REFLECTIONS

PGS Magazine **2014**

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GRAND DESIGNS

A lot of the time improving what we already have is sufficient. That's not a vision. Let's salute the big ideas.

PGS

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GRAND DESIGNS

For the most part, innovation is not about spectacular breakthroughs. Across the world, researchers and engineers, in science labs and office landscapes, slog their way through the minutiae of incremental improvement. They nudge us closer to our goals with each carefully worded patent application. But they seldom change the paradigm of science.

A grand design is something that lifts our eyes to the distant horizon. Though the route may be long and complex, it allows us to plot a new path to get there.

In this issue of Reflections we look at the visions and the visionaries. Paulo Johann of Petrobras is one of those. So too is the British industrial designer Sir James Dyson. Within our own stable we also have grand designs. Check out Ramform Titan, towed EM and the latest techniques to see under salt.

TORE **LANGBALLE**
SVP
Group Communications
tore.langballe@pgs.com

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BEFORE SEISMIC DATA THERE WAS NOTHING.

PAULO JOHANN

REFLECTIONS
Editor
Tore Langballe
Senior Vice President
Group Communications

Editorial Board, PGS
Pamela Risan
John Greenway
Eivind Fromyr
Andrew Long
Stein Arne Nistad
(Itera Gazette)

Design Itera Gazette
Cover photo PGS
Copies 6000
Contact info@pgs.com

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THIS IS LIKE NOTHING ELSE OUT THERE.
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REALITY COMES TO THE RESERVOIR

Paulo Johann, Reservoir Geophysics Manager at Petrobras, is a visionary who preaches his message with enthusiasm and conviction. In Stavanger, at the "The 2nd Permanent Reservoir Monitoring Workshop" he is among the faithful. These guys believe that the thirst for seismic monitoring will be as big as for exploration 3D.

Text Stein Arne Nistad **Photo** Linda Cartridge / PGS **Illustration** Jon Arne Berg/ByHands

DR. PAULO **JOHANN**

→ **Reservoir Geophysics Manager, Petrobras Dr. Johann holds degrees in geology from UNISINOS, Brazil; DEA and PhD reservoir geophysics from Paris VI University, France. His career has encompassed geophysical data acquisition interpretation, and reservoir geophysics. He has served as Vice President of the Brazilian Geophysical Society and the SEG.**

PETROBRAS

→ **Petróleo Brasileiro S.A. founded 1953, is a semi-public Brazilian multinational energy corporation based in Rio de Janeiro. It is the largest company in the southern hemisphere by market capitalization and the largest in Latin America by 2011 revenues. The company produces more than 2 million barrels of oil equivalent per day. