves positioning accuracy from the front to the tail of the streamers. Detailed knowledge of the location of the receivers is, of course, particularly crucial for time-lapse data," Svendsen explains.

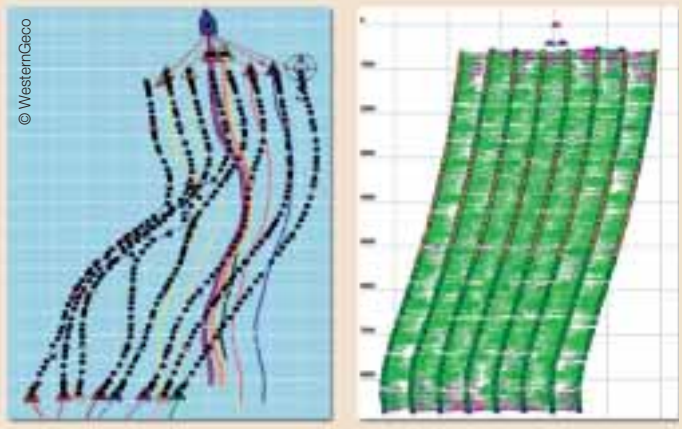
A surviver

The WesternGeco Oslo Technology Centre, nicely over-looking the beautiful Oslofjord, was originally the R&D division of Geco. Geco was acquired by Schlumberger in 198x and was later merged with Western. WesternGeco is now the world's largest seismic company.

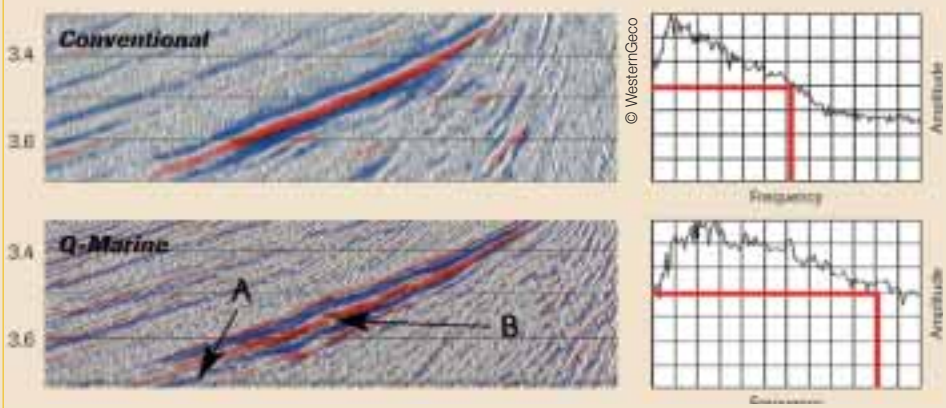
Having survived as a "centre of excellence" since the 1970's - through more than 25 years - is certainly a feat in itself, these days. Surviving in the Schlumberger system as one of few technology centres should be a good indication that it has been able to sustain quality through the years.

"It is well respected within Schlumberger," Ottar Kristiansen concludes.

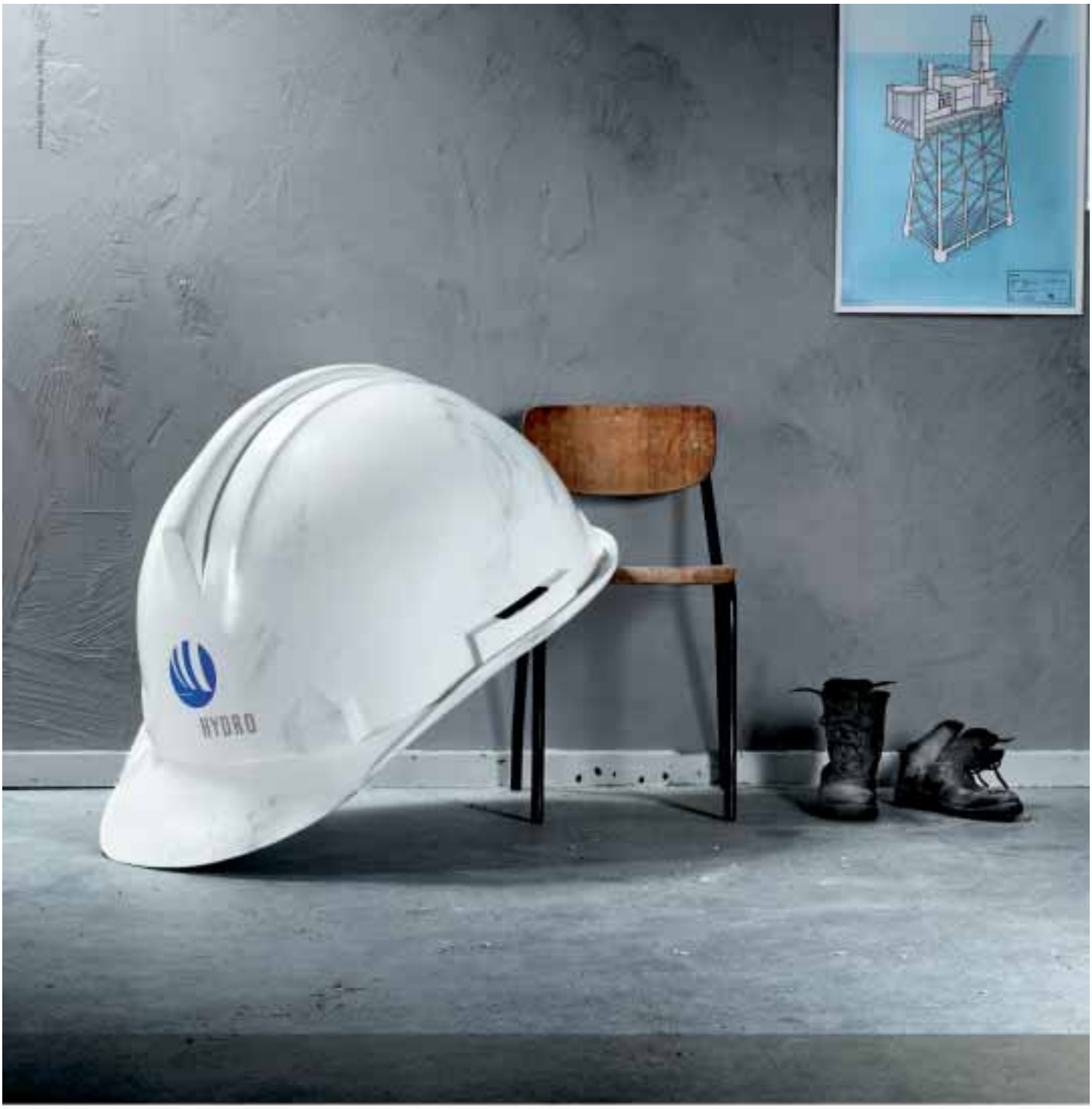
You don't need to be a geophysicist to appreciate that the Q-Marine system has the potential to acquire better three-dimensional data than conventional systems. This figure illustrates how the cables are kept in constant relative position when influenced by strong currents.



Conventional Q-Marine



An example from a deepwater field in the Gulf of Mexico demonstrates how Q-Marine technology can improve seismic data resolution. With improved recording technology, in this case it is possible to see both the contact between oil and water (A) as well as gas and oil (B). The conventional seismic data gave no clues to these important features.



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Changing Exploration Focus Paved Way for Success

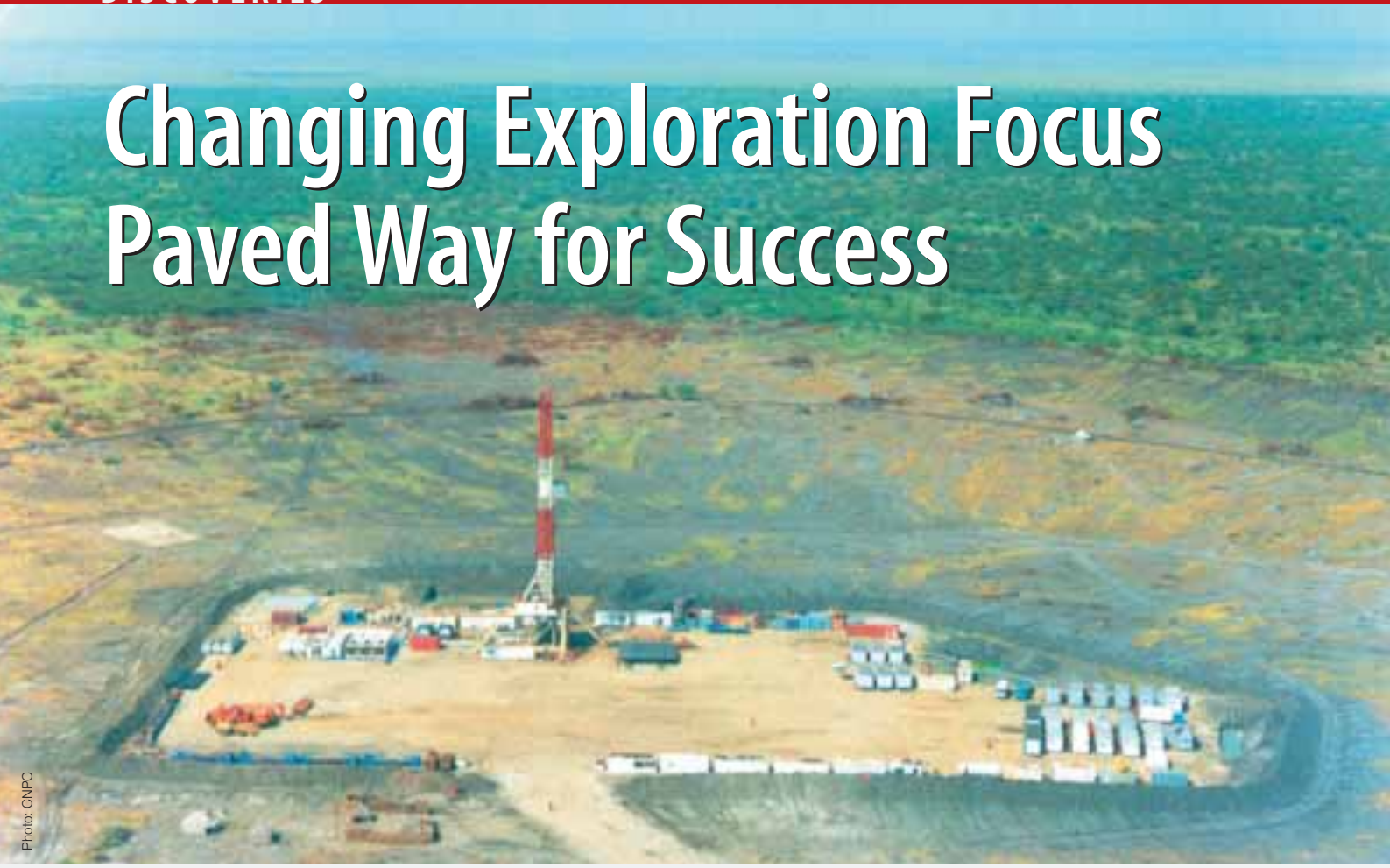


Photo: CNPC

Petrodar Operation Company (PDOC) spudded the wildcat Palogue-1 in the autumn of 2002 following a detailed study of the petroleum system of the Melut Basin. The well ultimately encountered 72.3m of net oil pay in Tertiary (Paleogene) and 9.9m in Cretaceous rocks. Paleogene sandstones constitute the main pay zone, and the interval from 1312 to 1333m was tested at an initial rate of 5,100 bopd. In the deeper pay zone, Cretaceous sandstones were tested at a cumulative rate of 300 bopd. Later the same year, another wildcat found more oil 2.8 km north of Palogue-1. It then became clear that a significant discovery had been made.

After only a few small discoveries in what appeared to be favourable geological conditions, a major study of the petroleum system of the huge, immature basin was conducted. The subsequent well hit oil in Lower Tertiary sandstones, and the discovery was later proven to be a giant (>500 million bbls of recoverable oil) within the prolific Central African Rift.

Mr. Tong Xiaoguang and Dr. Shi Buqing, China National Oil and Gas E&D Corporation (CNODC)

The Great Palogue Field in southern Sudan, 650 km to the south from Khartoum, was discovered in 2003 following a major exploration campaign. The field probably contains 2.9 billion barrels of oil, of which an estimated 600 million barrels (20%) are recoverable. It is by far the largest oil field in Sudan, and also one of few giant oil fields discovered in the 21st century.

According to the BP Statistical Review of World Energy 2005, proven reserves in Sudan at the end of 2004 were 900 million m^3 of oil (6.3 billion barrels). Sudan thus ranks as no. 5 in Africa with respect to oil reserves, only behind Libya, Nigeria, Algeria and Angola.

The reserve estimates for Sudan will most likely increase considerably in the years to come, as the prolific Muglad and Melut Basins are both largely underexplored.

Sudan has become a significant oil producer with an average output of more than 330,000 bopd last year. Sudan's bedrock of output is the 300,000 bopd of Nile Blend produced from the Muglad Basin with other fields adding another 30,000 bopd. This year, an extra 80,000 bopd is scheduled to come from block 5a and another 30,000 bopd from block 6, both in the Muglad Basin. Another 150,000 bopd will come from the Great Palogue field at the end of 2006.

Dry wells along the Red Sea

Petroleum exploration in Sudan dates back to the late 1950's when some preliminary investigations were carried out along the Red Sea coast. In 1959, Italy's Agip was granted concessions carrying out seismic surveys and drilling six wells. Following Agip into the Red Sea came Oceanic Oil Company, France's Total, Texas Eastern, Union Texas and Chevron. All yielded nothing for the next fifteen years.

The first successful results were achieved by Chevron in 1974, 120 km southeast of Port Sudan, where dry gas and gas condensate were found. No oil was found, however, and most companies relinquished their concessions in the region.

Exploration for oil in southern and southwestern Sudan began in 1975, when the government of Sudan granted Chevron a concession area of 516,000 km^2 (equivalent to some 90 North Sea quadrants!) in blocks around Muglad and Melut basins. Chevron started geological and geophysical surveys in 1976, and drilled its first well in 1977, which was dry.

The Muglad Basin

In 1979, Chevron made its first oil discovery in the Muglad Basin with Abu Jabra #1, where 8 million barrels were proven.

Chevron's most significant discovery was made in 1980 in the Unity oilfield. Heglig field, which lies 70 km north of Unity field, was discovered in 1982. Chevron estimated total oil reserves of 593 million barrels from the two fields combined.

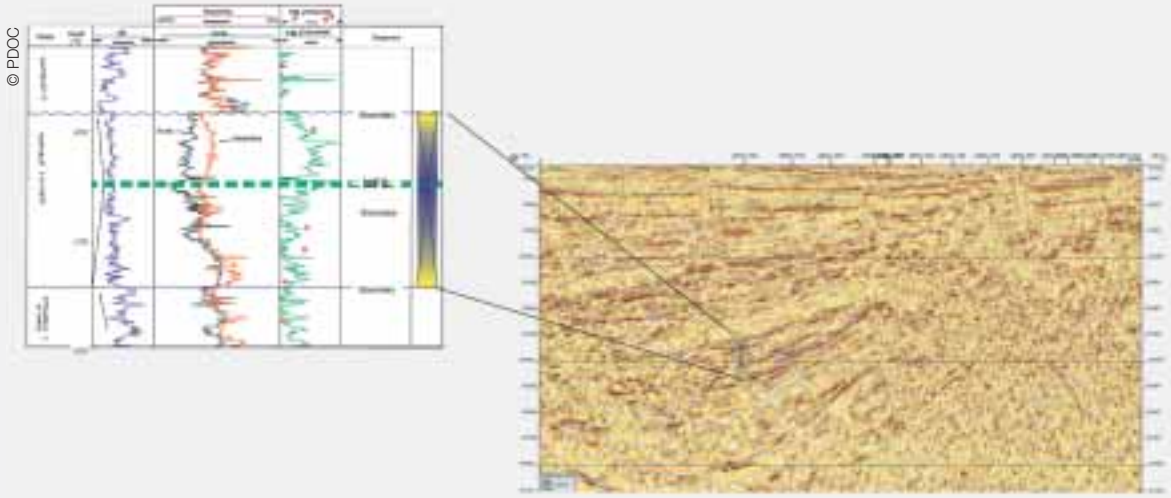
Oil has been produced since 1999 from the Unity and Heglig fields and transported via a 1500 km pipeline to Port Sudan on the Red Sea coast. It has a 250,000 bopd capacity that can be expanded to over 450,000 bopd with additional pump stations. Sudan thus became an oil exporter in August 1999, when the first shipment of oil left Port Sudan.

The Melut Basin

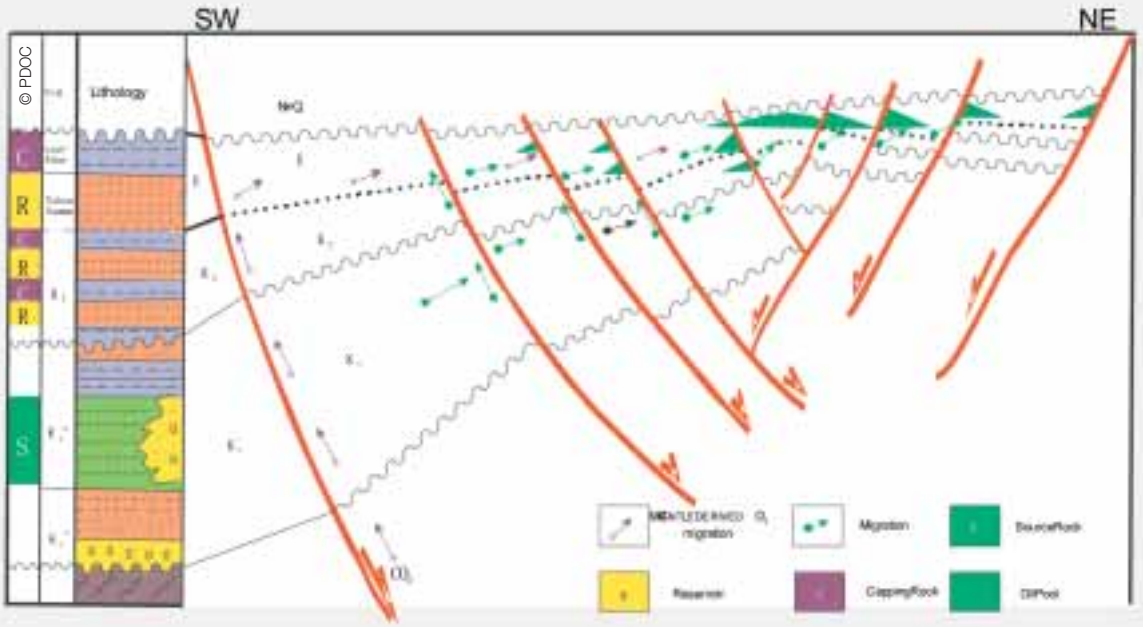
Chevron discovered the Adar-Yale oil field in Block 3 in the Melut Basin, east of the river Nile and some 150 km west of the Sudanese border with Ethiopia, in 1981. Four exploration wells were drilled that all showed flow rates in excess of 1,500 bopd from the **Yabus** Fm sandstones of Paleogene age (compare Geological Time Scale p.12). The field covers an area of about 20 km^2, but the average pay zone is only 2.9m, resulting in 168 million barrels of oil in place. The Adar-Yale oil field was therefore,

The Republic of Sudan

The Republic of Sudan with an area of 2,500,000 km^2 is the largest country in Africa. The scale of the map could be deceiving and may not easily convince you of Sudan's immensity. So then, imagine the entire country of France fitting within the borders of Sudan: five times. From north to south it also equals the US Lower 48 from north to south. The Nile and its tributaries dominate Sudan giving it an overall flat landscape, except where the mountains rise along the Red Sea coast and the western border with Chad. The climate in Sudan is tropical in the south while arid desert conditions prevail in the north. The rainy season is from April to October. Sudan's name derives from the Arabic "bilad al-sudan" which means "land of the blacks." Since independence from Britain in 1956, a north-south war has dominated Sudan's history, pitting Arab Muslims in the northern desert against black Christians and animists in the southern wetlands. Muslim Arabs control the government in Khartoum, but are only about 40 percent of the population. Blacks, or Africans, make up 52 percent of Sudanese, and are most numerous in southern and western Sudan. All the discovered oil and gas fields so far have been made in the interior southern part of the country, including the Muglad and Melut Basins. Pipelines are therefore built all the way to the Red Sea. The Great Palogue Field is located in the Melut Basin in the Upper Nile province, 650 km to the south of Khartoum, the capital of Sudan. The field lies in Block 7, now operated by the Petrodar Operation Company (PDOC), a joint venture between CNODC/CNPC, Petronas, Sudapet, SinoPec and Thani Corporation.



Stratigraphic summary of Lower Cretaceous source rock and corresponding reflection feature on typical seismic section in northern part of Melut Basin.



Hydrocarbon Migration Model

at that time, not considered commercial. However, after Chevron's departure in 1990, the Adar-Yale concession was awarded to Gulf Petroleum Corporation-Sudan (GPC) and it began producing 5,000 bopd in March 1997.

In November 2000, Petrodar Operation Company (PDOC) was established with China National Oil and Gas Exploration and Development Company (CNODC/CNPC) as operator and one of the largest shareholders. Firstly, seismic data was acquired around Adar-Yale oil field, and drilling improved the in place estimates from 168 to 276 million barrels. In 2001, three small oil pools were also discovered south of Adar-Yale oil field, adding another 129 million barrels. To the east of Adar-Yale, several wildcats proved to be dry.

By the turn of the century, the Melut Basin was thus a proven oil province with established production. However, the fields discovered were small and could not be produced with the investment burden of long-distance pipeline construction. PDOC therefore felt the urge to restudy the whole basin with the aim of defining prospects with significant oil potential.

New ideas

The study of the petroleum system in the Melut Basin led to several conclusions that had important implications for the exploration strategy. First of all, based on seismic correlation, it was apparent that the rich Lower Cretaceous source rock interval present in the Muglad Basin and other basins in central Africa, including the prolific Doba Basin in Chad, also was present in the Melut Basin. Moreover, according to the gravity data, the main source kitchen should be present in the northern part of the basin. This then shifted PDOC's exploration focus.

While the main pay zones in the Muglad basin is within the Upper Cretaceous, this stratigraphic interval is lacking in the Melut Basin. The study, therefore, also concluded that sandstones in the Paleogene **Yabus** and **Samma** formations should be the main play of Melut basin, which in consequence shifted the exploration focus from deeper Cretaceous to shallower Paleogene strata.

Two seismic surveys followed. In 2001, five 2D seismic lines with a total length of 103 km were acquired in the western part of the Palogue area. The year after 22 more lines totalling 538 km were acquired. The structural features of the Palogue area then became gradually known. In October

Great Palogue

The Great Palogue Field is located on a huge anticline trending SW-NE with a closure of roughly 80 km² and which is complicated by multiple faults. The closure is defined by faulting and pinch-out of the sandbodies. Each block has a different oil/water contact due to the complexity of the structure and sand continuity. The anticline developed from Late Cretaceous to Miocene.

A thick sequence of Mesozoic to Tertiary fluvial-lacustrine sediments has been penetrated in the Palogue area.

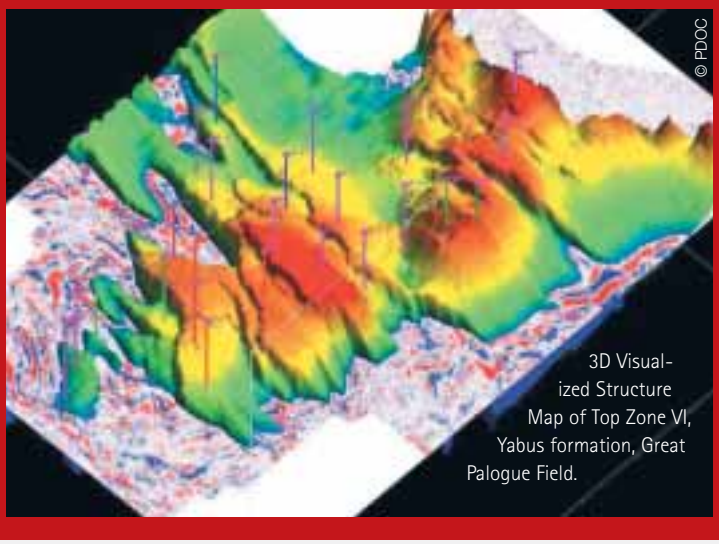
Coarse grained and conglomeratic sandstones of the **Yabus** and **Samma** formations (Paleocene to Oligocene) and the **Galhak** formation (Cenomanian-Santonian), all deposited by meandering rivers and braided rivers, are the main reservoirs. Sandstones in the **Melut** Fm (Upper Cretaceous Campanian-Maastichtian) and **Al Gayger** Fm (Lower Cretaceous Berriasian-Albian) also have favourable reservoir properties, but no discoveries have been made in them yet.

The porosity of lower interval of Yabus formation and Samma formation ranges from 24 to 33%, averaging 29%, while the permeability ranges from 245 to 1583 mD, averaging 643 milliDarcy.

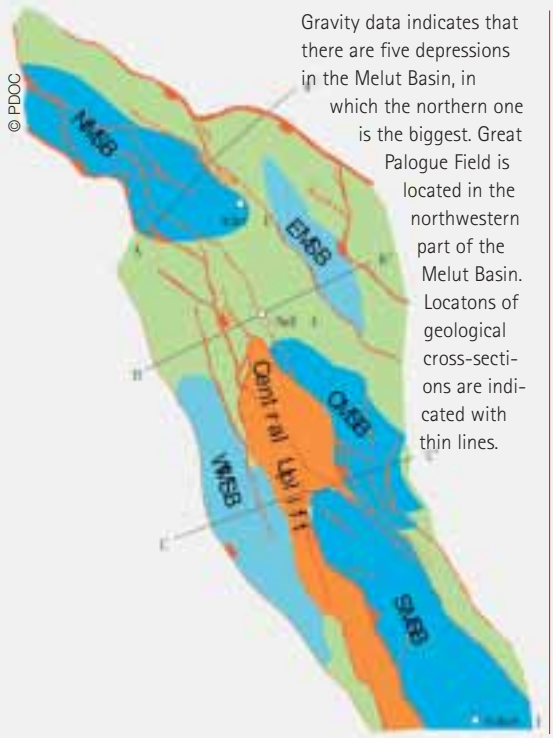
The Miocene section of **Adar** formation is considered the regionally stable seal for the underlying Yabus and Samma reservoirs.

The shales of Galhak Fm (Cenomanian-Santonian) and **Al Renk** Fm (Ablian) display good source potential.

Structure Map of Top Zone VI, Yabus formation, Great Palogue Field.



3D Visualized Structure Map of Top Zone VI, Yabus formation, Great Palogue Field.



Gravity data indicates that there are five depressions in the Melut Basin, in which the northern one is the biggest. Great Palogue Field is located in the northwestern part of the Melut Basin. Locatons of geological cross-sections are indicated with thin lines.

2002, CNODC/CNPC thus proposed to drill wildcat Palogue-1 on the apex in one of the faulted-anticlines.

Following the discovery, 308 km² of 3D seismic data and twelve 2D seismic lines with a total length of 431 km were acquired and processed on the main part of the Palogue structure. The 2D seismic grid was later filled in.

Two more wildcats encountered oil in the Paleogene **Yabus** and **Samma** formations and in the Cretaceous **Galhak** formation. Altogether 28 appraisal wells were then designed and drill in succession up to June 2004.

According to the Field Development Plan completed in 2004, 124 developing wells have been designed including the existing 3 wildcats and 28 appraisal wells. The recovery factor is 21%, well spacing is 600 to 800m and peak oil production rate is expected to reach 187,000 bopd 1.5 years after production start-up. The field will use water injection to improve the recovery factor.

The Great Palogue field is expected to start producing in June this year at a rate of around 75,000 bopd, quickly rising to 125,000 bopd and reaching 150,000 bopd by the end of 2006.

Fresh water is more precious than oil and gas in most of Sudan.

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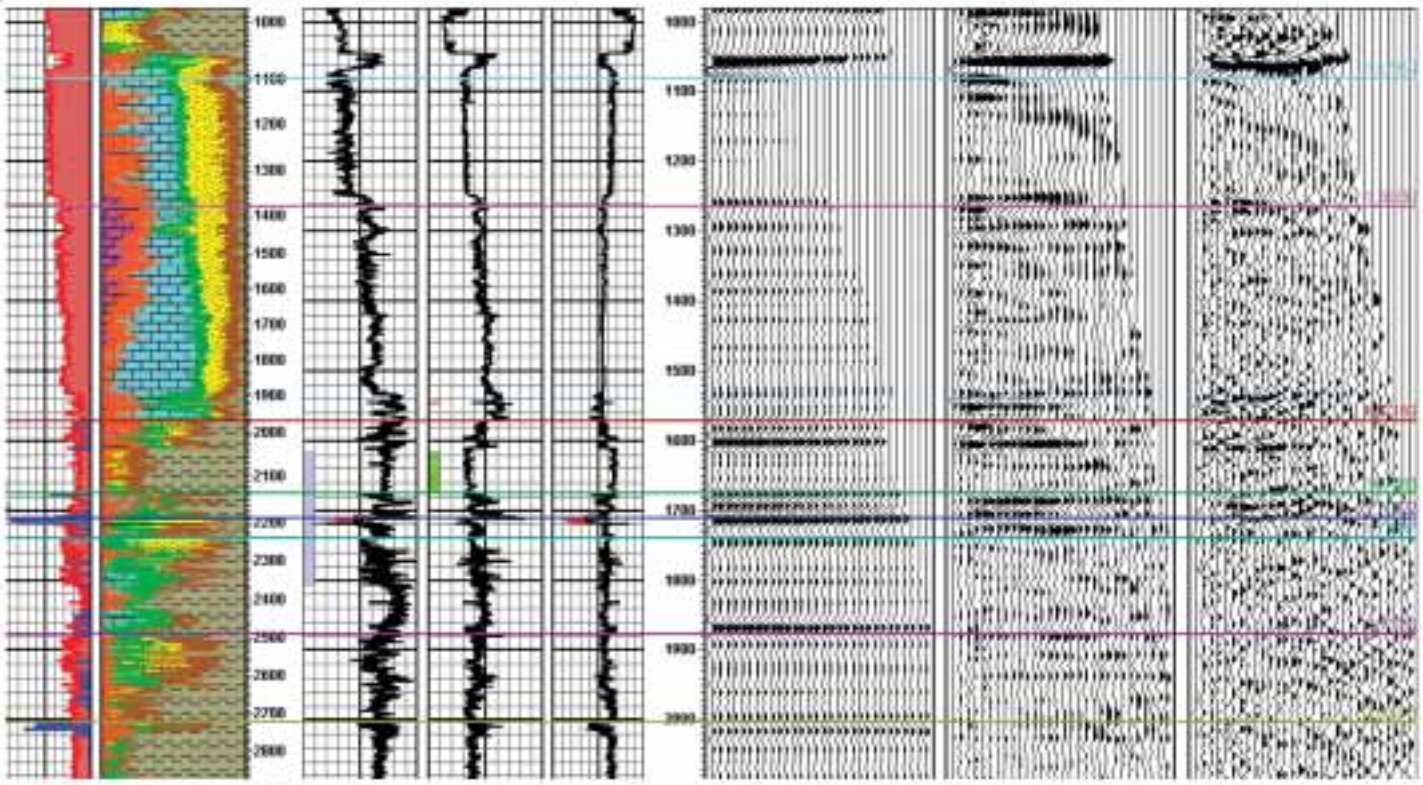

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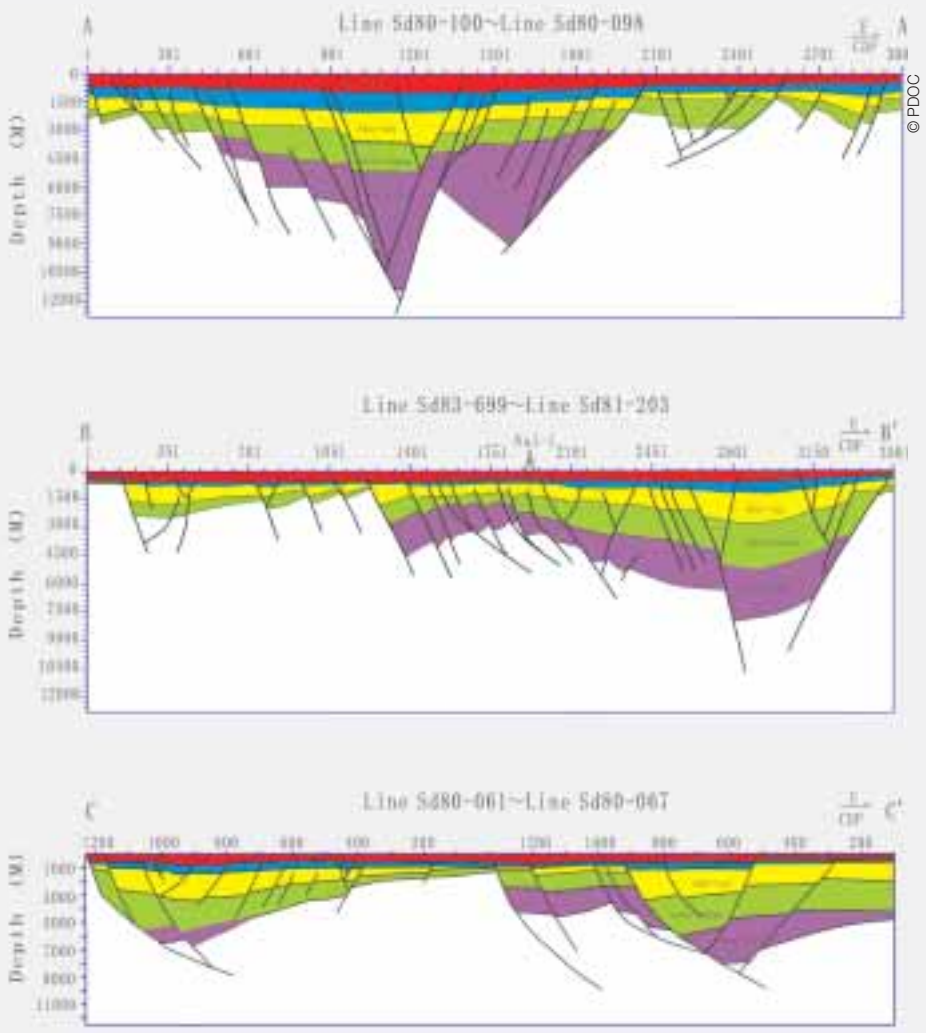

Geologic cross-sections in the Melut Basin showing the half-graben structural style. All basins were initiated in the Early Cretaceous, when a series of large NW-SE trending half grabens developed. From Early to Mid Tertiary, periodic pulses of extensional deformation occurred in the north (Tethys and Mediterranean) and the northeast (the Red Sea and the Gulf of Aden). During Late Tertiary times, transtensional reactivation occurred in response to collision along the northern margin of Arabia and cessation of fault activity in the Red Sea.

Oil in the Great Palogue field is mainly medium gravity (20°API to 34°API) and heavy gravity (15°API to 20°API), has a high pour point and high asphaltene as well as wax content. Deeper than 1250m, API gravity decreases with increasing depth. This implies that biodegration and possibly deasphaltizing by CO_2 derived from the upper mantle is entering the basin along the southern boundary fault of the northern Melut Basin.

The Upper Cretaceous Melut formation consists predominantly of massive sandstones interbedded with thin claystones. We consider these rocks to constitute the migration pathway from the source kitchen to the trap.

A Cretaceous rift

Both the Muglad Basin, roughly the size of the North Sea Basin, but with less than 150 exploration wells drilled so far, and the Melut Basin remain largely unexplored. Both basins are part of the huge Cretaceous rift system that extends across central Africa and which also includes the Doba Basin in Chad with significant oil production.

The richness of this rift system is related to the presence of organic-rich lacustrine source rocks deposited during the Lower Cretaceous.

The discovery of the Great Palogue field in the little explored Melut Basin was a result of a belief that both source rocks and reservoir rocks were present. Thorough geological studies using modern exploration technology proved to be successful.

Source, maturation and migration

Lower and Upper Cretaceous shales both have a good source potential in the Melut Basin. Total organic carbon determinations of ditch samples indicate intervals of good to excellent organic content within the lower part of Upper Cretaceous Galhak formation and upper part of Lower Cretaceous Al Renk formation. Results of Rock-Eval pyrolysis indicate that these intervals show variable capabilities for generating oil, mainly from type II kerogen.

Modelling has shown that the deepest part of the northern Melut Basin entered the oil window in the Late Cretaceous. During late Miocene, the Cretaceous source rocks began to generate oil. At this time the deepest part of Melut Basin entered the gas window.

Muslim Arabs make up about 40 percent of the population in Sudan.

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Time to redevelop an abandoned European oilfield?

Souring oil prices have inspired NAM to consider redeveloping one of Europe's largest oil fields. A 3D high resolution seismic survey will lower the structural uncertainties and horizontal drilling, in combination with new recovery procedures, means that the abandoned Schoonebeek Field could yield a further 100 million barrels of oil.

Jane Whaley

"High costs and low oil prices resulted in the closure of the Schoonebeek Field in 1996", says Michiel van Dongen, senior seismologist for the project. "NAM has been evaluating the opportunity to redevelop the field for the past three years, and we now feel that with the new recovery techniques available to us, plus a totally different oil price scenario, this field still has plenty of potential."

The Schoonebeek Field was discovered in 1943, and more than 250 million barrels of oil had been produced before the field was shut-in in ten years ago. Enhanced seismic techniques can help to clearly picture the structure of the field. Nederlandse Aardolie Maatschappij (NAM) is therefore keen to restart production. Using advanced recovery procedures they are hoping that Schoonebeek could yield a further 100 million barrels of oil.

50 years of operation

The Schoonebeek oil field lies in the eastern Netherlands, close to the border with Germany, about twelve kilometres south of the city of Emmen. The field extends across the border into Germany where it is known as the Ruhlertwist and Emlichheim fields. The amount of oil initially in place (STOIIP) was estimated to be in excess of 1 billion barrels, making it one of Europe's largest oilfields.

Production started in 1947, and eventually nearly 600 wells were drilled from 300 locations. The oil is heavy, with an API in the region of 25°, and over the years many different oil recovery techniques were used and tested in the field, including cold and hot water injection, wellbore heating, steam injection and in-situ combustion.

Production peaked at 24,000 bopd in 1954 and slowly declined over the years, until the field was finally shut-in in 1996. By then about 250 million barrels of oil had been produced from the Schoonebeek Field, only about 25% of the estimated oil in place.

Why was Schoonebeek abandoned ...?

As Michiel van Dongen says, "Abandonment was not an easy decision, especially since operations continued, and still continue, across the border in Germany. The abandonment of the field in 1996 was justified on economic grounds, based on the techniques and infrastructure available at the time. Essentially, the field was abandoned because operating costs were high and, as you will remember, oil prices in the early 1990s were very low, between $11 and $18 a barrel."

"In addition, there were some significant economic factors relevant to the field itself. Recycling water was adding between $1 and $3 per barrel to the operating costs, a factor which we have removed in our present plans for the field, as we intend injecting 100% of theproduced water into depleted gas fields."

... and why redevelop now?

"Although it is only ten years since the field was shut-in, both technological and economical factors have changed and advanced a great deal," says Michiel. "The idea of reopening the field has always been attractive due to the large volumes of remaining resources, at least 750 million barrels. This, coupled with the high oil price and the present lower taxation levels, has made us seriously reanalyse the potential of Schoonebeek."

New technologies which would be

The Schoonebeek Field during abandonment in 1996. The drilling rigs from the German part of the field, which continued in operation, can be seen in the background.

important for enhanced recovery include the combination of horizontal drilling and innovative high oil recovery techniques such as Gravity Assisted Steam Flooding (GASF). This is a new method of particular use in the production of heavy oils, such as those found in Schoonebeek. In a typical GASF scenario, a pair of horizontal wells is used, with steam being injected into a horizontal well located in between two horizontal producers. As steam enters the reservoir, it heats the reservoir fluids and surrounding rock. Hot oil and condensed water drain through the force of gravity to a production well at the bottom of the formation. A steam chamber grows around the injection well and helps displace heated oil toward the production well. Similar techniques are used when producing oil from the Canadian oil sands (GEO ExPro No 5/6, 2005, p.52).

The Solution Gas Drive Area (SGDA) of the Schoonebeek Field has been targeted by NAM as the favoured area for initial redevelopment. This is due to a combination of factors, as Michiel explains.

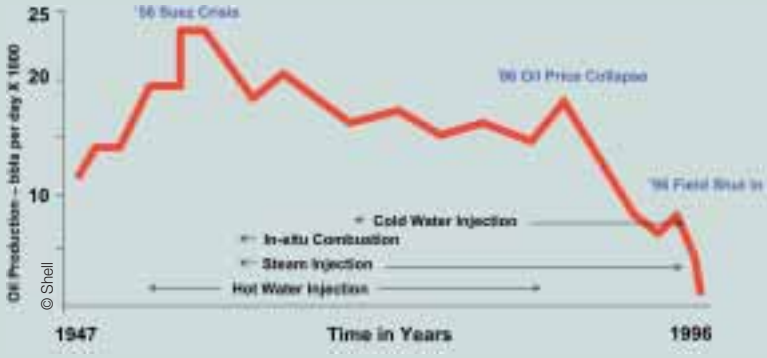
"The lower recovery levels to date in the SGDA mean that we can aim for higher enhanced oil recovery (EOR) targets in our future plans. In addition, the weak aquifer support in the SGDA will result in less water influx and associated water handling problems. This will allow us to operate at lower reservoir pressures, a key requirement for the chosen recovery process of Gravity Assisted Steam Flooding (GASF). We estimate that in the Solution Gas Drive Area the estimated oil in place is 350 million barrels. Using these enhanced techniques we can increase recovery in the SGDA from 15% to 45%."

Justifying new HiReS seismic

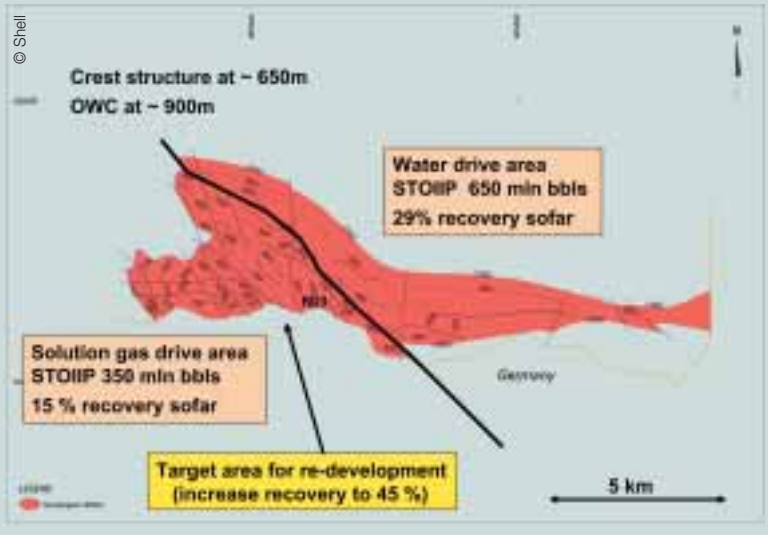
A number of 3D surveys had been undertaken to delineate the Schoonebeek area between 1984 and 1991, but these focussed on the deeper targets, down to 3,000m. Further reprocessing and merging of data was undertaken in the 1990s and some new 2D hi-res data was shot. Part of the discussion analysing the potential for reopening the field centred on the requirement and expense of acquiring further seismic, particularly 3D.

"1992 PosSTM data formed the basis for the Schoonebeek project," explains Michiel. "As can be seen from the example here we felt that this seismic was not yielding the best results, with weak responses from the base of the Bentheim reflector and poor fault resolution. It was important, however, to be able to prove that the acquisition of further seismic could be economically viable"

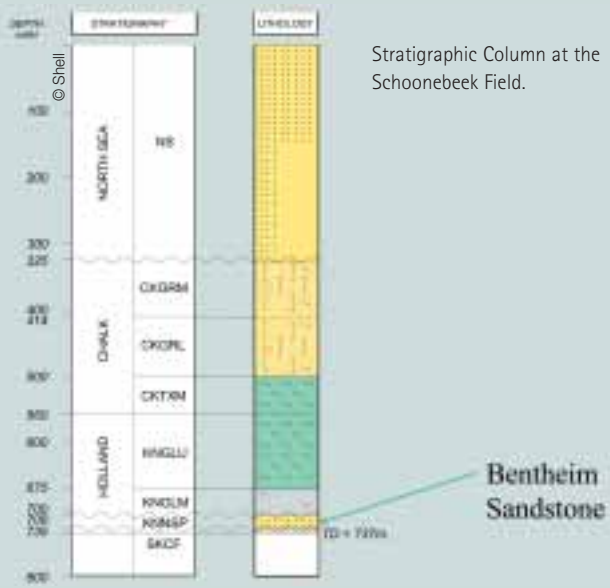
"We therefore decided to undertake a VOI-exercise (Value of Information) to look at the impact of new 3D HiReS on the project economics, assuming that the fresh seismic will significantly reduce the structural uncertainties. VOI is a method to quantify the value of new seismic information that enables better decision-making and lowers investment risk. We would acquire more



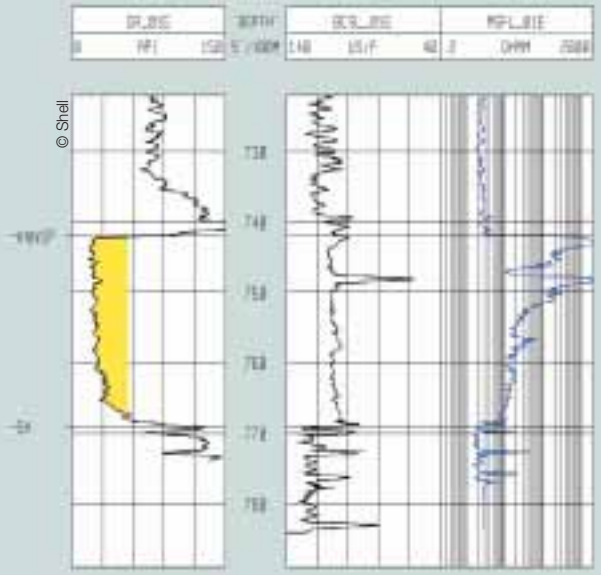
Schoonebeek field production profile, from discovery in 1943 to abandonment in 1996.



The Schoonebeek Field measures about 16 km from east to west and 4-5 km north to south. It is split into two non-communicating reservoirs by a major fault.



Stratigraphic Column at the Schoonebeek Field.



Example well log showing the reservoir horizon, the Lower Bentheim Sandstone.

seismic if the added value of new 3D HiReS seismic could be shown to be greater than its acquisition and processing costs."

"To quantify the value of 3D HiReS we need to determine the value of proper well placement. Proper well placement is key to the project, as the wells need to be positioned in the strike direction and preferably in the bottom third of the thin reservoir (15-30m in the redevelopment area). In addition, the wells should avoid any faults. We have to take into account structural uncertainties, which may result in the well being drilled off target, and we make the assumption that the improved resolution of the new seismic will halve the vertical uncertainties".

"To determine the value of proper well placement we compared the project value for two cases, the first with the current seismic, which we refer to as full uncertainty, and the second in which we assume that the new seismic will reduce the structural uncertainties by 50%. We then undertook uncertainty modelling in Petrel, by running 500 realisations. In each of these realisations, the planned wells are in a fixed position and the structures (top and base reservoir) vary in the vertical sense. The range of variation for the full case was twice that of the half uncertainty case. The realisations in fact comprised wells which were positioned off target, missing part of the reservoir section or positioned off-strike."

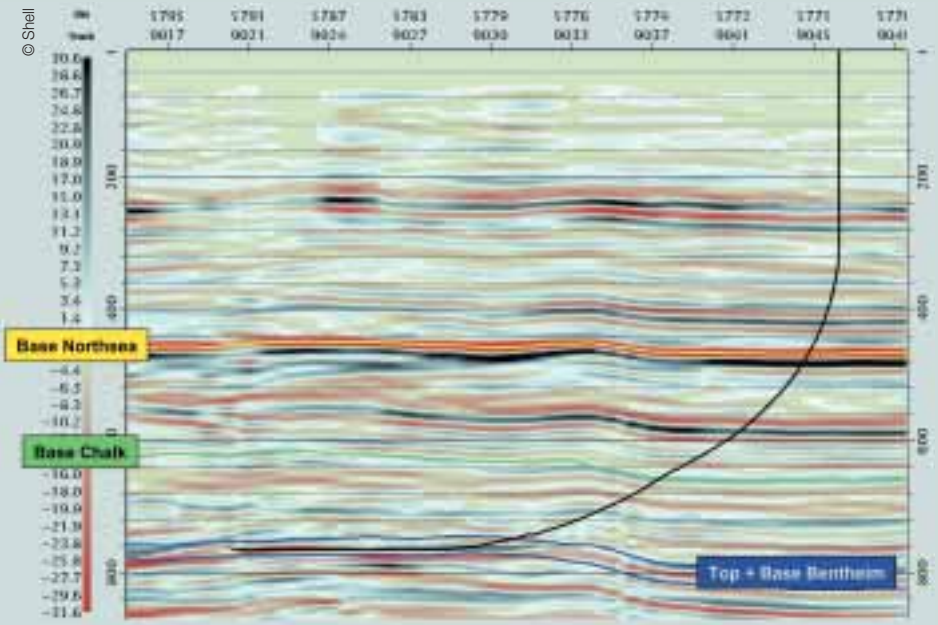
Project values were then calculated on the basis of the total cumulative oil which could be expected to be produced in the respective cases (using 5 realisations). Further value was attached to additional development areas. With new seismic, areas with thinner reservoir and a more complex structure could potentially be included in the redevelopment."

The result of the VOI studies suggested that it would be cost-effective to undertake further 3D HiReS seismic. "The value of the new seismic to the project was estimated to be more than US$12 million, split between improvement in well placement and the delineation of additional development areas," explains Michiel. "The cost of the acquisition and processing of new seismic would only be US$7.2 million, proving the case for new seismic. The decision to acquire the new seismic was taken in the summer of 2005, with the acquisition taking place in the autumn. Currently processing of the data is underway, with the first data expected to be available for evaluation in the summer of this year.

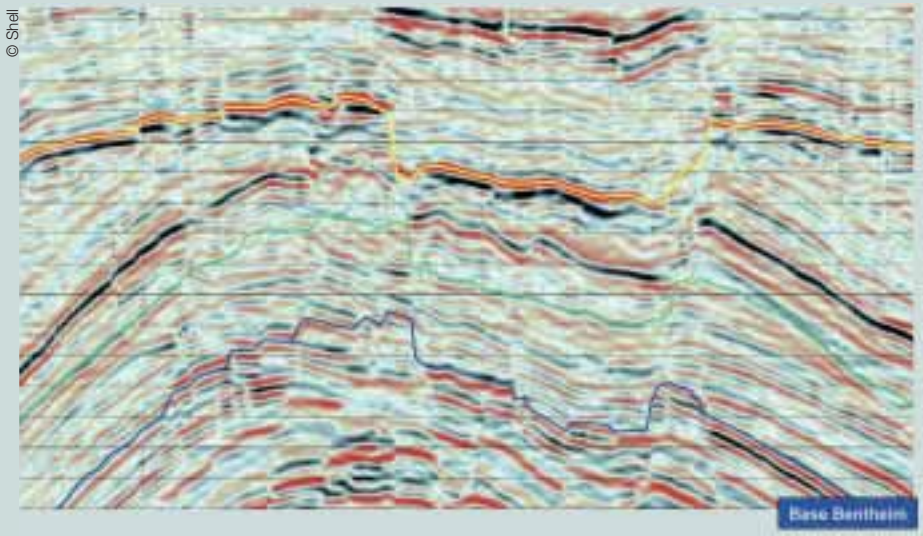
Redevelopment to cost US$500 million

If the Schoonebeek redevelopment project goes ahead, it is expected that the total project duration will be more than 25 years and it will cost in excess of US$500 million. The aim is to recover approximately 100 million barrels of oil from the western part of the field, drilling as many as 70 injector and producer wells from about 20 different locations. These are planned to be about 150m apart and grouped in fault blocks and it is anticipated that they will have 200 – 500m horizontal sections.

"Using horizontal wells and GASF tech-



Example production well.



Seismic line demonstrating the poor quality of the PoSTM data. The base Bentheim reflector is weak, mostly a soft kick, and not consistent. Amplitude varies due to lateral change in impedance contrast and the tuning effects from a wedging reservoir. In a noise-free environment 6m faults should be detectable, but in reality the detection limit is on average about 15m.

Michel van Dongen

nologies should allow us a very good recovery level. We will enhance the project efficiency through the generation of steam and electricity on site and our plans for 100% water disposal in depleted gas fields will effectively lower costs."

"NAM has been evaluating the opportunity to redevelop the Schoonebeek Field for the past 4 years. We expect to make a final investment decision in the course of 2007," Michiel adds.

If NAM decide in favour of the redevelopment, then by 2009 oil should once again be flowing from one of Europe's largest fields.

The Schoonebeek Field

The Schoonebeek field is extensive, measuring about 16 km from east to west and 4 to 5 km north to south, including the German part. It is one of Europe's largest oilfields, with over 1 billion barrels of oil in place. The reservoir is found in the Lower Cretaceous Bentheim Sand at a depth of between 700 and 800m. In the proposed redevelopment area, the thickness of the reservoir is between 15 and 30m, increasing towards the east, and it has a net to gross ratio of 0.98 and a porosity of 30%. It is sealed by the overlying Cretaceous Vlieland Shale and Upper Holland marl.

The trap is formed by a heavily faulted anticline with a crestal collapse graben. Michiel von Dongen explains the structure of this giant field. "As can be seen from the field outline map, the Schoonebeek Field is split into two non-communicating reservoirs by a major fault which runs northwest to southeast. To the east of this fault, the Main Water Drive Area (MWDA) is connected to a large high pressure aquifer which has contributed to early water breakthrough and water handling issues, but which has also increased oil recovery. In this area, in fact, we have achieved recovery of about 30% reserves in place."

"To the west of this fault, however, the Solution Gas Drive Area (SGDA) has experienced very little aquifer influx and this part of the field has much lower recovery levels, at about 15% of STOIIP."

The extension of the Main Water Drive Area into Germany is the Ruhlertwist Field, which is operated by Preussag Energy, while the southern extension of the Solution Gas Drive Area into Germany is called the Emlichheim Field and is operated by Wintershall.

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Seychelles, with a population of 81,000, comprises an archipelago of some 115 granitic and coralline islands which lie in the western reaches of the Indian Ocean. The largest Island is Mahé. It occupies a land area in excess of 455 km^2. Mahé lies some 1600 kilometres off the eastern coast of Africa and some 800 km north of Madagascar. Seychelles was granted independence from Britain in 1976 being ceded to Britain from France as reparations following the Napoleonic wars. Over 98% of the population profess the Christian religion and there is no religious strife on the islands. Victoria (pop 23,000) is the administrative capital of the Republic of Seychelles. Seychelles is serviced by regular flights from Dubai, London, Paris, Singapore and other European hubs and is a very popular tourist destination. There is one international airport and over a dozen smaller domestic airports, eight of which are paved. Victoria has an impressive deep-water port capable of supporting oil-field operations. Tourism, fishing (tuna) and supply of bunker fuel are the three main sectors that drive the local economy. PetroQuest permits are shown in grey and totals almost 23,000 km^2, while the Economic Exclusive Zone (outlined in red) covers 1,33 million km^2.

License policy

The legal system is largely based on English Common Law. The Economic Exclusive Zone (EEZ) comprises some 1.33 million square kilometres of territory, which is largely ocean. Oil exploration licensing is via a model agreement with the government of Seychelles and SEPEC (Seychelles Petroleum Company). Licences are extended out over 10 years and company tax is payable at 35%. Profit oil tax is via negotiation. There is a 5% royalty payment on oil production. The Seychelles government is development focused and is considering plans for a gazettal round in late 2006.

An oil prone frontier basin

Situated in warm azure waters of the Indian Ocean well outside the cyclone belt, Seychelles boasts one of the most pristine natural environments on the planet and offers a holiday experience that represents a powerful antidote to the demands of every day living. From sculpted granite boulders, coral reefs, untouched forests and bird sanctuaries to private resorts and exotic hideaways, visitors are 'spoiled for choice' when it comes to visiting easily accessible island venues. The Seychelles islands also boast a rich bio-diversity of both flora and fauna and has, in the past, been compared favourably to the Garden of Eden. Over 700 species of flowering plants have been identified on the inner granitic islands, and an additional 400 species are observed on the outer coralline islands. The World Bank is currently funding a bio-diversity study to the tune of USD 1.8 MM, this money being used to ensure sustainable development projects are conceived in Seychelles.

A multitude of geological data suggests that the petroleum system is in place. Rich, voluminous source rocks, likely migration paths, good reservoir rocks and huge traps all make the Seychelles offshore basins a tempting target for companies ready to explore a frontier province.

Lane Franks[1], Daire Sloan[2], Mark Sloan[3] and Chris J. Matchette-Downes[4]

By the end of 1996, due to the low oil price, all commercial exploration activity ceased in the Seychelles. However, against the backdrop of the current high oil price environment, interest levels in the Seychelles have been rekindled.

Currently, US independent PetroQuest International holds the only exploration license in the Seychelles. Covering some 23,000 km^2, the company is controlling an area that equals approximately four North Sea quadrants. PetroQuest International acquired the acreage following a promote by Albatross Energy Pty Ltd who identified the area as an over-looked petroleum province as suggested by the Seychelles National Oil Company (SNOC, latterly SEPEC).

Next to Billions of Barrels

The Mahé Island, including the Port of Victoria – the administrative centre – which boasts a spectacular backdrop of near vertical late Precambrian granite cliffs over 900 m high, is granitic in character and gives no clue to the petroleum potential of the offshore.

Generations of geologists have been puzzled by the fact that granitic plutons exist in the midst of the Indian Ocean. A bathymetry map provides insight to this conundrum. Approximately 60,000 km^2 area of ocean, the Seychelles Plateau, have water depth less than 200 m.

The explanation for the presence of the granitic plutons is fairly straight forward once we consider plate tectonic reconstructions for this part of the world.

Drilling activity on the Seychelles Plateau in the early 1980's confirmed that the Seychelles Plateau area is a drowned micro-fragment of Gondwanaland, a super-continent that lay to the south of the Tethys Ocean 225 Ma (million years ago). At this time the Seychelles is understood to have been conjugate to both Northern Madagascar and India. During the break-up of Gondwanaland, commencing 200 Ma, a portion of continental crust that underlies the Seychelles became detached from both India and Madagascar by the opening of the Carlsberg Ridge. As the Seychelles fragment detached it moved and rotated along a sinistral wrench fault system which now adjoins the northern tip of Madagascar.

The plate reconstructions nicely show the geological closeness of the proven petroleum systems in both India and Madagascar. In India, the prolific Bombay High oil province has proven some 3 billion bbls of Tertiary derived oil in place. In Madagascar, there are billions of barrels of heavy 8-13° API crude in exhumed reservoirs (Belomanga tar sands with 22 billion bbls and Tsimiroro oil sands with 8 billion bbls, both within the Morondava Basin).

Four Exploration Wells

The juxtaposition of the allochthonous continental terrane, upon which Seychelles is founded, has prompted interest from a significant number of major oil companies since the 1970's. First, Mobil investigated the possibility of exploring for oil in the Seychelles. Later, in the latter part of the 70's, a consortium led by the Burmah Oil Company chased up interests in the waters around the Seychelles.

In 1980-81 Amoco decided to test the theory that continental crust extends below the Seychelles Plateau by drilling three wells: **Reith Bank-1** (no seal present at top Karoo), **Owen Bank-1** (did not reach the objective) and **Seagull Shoals-1** (no depth closure identified in the post well mapping). These wells were unfortunately spatially clustered together, just testing the extreme western corner of the platform area.

The **Reith Bank-1** well drilled over 1900 m of non-marine intercalated sandstones and mudstones of inferred upper Triassic to Lower Jurassic age, this succession pertaining to the Karoo Supergroup. The drilling of such considerable thicknesses of sedimentary rocks proved beyond doubt that the Seychelles Plateau is underpinned by continental crust.

The **Owen Bank-1** well penetrated a similar thickness of Cretaceous and Middle Jurassic mudstones and sandstones.

Finally, **Seagull Shoals-1** drilled about 300 m of Karoo age sediments. Sands encountered at 2,734 - 2,737 m RT in this well have good visual porosity due to secondary

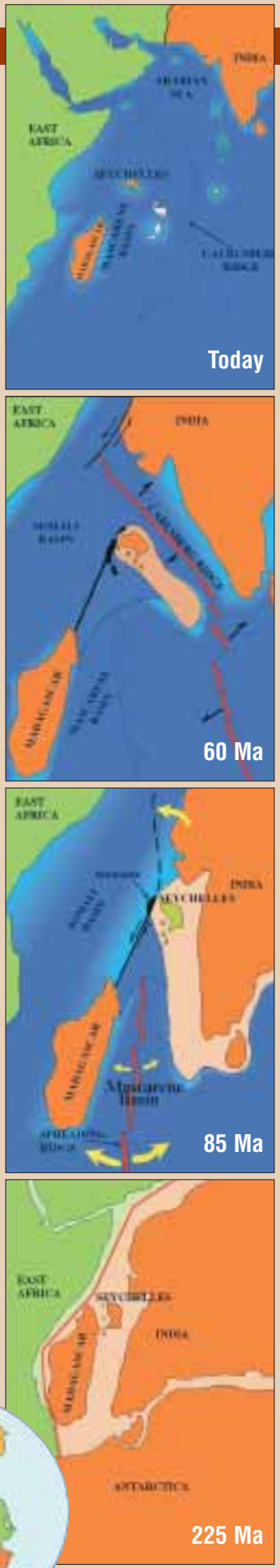


Plate tectonic development since Early Permian times.

[1] Managing Director PetroQuest International
[2] Managing Director Albatross Energy Pty Ltd, Perth Australia
[3] Founder of Albatross Energy Pty Ltd, presently Conoco Phillips Australia Ltd.
[4] East Africa Exploration, PO Box 72678, Dubai, UAE

porosity development via quartz and feldspar dissolution.

All wells failed to reach crystalline basement, and they did not encounter commercial quantities of oil. However, sidewall cores taken within the Karroo section at Reith Bank-1 yielded streaming cut fluorescence and bleeding beads of oil over a significant depth interval in excess of 630 m. A production test within the Karroo flowed water at a rate of 1,200 bbls per day with 0.7 ppm of benzene indicating the likely presence of hydrocarbons close by. The healthy flow rate suggests reasonable permeability.

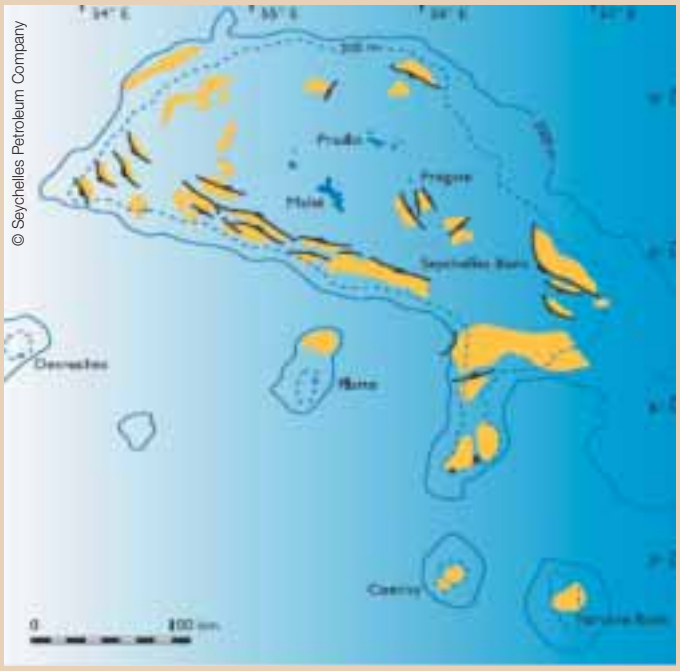
A fourth well, **Constant Bank-1** (1995) was drilled to the southeast by Enterprise but was TD'd after drilling 900 m of volcanics at a time when oil dipped to USD 9.0 a barrel. A similar (400 m thick) layer of basalt, interpreted to be of the same age (Late Cretaceous/Early Tertiary?), was drilled in the Owen Bank-1 well. Volcanics of this age also occur in Seagull Shoals-1, but are significantly thinner. Subsequent VSP work suggests that the volcanics in Constant Bank-1 were ~1270 m thick and that sediments akin to those found in the Amoco wells also exist in the East.

In Search for Good Data

Approximately 24,000 kilometres of 2D seismic data was acquired over the Seychelles Plateau between 1980 and 1996. During this period of active exploration a number of airborne aeromagnetic surveys, marine gravity surveys, marine sniffer geochemical surveys and passive airborne UV fluorescence were also acquired.

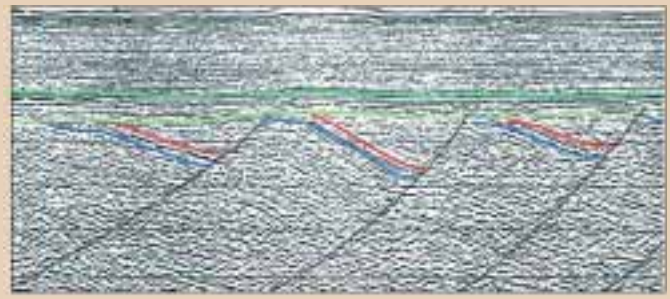
Unfortunately, in the case of the seismic, there is no digital seismic database of migrated seismic records. Problems with archive field tapes and observer logs make reprocessing a major undertaking. In many cases only old paper sections are available for scanning. Equally frustrating is the fact that the majority of the acquisition is of 80's vintage and data was acquired with short cables and low volume sources in almost all cases. Consequently, much of the existing seismic data is considered to be acquisition constrained.

There is no question that modern seismic data is required for

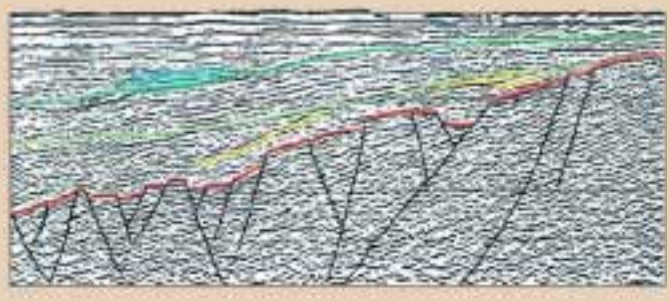


Prospects and leads in the Seychelles Plateau. Seismic acquired this year will hopefully mature some of them to be drilled.

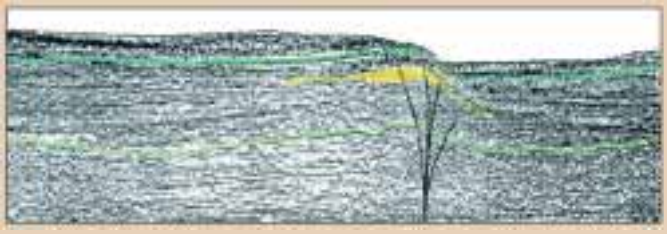
Tectonic framework reconstruction 225 Ma.



Stratigraphic pinchout/reef/tilted Fault block along the southern flank.



Stratigraphic pinchout/reef/tilted Fault block along the southern flank.



Wrench Fault anticline in deep water.

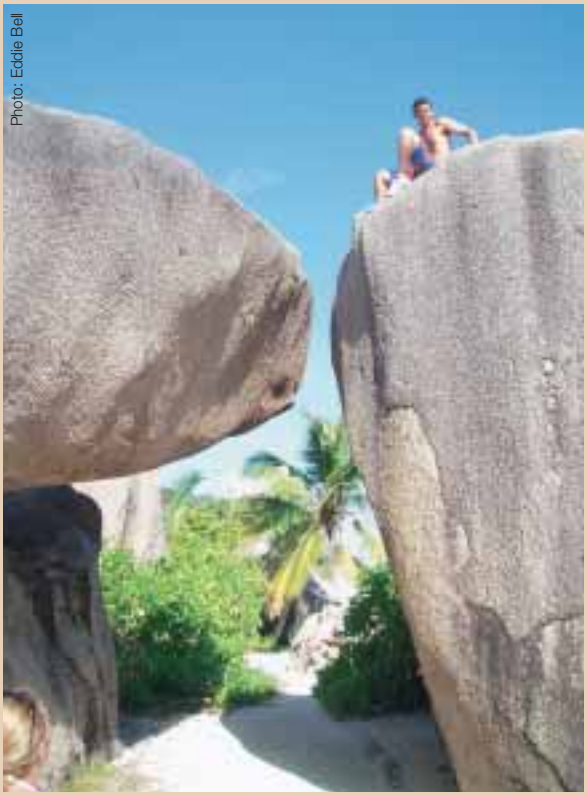


Photo: Eddie Bell

Granites exposed onshore give no clues to the offshore petroleum potential.

Seychelles as currently available seismic is challenged by the presence of a thick near surface carbonate layer, an approximately 900 m thick layer of basalts that were extruded during the Deccan Trap thermal event and that are probably present over a good portion of the plateau area.

An Oil Prone Petroleum System

Based on the work conducted to-date, including the results of 4 wells, and the results of recent geochemical analyses conducted by PetroQuest International, the Upper Triassic/Lower Jurassic petroleum system should be no longer in dispute.

We have, first of all, shown the presence of oil generative source rock intervals. An oil prone source rock system with TOC's in excess of 6% (now partially depleted) of Upper Triassic to Lower Jurassic age underlies and flanks the Seychelles Plateau. Geochemical analyses of extracts of locally derived migrant oil have been tied via isotopes and biomarker analyses to source rocks penetrated in the wells.

Oil shows, including head space gas, and migrant oils recovered in wells have been typed to source rocks penetrated in these same wells.

Peak oil generation commenced in the Cretaceous and continues to the present day at burial depths in excess of 2000 m. Beads of oil have been observed weeping from side-wall cores taken from good reservoir rocks of Karoo age in the Reith Bank-1 well and good oil shows including streaming cut fluorescence have been observed over an interval in excess of 630m in the same well.

A source kitchen area with a fetch extending 10,000's of km^2 has been recognised immediately down-dip from the PetroQuest permits, and conduits out of this kitchen area are observed as both carrier beds and clearly defined normal faults into the PetroQuest acreage. Migration is therefore not an issue.

A classic and robust source system at optimal maturity available to charge the vast structures seen on the seismic within and on the flanks of the Seychelles Plateau has therefore been defined.

As for reservoir, some 1,980 m of sandstones were penetrated in Reith Bank 1. The main Karoo Supergroup consists of non-marine multi-storey channel sands of Upper Triassic/ Lower Jurassic age. Sandstones with porosities in excess of 20% and good permeabilities have been recorded from log analyses and core data. Individual sand units in excess of 25 m are present in the Karoo interval in both the Seagull Shoals-1 and Reith Bank-1 wells.

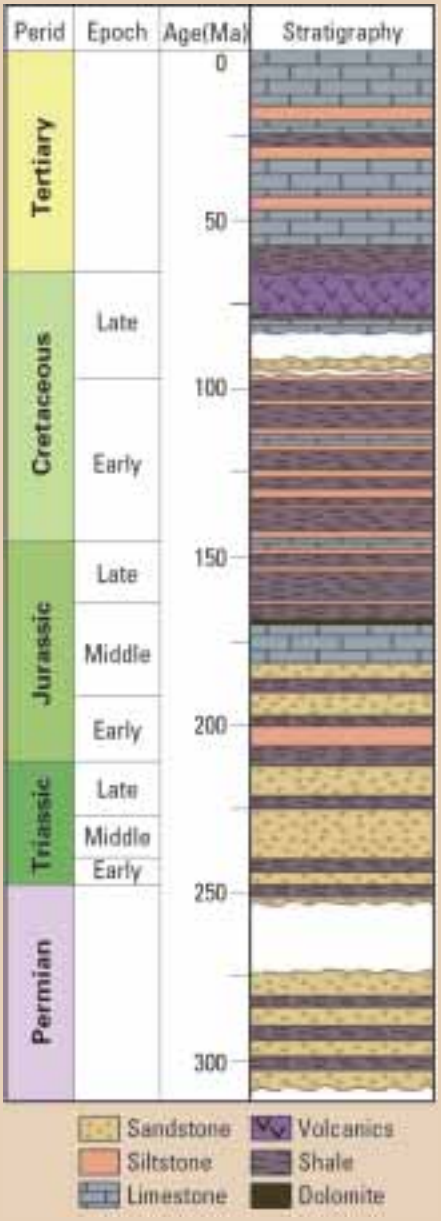
Seal is provided by regionally extensive 'drift marine shales' which have been penetrated in Owen Bank-1. A base seal is identifiable and mappable on seismic data and is inferred over the PetroQuest acreage position.

A significant number of structural closures have been mapped by Texaco (the previous operator) at the base of the drift shales over the PetroQuest lease area.

Consequently, we look upon the Seychelles Plateau as a high grade, oil prone frontier basin.

Next Phase on its Way

The next active phase of petroleum exploration on the Seychelles Plateau is now underway. During May, SeaBird Exploration operated a 2D seismic survey totalling more than 2200 km with the seismic vessel Geomariner. The program covers a number of huge structures and may prove up several drillable prospects, some of which may have multi billion barrel oil potential, in both shallow and deep water down to 2000 m.



Generalized stratigraphy of the offshore basins.

Remote Sensing – The Rise of the Virtual Geologist

Over the years remote sensing has developed from an obscure and expensive experiment to an essential and cost effective tool in the search for hydrocarbons, particularly in remote and inaccessible parts of the world. We talk to Infoterra, one of the leading exponents of this complex and fascinating discipline.

Jane Whaley

Ever since man first sent a camera into space in 1960, we have been mesmerized by this very different and spectacular view of the earth. Very soon it was realised that satellite imagery could afford us some unique insights into the earth's surface and what lay beneath. Oil companies rapidly saw the value of the technology, many of them setting up their own satellite imaging departments with dedicated hardware and software. Eventually, however, they found it more cost effective to divest themselves of these and turn to specialist companies for remote sensing acquisition and interpretation services.

Dr. John Diggens explains the advantages of satellite imagery for structural interpretation.

Developing into a worldwide tool

"The first commercial Earth observation satellite was launched in 1972 amid great excitement in the oil industry. This initial enthusiasm started to wane as doubts over the value of satellite imagery set in, probably partly as a reaction to the original overhyping of the tool," explains Dr. Anthony Denniss, Technical Director of Infoterra Ltd.

"The usefulness of satellite imagery then was constrained by the limitations of a single satellite and the relatively simple level of the technology at the time. As the number of satellites increased and the range of spectral bands gathered improved, together with better spatial resolution, the true effectiveness of satellite imagery to the oil industry as a way of looking at prospective areas became apparent, and the market rapidly opened up."

The acquisition of satellite imagery generates vast quantities of data which initially had to be stored on huge dedicated computers. This also contributed to the initial loss of faith in the technology. With the rapid increase in computing power over the last decade, together with the concurrent decrease in the physical size of computers, processing large volumes of satellite imagery has become more feasible, so much so that a great deal of the image processing can now be done on a laptop computer.

Anthony considers that a major advancement in recent years has been the reduction in the purchase cost of satellite data. "In the 1990's LandSat data at what we now consider to be low resolution cost approx $3,000 per scene; we can now download this same data free. Most other satellite systems are commercially owned but even their rates have dropped as a result of competition".

"In addition, there are now extensive archives of data, so that you can obtain data only 6 months old for half the price of up to date data. It is also possible to order coverage on demand, but obviously you pay a premium for that. The 'open skies' policy means that we can now explore almost the entire world remotely," says Anthony Denniss.

Range of data available

"The range of uses for remote sensing in the oil and gas industry increases all the time" adds Paul Murphy, Business Development Manager at Infoterra Ltd. "To enhance our interpretations we use a variety of datasets from different sources and with different resolutions and footprints: the smaller the footprint, the more detailed the dataset and the larger the file size. As we were able to acquire higher resolution images, we could look at smaller areas in greater detail,

What is Remote Sensing?

Remote sensing can be defined as the science of deriving information about the Earth's land and water areas from images and digital data acquired at a distance, either through airborne sensors or from sensors carried on satellites. The latter includes collecting data in both the visible and non-visible portions of the electromagnetic spectrum. Applications associated with satellite imagery are most commonly used for the oil and gas industry.

Optical satellite imagery is defined by two major criteria, the resolution and the band or colour content. The resolution of a satellite is defined as the size of the smallest individual component or pixel from which the image is constituted, so that if a satellite's resolution is stated as '5 metres', this means that each pixel in the imagery is 5m by 5m in size. Current commercial satellites provide data at resolutions ranging from 0.6m to several kms for weather type satellites.

The colour content is defined by the number of 'bands' of data that are available within the imagery provided. Each band of data is acquired separately and filtered so that only the information for a defined portion of the electromagnetic spectrum is recorded. An image consisting of the visible red, green and blue bands of data (RGB), for example, represents a natural colour image when combined. Most satellites acquire their imagery in four or more "bands", many of which are outside the visible colour spectrum and it is this characteristic that allows data which is not normally visible to the human eye to be used in an interpretation of the components of the earth's surface.

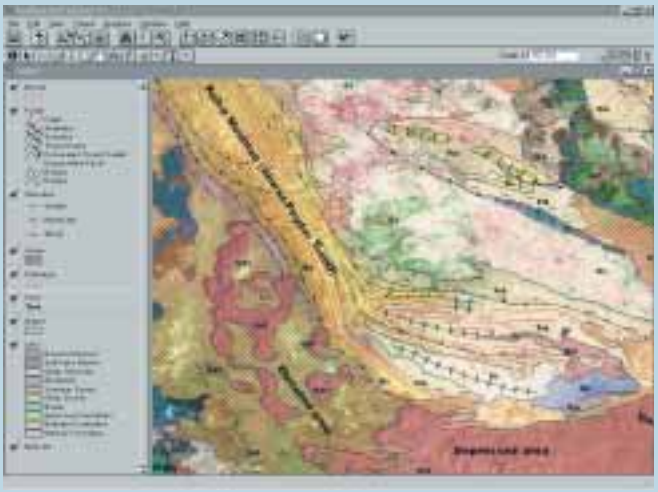
All satellite imagery is recorded as distinct areas, known as scenes, at a predefined size. This is usually defined as the square area of the satellite's swath width, which is the distance on the earth that the satellite scans in a single pass. For example, if the swath width of a satellite is 60 km, then a scene will usually be delivered as a 60 km x 60 km image. Combining 2 or more scenes together is referred to as mosaicking.

This image shows an area of the UAE using Landsat & multispectral bands 3, 2, 1 as Red, Green, Blue, giving a true colour image.

The same area of the UAE visualised using Landsat & multispectral bands 4, 5, 3 as Red, Green, Blue. This gives a false colour image, which is good for highlighting vegetation, seen in red.

Using Landsat & multispectral bands 7, 4, 2 as Red, Green, Blue gives a false colour image, which is good for highlighting lithology in arid areas. This images shows that the coastal plain includes dune sand (yellow), gypsum and/or sabkha (turquoise blue), and cultivated areas (vivid green). The mountainous area to the east is mainly composed of a thick carbonate sequence (browny-green to pale yellow).

3D visualisation using satellite imagery is very valuable when undertaking landcover and elevation analysis for pipeline route planning.



Geological and structural interpretation from Satellite Imagery.

which opened up new applications for the technology, such as pipeline route investigations and facilities monitoring. The different resolutions equate to a scale range of 1:2,000 to 1:500,000."

The US series of Landsat satellites has been providing high quality multi-spectral data for many years and can now offer a worldwide database of scenes with a spatial resolution down to 15m. Further detail can be interpreted using ASTER data, which provides higher spectral resolution in 14 different wavelengths of the electromagnetic spectrum.

"These satellites use light reflected from the earth, which obviously is a problem in areas where the sun is frequently obscured by cloud cover, such as the Nigerian coast," explains John Diggens, Senior Geological and Environmental Consultant with Infoterra Ltd., "but in these cases we can enhance our understanding through Synthetic Aperture Radar (SAR) data, which penetrates cloud, fog and haze."

A further recent advancement of great help to the geologist has been the development of stereoscopic data using the SPOT, ASTER, IKONOS or QuickBird satellites, which produces very detailed terrain mapping information from space. It takes 2D info and puts it into 3D context, ideal for the geologist.

John describes how this can be used. "Our first step after geo-referencing the various images is to make a digital elevation model (DEM) or a digital terrain model (DTM) of the area. We can then drape the different interpretations and images onto this to give a full 3D view of the area. By using anaglyphs - images displayed in different hues, usually red and green - and stereo instrumentation or glasses, the eye can distinguish features in the imagery in 3D. We also run our interpretations through software which can create a 'fly through', to give our client an idea of what the area looks like on the ground. This is particularly useful in poorly explored areas.

Sophisticated imagery and multiple uses

"We have 15 geoscientists in the Oil, Gas and Minerals Exploration division," explains John Diggens. "We undertake investigations throughout the range of exploration work, from regional evaluation through to licence and prospect evaluation and environmental modelling. Satellite imagery is an invaluable tool for mapping in remote areas or difficult terrain, particularly in the initial stages of analysing and developing a prospect, where

Largest in Europe

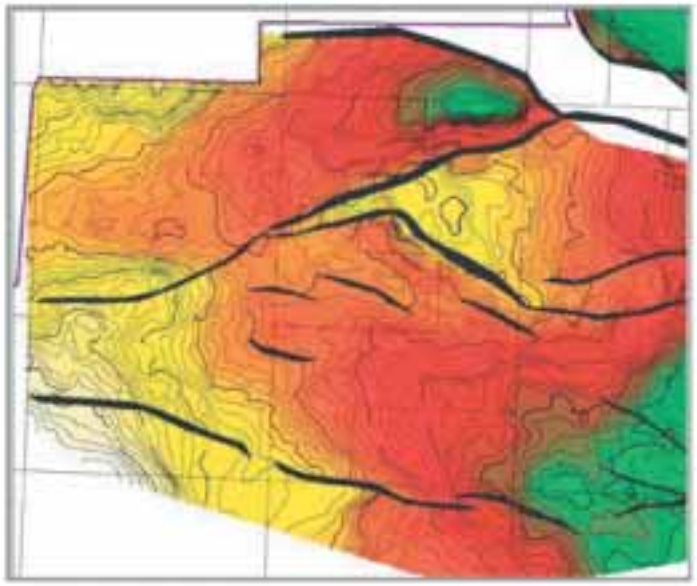
Infoterra was established 25 years ago as part of the Royal Aircraft Establishment, based in Farnborough, Hampshire. It was privatised in 1991 as the National Remote Sensing Centre and in 2001 the company changed the name to Infoterra and became part of EADS, Europe's largest aerospace company. EADS covers the whole range of the aerospace business, including building and launching Earth observation and telecommunications satellites whereas Infoterra Ltd., based in Leicester and Farnborough, concentrates on creating applications and offering interpretation and consultancy services.

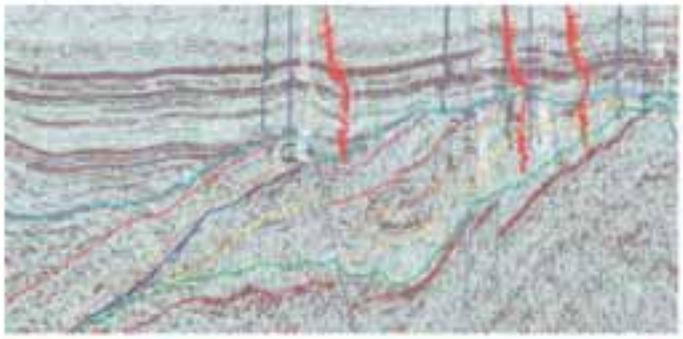
The interpretation of remotely sensed data for use in the hydrocarbon and mineral extraction industry has always been a key business for Infoterra. The interpretations are used for geological, environmental and logistical applications at both exploration and development stages. Practical uses of satellite interpretation in the hydrocarbon industry include geological and structural mapping, the recording of offshore oil seepage, seismic quality studies, pipeline and infrastructure planning, geohazard mapping and hydrology.

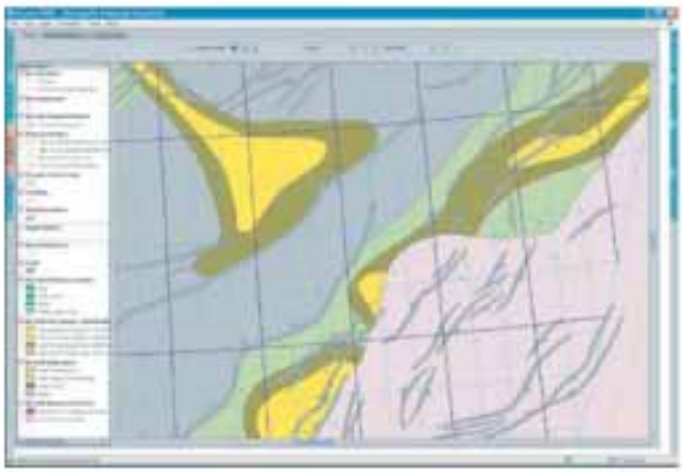
Dr. John Diggens, Senior Geological and Environmental Consultant and Paul Murphy, Business Development Manager at Infoterra Ltd (left).

CONSULTING THE SUBSURFACE

Aceca is a multi-disciplinary geoscience consultancy offering a unique range of products and services to the oil and gas industry. With more than 40 experienced geoscientists in our London and Stavanger offices, we provide integrated solutions for exploration, appraisal and development.







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detailed field geology is not an option. For the client this is a very cost effective way of assessing the economic risk of an area."

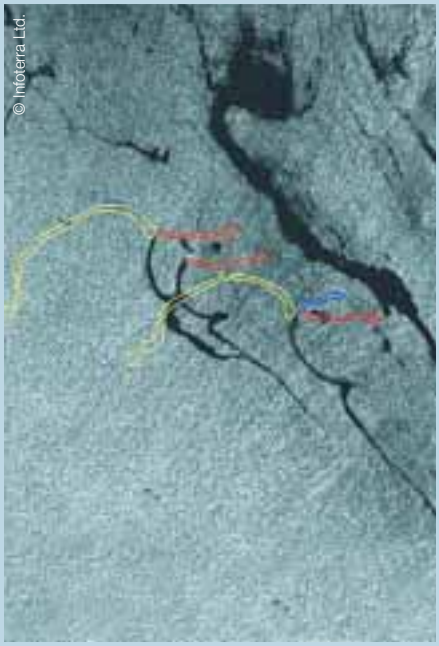
John goes on to discuss how the geoscientists tune the images and manipulate spectral bands to look for the spectral responses of different features and land cover types. "By using both 'true' and 'false' colour images we can map a wide range of features. The 'true' colour bands show features, which are visible to the human eye, and we use this to aid in the interpretation of geological structure, easily identifying faults, dips, anticlines and synclines. 'False' colour images use wavelengths collected outside the range of human visibility, so that, for instance, near infrared is useful for studying vegetation. Short wave infrared highlights different rock types and is used for geological and mineral mapping. It has now become so sophisticated that with the latest developments in satellite sensor technology it is possible to identify, for example, not just clay, but subtle compositional variations such as kaolinite and illite."

Environmental baseline studies and risk assessments, a prerequisite for many new exploration licences, is a sphere which is making increasing use of remote sensing. Through archived images it is possible to picture an area before hydrocarbon exploration, which can then be monitored during exploration and production activity and the imagery can ensure that sites are restored to their original condition if necessary. As John says "the thermal bands in use now can even pick out warm currents, indicating pollution by production water, as well as identify oil slicks, which could indicate potentially prospective oil seeps, or maybe just ships emptying their bilges."

All the interpretation is undertaken on-screen in a GIS environment, so that the results are easy to combine with other datasets.

Turning into Virtual Geologists

John Diggens brings his extensive field experience to bear when looking at images and can often imagine himself walking along the outcrop. He says that, for him, interpreting satellite imagery is "like being on a field trip every day. In any field situation it is important to stand back first to look at the whole thing before going in close to the outcrop. Therefore - with the latest high resolution data - we are able to get a lot closer to the rock face. It is now possible to undertake detailed fracture analysis and follow individual beds. I used to be a geologist – now I'm a virtual geologist!"



Example of remote sensing used to identify oil seepage in the Caspian Sea. Interpretations from earlier scenes (in colour) show how the seeps have moved over time.

Anthony Denniss considers that "remote sensing is an industry that will continue to develop, with, for example, new satellites such as TerraSar-X , due to be launched in Q4 2006. This will enable the collection of synthetic aperture radar (SAR) data at an incredible 1m resolution.

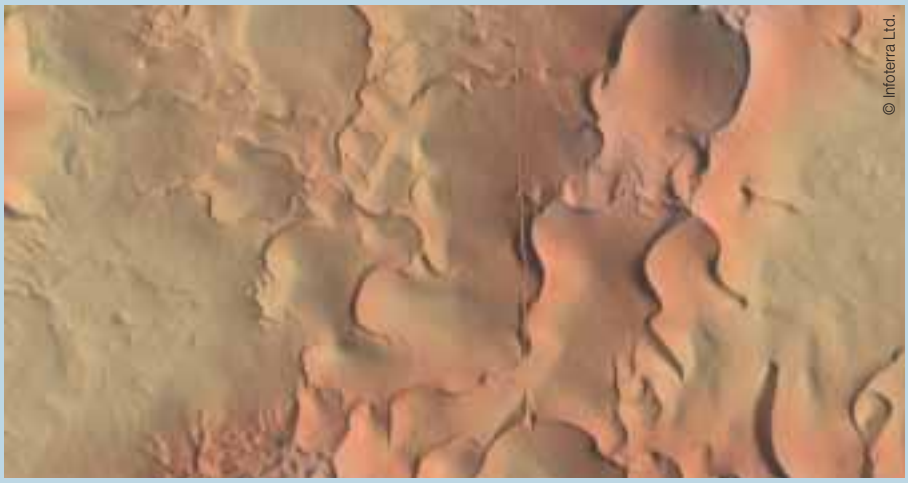
"The most important aspect of remote sensing to the hydrocarbon industry is that it ensures a company can effectively target field resources. As the technology develops even further, it will open up more and more applications and become even more important to the industry," concludes Anthony Denniss.

Seismic Route Planning

An interesting recent extension of the use of remote sensing in the oil and gas industry is in the planning of seismic survey routes in areas of difficult terrain, particularly in desert regions. Infoterra have been working with WesternGeco to investigate the quality of seismic acquired in the Algerian desert, using ASTER imagery and digital terrain modelling to ascertain the types of terrain through which the survey passed. Information from this ground-truthing exercise can be used to help plan more cost effective surveys in future, avoiding the need to reshoot poor quality data by predicting likely areas of poor seismic returns.

Vibroseis trucks can operate easily on gentle slopes, and can be used with care on slopes between 10° and 15°. Slopes steeper than 15°, however are not feasible. Infoterra mapped the survey area using relief shaded optical imagery and digital terrain modelling, colour coded to show slope information, clearly identifying the most suitable route to avoid the steeper slopes. The mapping also distinguished different dune types, with the more stable star shaped dunes clearly differentiated from the softer rounded dunes.

Gypsum and sabkha give poor seismic returns and remote sensing images can be used to identify these areas, highlighted through colour coding, again making it easy to plan a route which would avoiding the shooting of poor quality or unusable seismic data.



Lidar Digital Elevation Model from the Sahara Desert.

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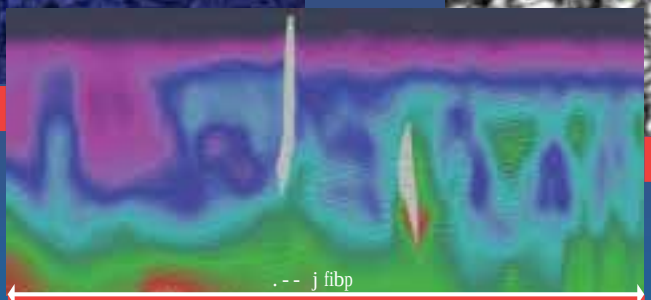

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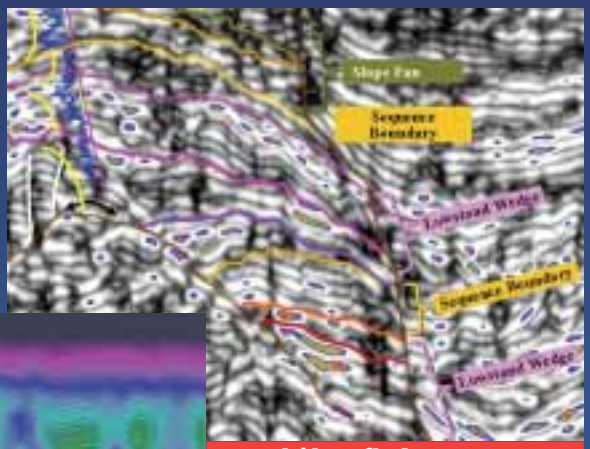

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Relationship Building is the Key to Success

Photo: Jane Whaley

Iman Hill has risen through the ranks from petroleum engineer to senior management roles with Shell and BG. She talks to GeoExpro about the skills needed to thrive in the modern oil industry, the paucity of women in high-ranking jobs – and about the pleasures and pitfalls of juggling a successful career with the demands of a young family.

Jane Whaley

"Self-discipline, consistent performance and setting clear boundaries are essential" explains Iman Hill, who has recently become Vice-President and General Manager, Developments, at BG Group. "My children can see that it is necessary to be disciplined and to work hard in order to achieve, and I think that is one of the best examples I can give them. They also see that women can and should do anything."

Iman has now worked in the oil and gas industry for more than 20 enjoyable and fruitful years. She considers that her aim in any job is to deliver beyond expectation, be dependable and to create opportunities for others.

The rise of the NOC

Why does she enjoy working in this business? "It's a very dynamic industry," she says, "allowing you to see a lot of the world and to continue learning, all the time. While I enjoyed practical work as a petroleum engineer, what I really like is looking at the whole value chain, generating innovative strategies and creating relationships to win new business."

"The industry is changing." Iman continues. "Decreasing resources means more competition. The independent oil and gas companies in particular need to recognise the rising capacities and capabilities of the national oil companies, whose abilities are now matching their aspirations. The balance of power is shifting, which to me means that the international companies need to be dynamic and to understand their own strengths and capabilities and work them to the limit within their strategic framework. The way ahead is to allow your best people to build relationships with each other, with your industry partners and with the NOCs. I firmly believe that relationships are the foundation of the industry and the future, and that those companies who want to work in true partnership with host governments will be successful. The important distinction here is that being a true partner means creating value for all, not just driving your own business agenda, and sometimes this means compromising on something you want."

A successful and high achieveing woman, Iman Hill is still a rarity in the industry.

"Companies have to be wary of risking their long term future for short term goals. For success in the oil industry you need to make the most of your existing assets and create value. You must be able to bring good opportunities into the 'funnel', whilst making sure these are worked on in a timely fashion. A company also needs to focus on 'today's core countries', as well as those which will become core in the next decade, and build sustainable relationships at every level. And don't forget that it is always very easy to overestimate how good your relationship is, when you're the one doing the assessing!"

Structured training at BP

Iman had not always envisaged a life in the oil industry. She was born in Saudi Arabia to an Egyptian mother and Palestinian father, the eldest of 6 children. Her parents, both doctors, sent her along with her two sisters to boarding school in Edinburgh, which was, as she says, "Quite a challenge - we didn't speak much English and as the eldest, I had to look after my younger sisters. I was only 5!"

Iman went to Aberdeen University and studied Biochemistry, but she decided that the career opportunities offered in this domain did not appeal to her, so she took a Masters in Computing and then began to look around for a job. "Obviously, all the big companies in Aberdeen were in the oil industry, so I suppose it was inevitable that I would end up working for one of them," she laughs. In 1986 she started with BP as a trainee petroleum engineer.

"In those days there were few degrees in petroleum engineering, so companies like BP picked good science graduates and put them through an excellent structured training programme. While my academic background wasn't an obvious route for a petroleum engineer, my undergraduate degree showed that I was both scientific and practical, while computing demands ordered thinking. BP looked after us well, with a structured training programme which took three years and covered a whole range of disciplines, including petrophysics, production technology and well site engineering. Yes, I did my stint on the rigs in the North Sea!"

What did Iman think of working on the rigs? "Well, I was the only woman, but I just got on with my job, which was to learn the practical work of the petroleum engineer. My male colleagues accepted me when I showed them that I could be a useful member of the team. I think all graduates in the industry should do well site work, as not only do you learn the hands-on details of the job, but it also teaches you to depend on one another. My main problem with working on the rigs was the horrible weather. And I don't like heights! We often had to go up to the monkey board 100 feet above the rig floor, so I really had to conquer my fear!"

New Challenges

After 11 years at BP, with postings in Aberdeen, London and Glasgow, Iman decided she was ready for a fresh challenge and in 1994 she moved to London to work as a freelance petroleum engineer. "I wanted to be a consultant to prove that I could work in any business and physical environment, without large company support," Iman explains. "I think it is important to move out of your comfort zone, and working independently challenges you and builds your skills and experience.

Also during this time in London Iman met and married her husband Albert, and had their first child. "We decided early on that one of us would stay at home with the children while the other was the breadwinner – unfortunately, I drew the short straw! I have always believed it important not to expect allowances because I am a woman,

even if that means working up until the day I gave birth, which is what happened with my second child. I had started a new job and it was important to me to show my boss and my team that I was a good choice and a dependable colleague!"

In 1996 Iman was headhunted by Shell to be Principal Petroleum Engineer in Shell Sarawak. "This should have been an enjoyable posting, but unfortunately our arrival coincided with the forest fires in that area and the whole country was covered in haze, which affected our young daughter very badly." Iman explains. "We stayed 18 months, but by then Nadine had been hospitalised and had severe asthma. Shell was enormously supportive of us throughout this and relocated us to The Hague, where my daughter rapidly recovered."

"In the Hague I was appointed Business Interface Manager, Middle East, for the Technology organisation. This was an interesting role, which involved ensuring that technologies developed in the Shell's extensive Research and Development Laboratories, such as water shut-off techniques, and expandable tubulars, were being implemented in the field."

From 2000 to 2002 Iman was in charge of Shell's Exploration and Field Development Planning Unit in The Hague, helping to rebuild the company's regional exploration capability and creating a team capable of delivering best-in-class field developments, before becoming Senior Regional Advisor for Africa to Shell's Committee of Managing Directors (CMD). "In this role I covered all of Shell's core businesses; E&P, Gas and Power, Downstream, Chemicals and Renewables" she explains. "I also developed and implemented various business and sustainable development strategies, but the core job was about building relationships. This was a defining job for me. I learnt a huge amount and I met some fascinating people, including many of Africa's Heads of State and Oil Ministers. I also got to do things like working with the Government of Ethiopia to bring more foreign direct investment to the country. I really enjoyed that job, although it was stressful - particularly for my husband, as it entailed a lot of travel, which meant Albert was on his own with the children quite a bit!"

Egypt Country Chair

In 2004 Iman Hill became Country Chairwoman for Shell Egypt, based in Cairo, another job she really relished. "The job of Country Chair is also all about relationship building," she explains. "Relationships not just with our own staff, but with the government, oil ministry and national oil companies of the host country. The Chair must understand the needs of both Shell and the country and work hand in hand with the host government. These things enable business to happen. I was also ultimately responsible for the staff and effectively never off duty, so it is hard work, but I loved it."

Iman and her family, now consisting of five children ranging in age from 2 to 11, really enjoyed the 18 months they lived in Egypt. "It's a very pleasant place to live and the kids had a great time with all the swimming and the good weather. In addition, my mother lives in Cairo, so it was wonderful for them to get to know each other better. I enjoyed getting a chance to use my Arabic and liked the different lifestyle, though I have to admit, I never got used to the driving!"

After 18 months in Egypt, BG approached Iman and she was enticed back to the UK to head up the Developments section for them. "I loved working for Shell, but was intrigued to come to a smaller company like BG, which has an excellent reputation and is known for being dynamic and fast moving," Iman says. "I felt I could make a good personal impact and see the effects of that in a much quicker time frame due to the size and culture of BG. I've been here 8 months now and I haven't been disappointed".

Why So Few Women?

The family have moved back to England, to a house 20 minutes drive from BG, which they found on the internet and only saw the day before they bought it! "The children have settled well into their new schools and are enjoying life," says Iman.

"I try to be home in time to cook their dinner, help with homework, bathe them and all the usual things a mother does, but I admit that I am very torn sometimes. I often find myself on the phone at the weekend, trying to sort out a problem at work, while the children are running in and out and asking me to play with them. The kids consider Albert to be the 'fun' part of their lives and come to me for emotional support. But I think he has the harder time, as our society is still getting used to the idea of Dads being at home, so it is quite a lonely role. Knowing that the children are safe with Albert has been fundamental to my success. He too is an excellent role model for our brood as they will grow up with no pre-conceived ideas of the roles of women and men!

Iman agrees that there are still very few women in senior management roles in the oil industry. "Although plenty of young woman enter the business, it remains a male dominated industry. Perhaps this has to do with the inherent culture of the oil industry. Even though anti-discrimination laws as well as workplace rules allow flexible working, career breaks and childcare support, women still perceive that they will not be taken seriously or advance if they take advantage of these supportive policies. Efforts have been made to change this, but deep down the perceptions remain. This sounds negative, but I am very positive about the opportunities this creates for all of us as individuals to develop an inclusive culture in our own organisations, one that nurtures and promotes diverse ways of doing things. Your competitors may copy your strategies but they cannot replicate your people."

Would Iman encourage her children to go into the oil industry? "I want my children to do whatever will make their souls light up!" she laughs. "If that means the oil industry – well it's a tough business, but it's fun, and if that was the challenge that they wanted and they felt they could make a difference, then yes, I would encourage them!"

"Our ability to accumulate and add value to data underpins our business"

The full interview with Richard Fowler in GEO ExPro No. 2/2006 is available online: www.geoexpro.com ("People").

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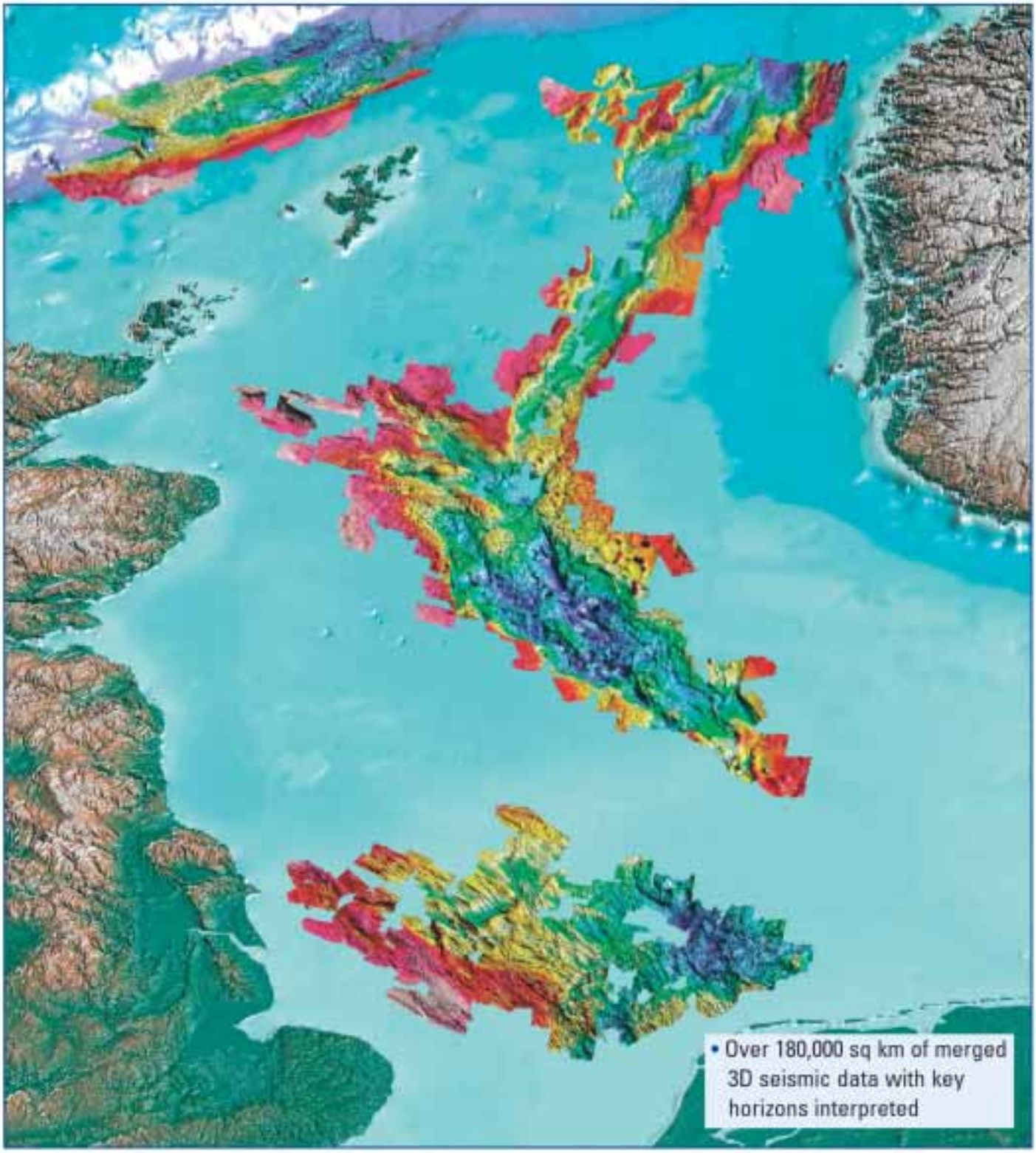

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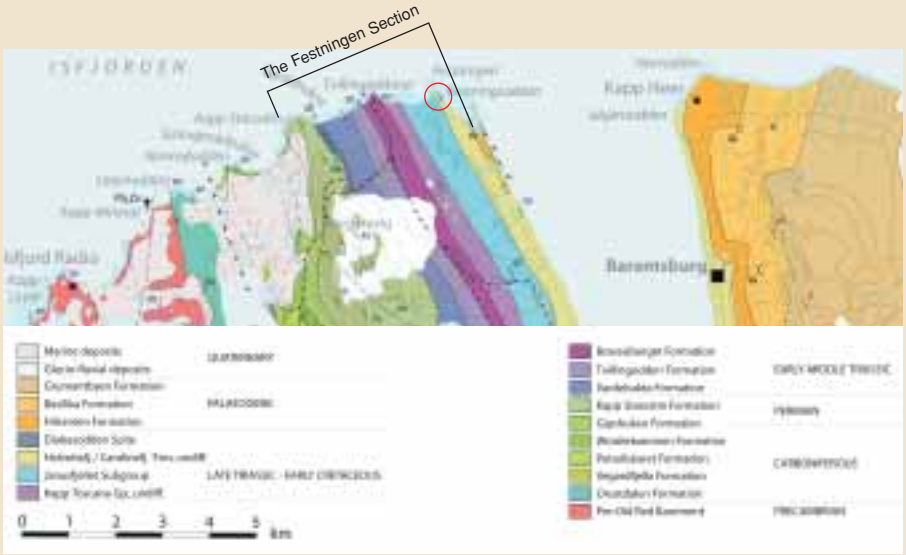
A World Renowned Section

With relatively easy access from Longyearbyen, the Festningen Section is a very popular geological attraction that displays an almost complete section of sedimentary rocks throughout the Mesozoic. Scientists, students and oil company geoscientists come every year from all over the world to learn basic principles of sedimentology and sequence stratigraphy.

Atle Mørk is Senior Geologist with SINTEF Petroleum Research and has more than 25 field seasons in Svalbard.

Photo: Hans Arne Nakrem

In August, "the Sub-commission on Triassic Stratigraphy" have there annual meeting in Longyearbyen. http://natmus.uio.no/triassic-2006/



An almost continuous section, although folded and partly repetitive, from the Late Permian to the basal Cenozoic is well exposed along the coastal cliffs of the Festningen Section. Organic rich shales that should be considered potential hydrocarbon source rocks occur in the Middle Triassic and Upper Jurassic, while sandstones with reservoir quality are found in the Upper Triassic and Lower Cretaceous. The outcrops thus constitute important analogues for petroleum geologists exploring the Barents Sea further south.

Sandstones of the early Cretaceous Helvetiafjellet Formation that are exposed on the Festningen Islet continue onshore and stand out as a prominent ridge. Dinosaur footprints (mentioned in the text) were first found on these beds in the 1960'. Students and professional geoscientists visit Svalbard - and the Festningen Section in particular - because of excellent exposures that are not covered by vegetation.

Atle Mørk, SINTEF Petroleum Research

The Festningen Section is a world-renowned geological profile with excellent exposures of sedimentary rocks ranging in age from the Carboniferous to the Cenozoic. Located strategically in the outer Isfjorden of western Svalbard, it is easily spotted by tourists as well as geoscientists on their way by boat to Longyearbyen, the "capital" of Svalbard and the world's northernmost city.

A continuous section from late Precambrian to Cenozoic can be studied in this location. This is because it is practically turned vertical by folding when Greenland and Svalbard collided during the initial phase of opening of the North Atlantic Ocean during the early Cenozoic. Along the shoreline you can walk five km along well-exposed coastal cliffs. Harsh winter storms with rough waves and drifting ice wash the section clean, and in this way we get new, clean exposures every year.

The section is named after Festningen ("The Castle"), a small islet with a lighthouse. It is formed by the indurated Festningen Sandstone of Cretaceous age that consists of river deposits. It is now also famous for its large dinosaur footprints.

Dinosaur footprints

During the early part of the 20th century, Norwegian geologists and palaeontologists measured the section bed-by-bed and collected numerous fossils. International specialists later studied them for the purpose of making a detailed stratigraphy.

The discovery of dinosaur footprints was made on an international geological field-trip in 1960 attended by Professor De Lapparent. *Iguanodon* was kept responsible for the traces that were 68 cm long with a distance between them of 2m showing that quite a big beast had wandered around in Late Cretaceous time. Casts in plaster were made of the traces the year after, luckily, as the rocks have now fallen down due to weathering. These casts can be seen at museums in Longyearbyen and at the Paleontological museum in Oslo. When I visited the place 20 years later, new traces - however not so big and nice - were exposed in the vertical cliff, and visitors to Festningen can still see well-preserved footprints. At the time of formation, the area had already drifted to high latitude indicating that the dinosaurs needed to be warm blooded to survive the winter.

Renewed interest for the Festningen Section started with the Norwegian oil industry moving into the Barents Sea. Student groups from the universities in Oslo and Bergen began detailed investigations. The purpose was primarily to understand the sedimentology and depositional history of the area. This also started the use of the Festningen Section for excursions during the short summer from June through August. Following the universities, the Norwegian Petroleum Directorate visited the section through several summers, and thereafter Statoil, Norsk Hydro and other oil companies as well as IKU (now SINTEF Petroleum Research) made several field trips. A series of master and doctor thesis resulted.

The organic rich and soft Middle Triassic shales (Bravaisberget Fm) have been strongly folded making stratigraphic studies complicated.

The Paleozoic

Carboniferous fluvial conglomerates and some carbonate beds are found only locally, but from the late Permian Kapp Starostin Formation (named after this locality) and upwards, the section is well exposed. Limestone banks with brachiopods form the base of the exposure. The limestones grade into shales found in this deep cold-water shelf sediment. Towards the top of the Permian, soft clays silicified by sponge skeletons have produced a glassy unit standing out as a peninsula towards the bay eroded into soft Triassic shales.

The Mesozoic

The Lower Triassic Vardebukta Formation is named after the cairn on the coastal cliff used for navigation by trappers along the coast in earlier days. Results of the extraordinary mass extinction at the end of the Permian can be seen as fossils are sparse in the uppermost Permian sediments and almost absent in the lower 100 meters of the Triassic. Even trace fossils are quite sparse.

A major transgression that can be traced all over the arctic, and also globally (see article by Ashton Embry in GEO ExPro No. 2/2006, p.26). It occurs at the base of the Middle Triassic resulting in organic rich, dark mudstones that has been strongly affected by the early Cenozoic folding. This unit forms a major source rock for oil further east and in the central part of the Barents Sea (Steinkobbe Fm). The coastline later prograded eastwards and prominent well-cemented shallow marine sandstone were deposited all along western Spitsbergen.

In Svalbard the polar bear is a constant threat making it necessary to carry guns. When big groups it is normal to have a guard watch for this very dangerous animal.

CENOZOIC

CRETACEOUS

Firkanten Fm.

2200

Carolinefjellet Fm.

2000

Helvetiafjellet Fm.

Rurikfjellet Fm.

JURASSIC

Agardhfjellet Fm.

1500

TRIASSIC

Wilhelm-ya Subg r.

UPPER

De Geerdalen Fm.

MIDDLE

Bravaisberget Fm.

1000

LOWER

Tvillingodden Fm.

Vardebukta Fm.

500

PERMIAN

Kapp Starostin Fm.

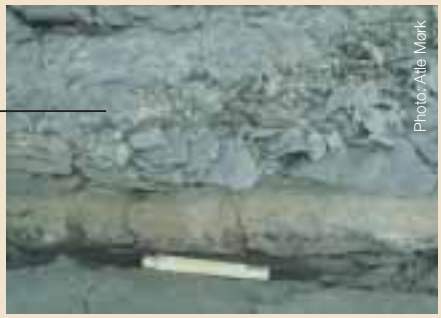
0 m

M Silvi I m Sst Cgl

The basal Cenozoic conglomerate overlies shallow marine shelf deposits; tens of millions of years are missing at this contact.

Dark Cretaceous shales are overlain by the fluvial channel deposits of the Festningen Sandstone.

Limestone bank deposits formed by phosphatic ooids (inset) demonstrate a high energy period within the Middle Triassic.



Galleries of phosphate nodules, mostly formed as tunnel infillings, and phosphate nodular beds in the organic rich sediments show that life flourished at times between anoxic periods.

Bivalve (aquatic mollusks) bank deposits forms the first mass occurrence of life in the Triassic.

A major sequence boundary occurs on top of the hard Permian cherts that are overlain by soft Triassic shales.

Bryozoans are important fauna elements in limestones of the Upper Permian Kapp Starostin Fm.

This section nicely displays a transgression with continental deposits to the right (Helvetiafjellet Fm) and marine deposits (Carolinefjellet Fm) to the left.

A new major transgression took place in the Upper Triassic. This was accompanied with a dramatic shift in sedimentation pattern. The marine dark sediments were replaced with shallow marine sandstones deposited on a shallow shelf. In the Barents Sea, thick deltaic units were formed at this time.

A condensed section of only 20 m thickness spans the Triassic – Jurassic boundary at Festningen. Further to the east and in the Barents Sea, this unit consists of sandstones with excellent reservoir quality. At Festningen, spectacular conglomerates form the boundaries at base and top.

Above the conglomerates, a thick, dark shale unit represents the Cretaceous – Jurassic boundary. The Jurassic has abundant organic matter and is an equivalent to the Hekkingen Formation of the Late Jurassic source rock system in the Barents Sea. The Helvetiafjellet Formation at Festningen has several distributary channels with thin interbedded coals and represents the deltaic environment where dinosaurs wandered around.

The Cenozoic

A major erosional gap spanning 60 – 70 million years separates the Cretaceous sandstones from the basal Cenozoic conglomerates initiating the last depositional succession on Svalbard.

The Tertiary is also well known for its coal beds that have been mined for more than 100 years. Today, Store Norske Spitsbergen Kulkompani is producing nearly 3 million tonnes of coal per year in the mine Svea Nord, while the Russian company Trust Arktikugol has a far lower output from Barentsburg. An abandoned coal mine is found a few meters above the base of the Cenozoic at Festningen and demonstrates early prospecting for this important energy resource.

Visiting the Festningen Section

Detailed planning is necessary if you want to do field work in Svalbard as there is no public transport. You will need a helicopter or a boat that can be rented in Longyearbyen. The Festningen Section can be reached by boat from Longyerbyen in about 3-5 hours.

The old hunting cabin at the base of the section with scattered Carboniferous conglomerates provide a natural harbour at a river outlet. In the Upper Permian and Mesozoic sections, access is easiest on high tide. Note that access has to be parallel with the strike. If not, your propeller may map sandstone ridges.

The pioneers of Svalbard used large, sturdy wooden boats when doing fieldwork, surely creating hazardous episodes. The detailed work they carried out during long summers is therefore quite impressive. Even today, with modern rubber-boats and survival suits, landing can be rough and wet. The reward is, however, worth the effort as the Festningen Section displays one of the most complete continuous sections through the Mesozoic anywhere in the world.

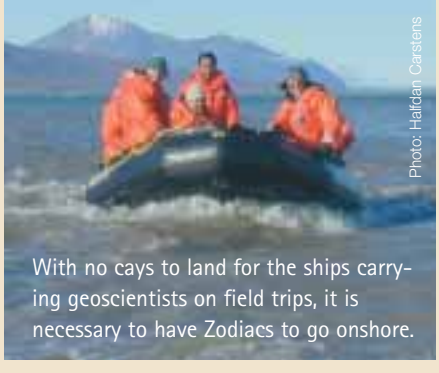
Svalbard

Svalbard is an uplifted corner of the Barents shelf made up of islands totalling some 63,000 km^2 (the equivalent of more than 10 North Sea quadrants). The main island is Spitsbergen, a name given by the Dutch explorer Wilhelm Barents in 1756 because of its jagged, frost-splintered peaks and valleys submerged in huge glaciers, which can be seen far away from the coast. "Svalbard", a name given by the Norwegian Vikings, means the "cold coast". With summer temperatures generally below 10 °C, visitors have no problem in accepting this. However, with four months of 24 hours daylight in Longyearbyen (April 22nd to August 22nd), Svalbard also deserves the nickname "land of the midnight sun".

It is often said that Svalbard is like a complete geology textbook, neatly representing all the formations from the Precambrian through to the Quaternary. The lack of vegetation enables geoscientists to study the rocks with relative ease. However, most locations are difficult to access as there are no roads outside Longyearbyen, necessitating transport by boat or helicopter, and the polar bear is a constant nuisance for tourists and geologists alike.

Several exploration wells have been drilled on the archipelago since 1960. No discoveries have been made, but good oil shows were reported in two wells drilled by the Russians in the 1990's and gas shows have been recorded in several wells. It is widely believed that Svalbard does not contain significant amounts of oil and gas because of tight reservoirs.

The real value of Svalbard for petroleum geologists is excellent outcrops that can be used as analogues of North Sea depositional systems and to the geology of the Barents Sea.



With no cays to land for the ships carrying geoscientists on field trips, it is necessary to have Zodiacs to go onshore.

Towards a World Record

Innovative drilling technology now makes it possible to drill into satellite fields that are located several kilometres away from the original field.

In the North Sea, Statoil is currently drilling an "extended reach well" – up to 85° from the vertical – from the Gullfaks field into the comparatively small field Gulltopp some nine km to the west. The purpose is to tap a satellite that has reserves of approximately 25 million barrels of oil. If successful, this well will save development costs and at the same time make it possible to produce several satellite fields that have previously been considered uneconomic.

However, this is by no means an ordinary production well. Statoil is now testing the limits of the drilling technology and will with this well set a new world record. With a total length of more than 10,000m (planned vertical depth is 2,450m), it will be the longest "extended reach well" ever drilled from a fixed production platform.

More important, however, this well will enable Statoil to tap a reservoir much more cost efficient than by drilling a well from a separate drilling rig with sub-sea completion and a pipeline tied back to Gullfaks A.

The Gullfaks A platform is located in the northern North Sea and is producing approximately 80,000 bopd from Middle Jurassic sandstones.

Photo: Halfdan Carstens

The drilling of wells from Gullfaks A is utilizing modern technology that is highly automatic involving a minimum of personnel. All drilling parameters are shown on monitors watched by the drilling supervisor and his crew.

Photo: Halfdan Carstens

The geological descriptions of the borehole cuttings are carried out by a service company that is manning the "mud logging unit". The two geologists are also monitoring drilling parameters and all recordings that relate to the drilling mud, including oil and gas shows.

Photo: Halfdan Carstens

Communication between the drilling engineers on the platform and the onshore drilling office is facilitated by fiberoptic cables enabling the two parties to discuss all matters related to the drilling in "real time". In addition to being cost efficient, it also leads to safer operations.

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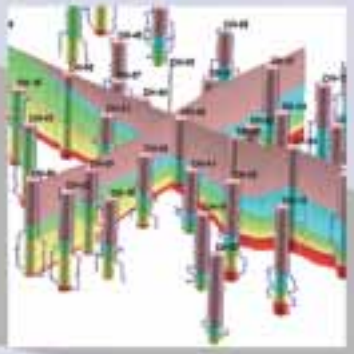

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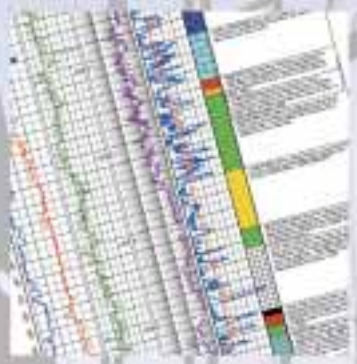

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Moving in the right direction

Dr. Gareth Williams is President of EAGE. We have talked with him about the organisation he has been serving for many years as well as the future of the oil and gas industry.

Photo: Private

Dr. Gareth Williams is presently Vice President Geophysical Technology with Veritas DGC. With a BSc, Msc and PhD from Southampton University in physics, a Fulbright Scholar at Colorado University and a Post-Doctoral Research at Imperial College, London, he has a solid scientific background. Dr. Williams has served EAGE in several positions: Research Committee 1999-2000, Oil and Gas Committee 2000-2003 (chairman 2001-2003), Vice President elect 2003-2004, Vice President 2004-2005 and President 2005-2006. Here he is photographed when visiting the SPG conference in Calcutta in January on behalf of the EAGE.

EAGE stands for the European Association of Geoscientists and Engineers. That is a very broad ambition. Are you able to accommodate the needs of all members?

It is true that our 'mission' is indeed very broad and covers a range of industries and a range of scientific disciplines – geophysics, geology and reservoir engineering – but I think this is one of our key strengths. Many oil companies are organised into 'Asset Teams' containing a range of scientific disciplines so it is important that we reflect this in the events we organise. Our aim is to provide services for specialists in each of the scientific fields while at the same time creating opportunities for the experts to learn from each other and thus optimise the value of each other's work. Also, by working with each of the American societies, AAPG, SEG and SPE, we are improving our offering of conferences, workshops and field trips across the board. So, we are not there yet, but we are certainly moving in the right direction.

EAGE is still by many seen as largely an organization for geophysicists. Do you have any plans to change this and make it more attractive for geologists to join?

We are actively working to re-dress this perception but it takes time for this to happen. I suspect that our actions are a little ahead of perceptions! For example, we are careful to ensure that our committees are composed of all the disciplines we represent. Equally, we have a geologist as President every 3 years, just the same as for geophysicists and engineers. On the other hand, we always need more volunteers, especially geologists. In my mind, liaising with other societies, where we can, will also improve our geological services.

What is the reason that EAGE is now increasing their membership?

From December 2000 to December 2005, our membership has risen from approximately 5500 to 9500. This is a very strong growth that I believe has been caused by many factors. During that time we have expanded rapidly the number of events we organize each year, improved the quality of our publications, improved our on-line capabilities, incorporated the Near Surface division into the EAGE and bolstered our geological and reservoir services. Geographically, we have also significantly raised our commitment to North Africa, Eastern Europe, Russia and the FSU, and also the Middle East. Earlier this year, we formally opened our Moscow office and our Middle East office was opened early in May. First Break is now available in Russian as well as English. We also have a well-established biennial conference in North Africa.

What do you consider the main tasks of EAGE?

I see two major themes for us. First, we have to provide services for specialists in each of our scientific disciplines and industries while at the same time providing opportunities for the different specialists to interact with experts from other disciplines. Second, we must look to the long term by supporting students already studying geosciences and reservoir engineering and by encouraging more young people to study science in school.

Can you give three reasons why young geoscientists should join the organization?

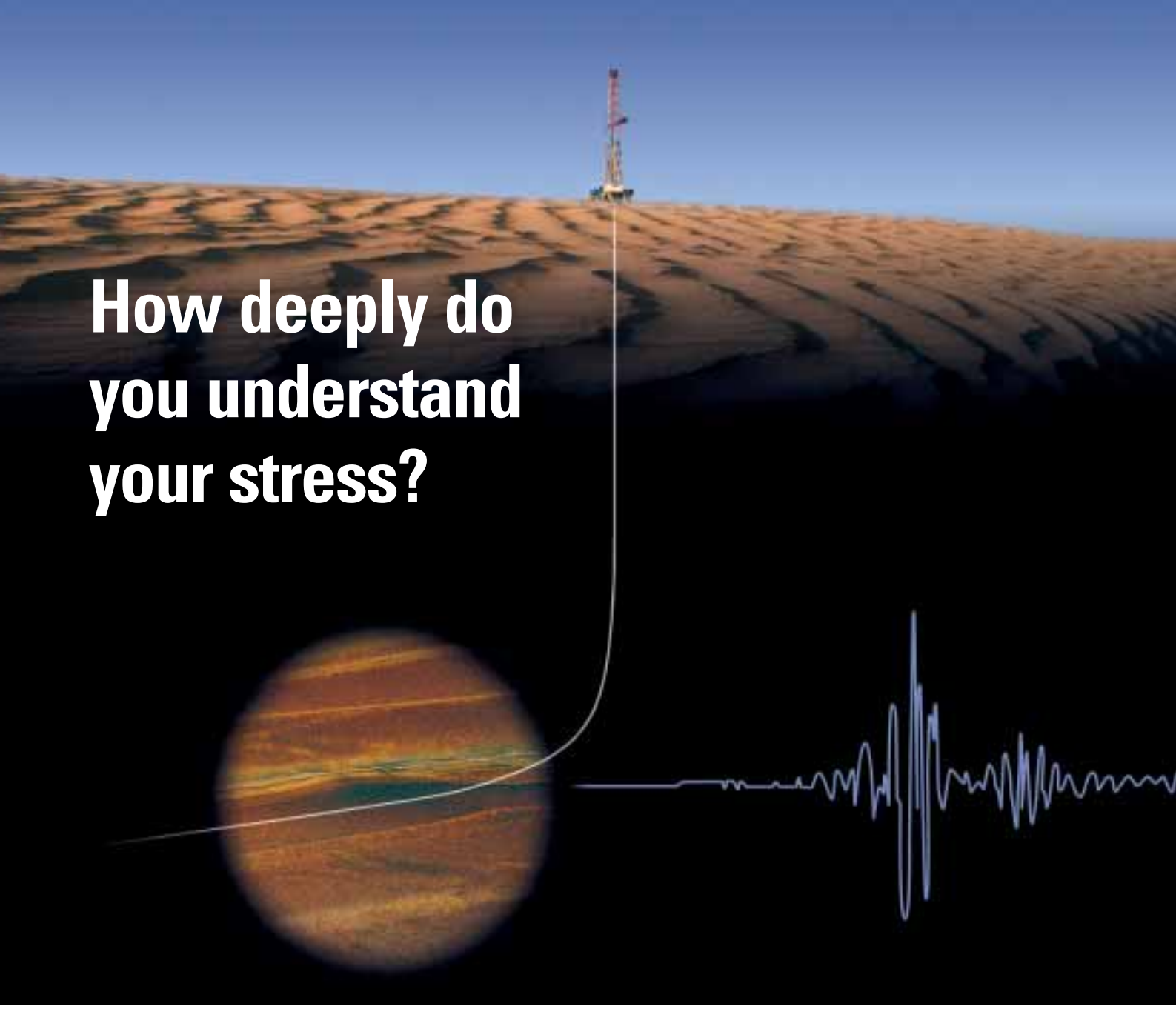
1: To gain access to our journals, to the reduced registration fees for our various meetings and to our support for students, 2: To establish contacts with fellow members across the range of disciplines, and 3: To contribute to and be part of a society that reaches out across international borders and across scientific disciplines

How do you look upon the future when the need for energy is increasing at the same time as the opposition from environmental groups is also increasing?

To my mind, the petroleum industry performs a valuable service and receives a remarkably and often unjustifiably bad 'press'. Our everyday lives would be very different without our industry and most people would find it a change for the worse. So, we need to change the perception that we are ruthless profiteers who will destroy anything in our way if we are allowed to. The way to do this is to engage in discussion and action with environmentalists so that they understand us better and so that we do a better job of protecting both the environment and our valuable, limited hydrocarbon resource.

What do you consider the main issues?

It seems there are 2 distinct areas of concern for environmentalists – first, damage to the environment during exploration and production and second, damage caused by burning of fossil fuels. With regard to the first issue, we have come a long way as an industry but it is undoubtedly true that different environmental standards are still applied in different parts of the world. We must continue to work with all concerned to apply high environmental standards globally. I would hope that a society such as ours – incorporating Near Surface scientists as well as E&P professionals – could contribute to achieving this goal. As for the second issue, it is clear to me that we should use our hydrocarbon resources as efficiently as possible – not least for the sake of our own exploration industry. Once all the oil has been used, it cannot be used again and our industry will be finished. Perhaps our long-term interests are aligned very well with those of the environmentalists after all!



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Do we produce enough oil?

The peaking of world oil production presents the world with an unprecedented risk management problem. As peaking is approached, liquid fuel prices and price volatility will increase dramatically, and, without timely mitigation, the economic, social, and political costs will be unprecedented, according to a report published by Robert L. Hirsch, a senior energy program advisor, and others last year.

The world consumes slightly more than 80 million barrels of oil per day. In the next 20 years it is predicted that the consumption will rise to more than 120 million barrels per day. Needless to say, more – a lot more – oil has to be produced to meet demand.

Besides further oil exploration, there are, according to the report, several commercial options for increasing world oil supply and for the production of substitute liquid fuels: 1) Improved Oil Recovery (IOR) can marginally increase production from existing reservoirs, 2) Heavy oil/oil sands represents a large resource of lower grade oils, now primarily produced in Canada and Venezuela; those resources are capable of significant production increases, 3) Coal liquefaction is a well established technique for producing clean substitute fuels from the world's abundant coal reserves; and finally, 4) Clean substitute fuels can be produced from remotely located natural gas, but exploitation must compete with the world's growing demand for liquefied natural gas.

However, world-scale contributions from these options will, the report says, require 10-20 years of accelerated effort. Dealing with world oil production peaking will be extremely complex and require many years of intense effort. In addition, it will be very expensive.

To explore these complexities, three alternative mitigation scenarios were analyzed based on when action is initiated; when peaking occurs, 10 years before peaking and 20 years before peaking.

The inescapable conclusion is that more than a decade will be required for the collective contributions to produce results that significantly impact world supply and demand for liquid fuels.

Important observations and conclusions from this recent study are as follows:

- **When world oil peaking will occur is not known with certainty**. A fundamental problem in predicting oil peaking is the poor quality of and possible political biases in world oil reserves data. Some experts believe peaking may occur soon. This study indicates that "soon" is within 20 years.
- **The problems associated with world oil production peaking will not be temporary**, and past "energy crisis" experience will provide relatively little guidance. The challenge of oil peaking deserves immediate, serious attention, if risks are to be fully understood and mitigation begun on a timely basis.
- **Oil peaking will create a severe liquid fuels problem for the transportation sector**, not an "energy crisis" in the usual sense that term has been used.
- **Peaking will result in dramatically higher oil prices**, which will cause protracted economic hardship around the world.

The problem of the peaking of world conventional oil production is unlike any yet faced by modern industrial society. The challenges and uncertainties need to be much better understood. Technologies exist to mitigate the problem. Timely, aggressive risk management will be essential, the report says.

Photo: Halfdan Carstens

Oil being pumped in Russia.

CONVERSION FACTORS

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

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

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

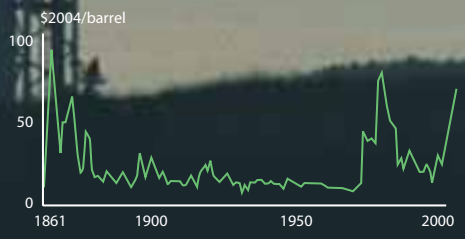
Numbers
Million = 1 x 10^6
Billion = 1 x 10^9
Trillion = 1 x 10^{12}

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

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

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

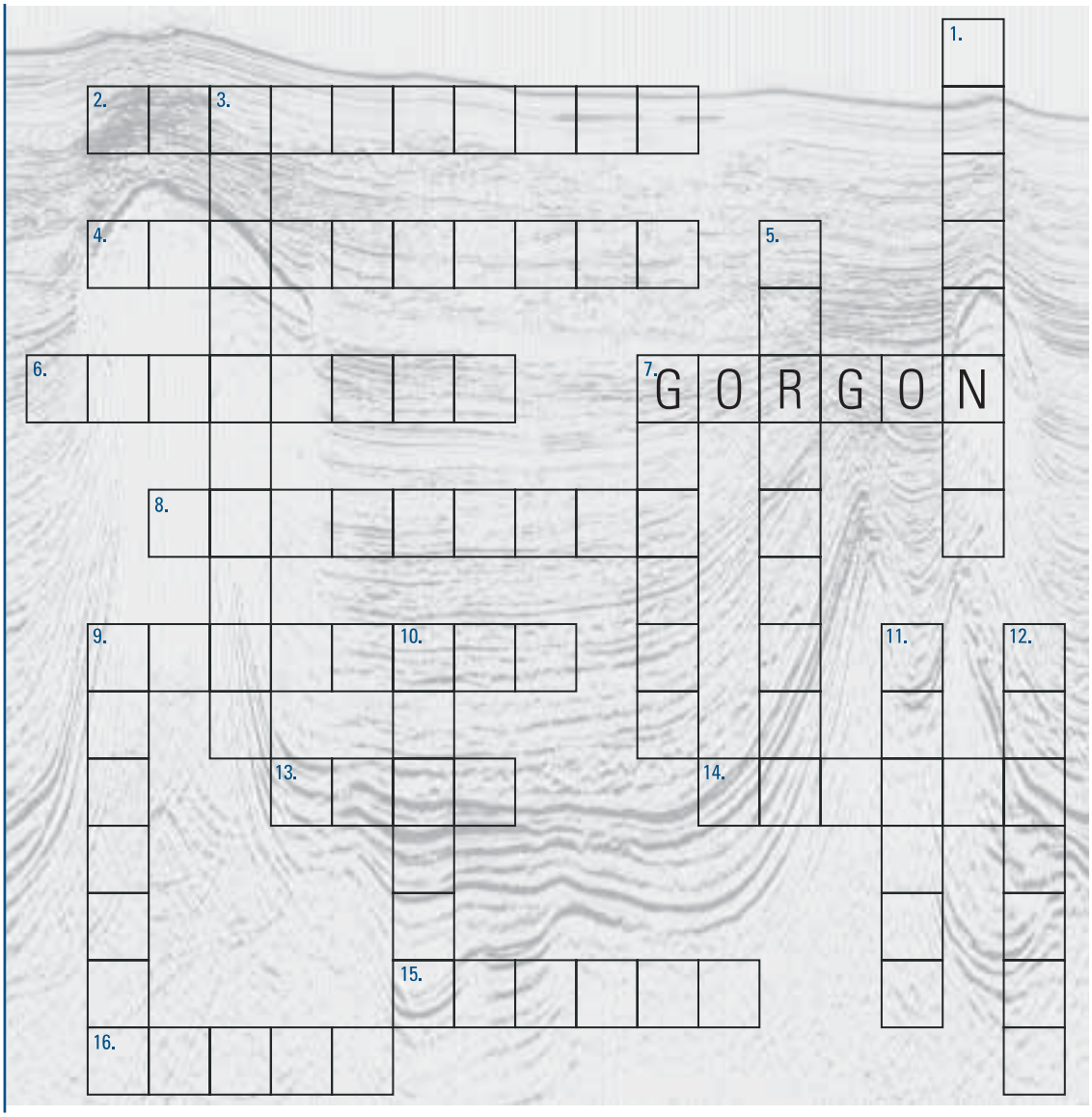
Historic oil price



LOOKING FOR A HYDROCARBON FIELD?

Across:
2. Highest peak in the western hemisphere (hint: Argentina)
4. First giant Texas oil find
6. Giant Ape, also a Gulf of Mexico field
7. Giant Australian offshore gas field
8. Famous heavy rock band
9. Russian Barents Sea giant
13. 4th planet from the sun
14. Giant find in Kazakhstan
15. The most famous Disney character
16. A Norwegian bogeyman, also an oil field

Down:
1. Largest Eastern Canada oilfield
3. New field in Mauritania
5. Big offshore storm, also a Deep Shelf (GOM) discovery
7. The biggest of the big in Saudi Arabia
9. Norwegian for "Snowhite"
10. Long-billed ocean fish, Brazilian name
11. A fortified wine
12. Significant UK find, also a type of vulture



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SeaBird Exploration

SeaBird Exploration

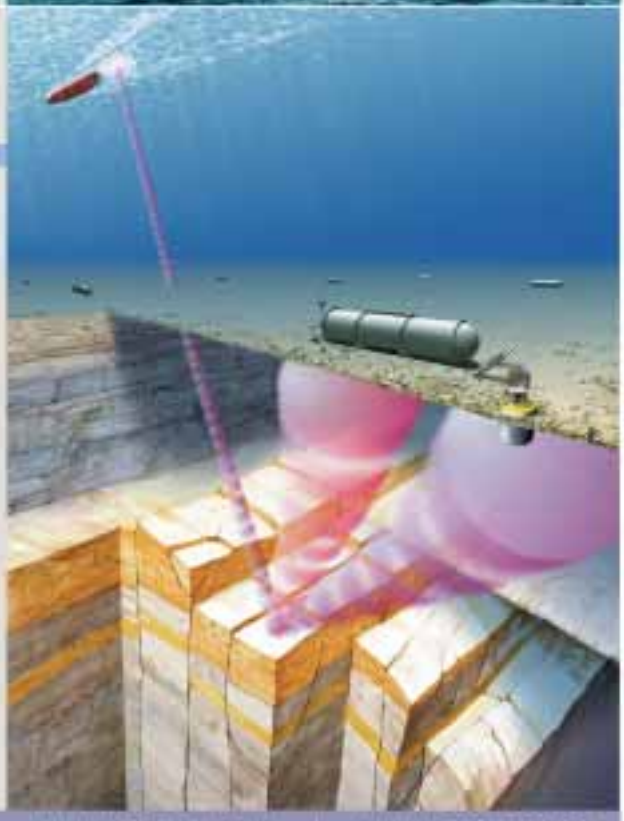
ACTIVITIES

- Source Vessels
- 2D Seismic Acquisitions
- 3D Shallow Water Acquisitions
- Conversion, Project Analysis and Development
- Market Studies and Analysis
- Seismic Management

SeaBed

ACTIVITIES

- Feasibility Studies
- Survey Design
- 4C Acquisitions
- Processing
- Interpretation



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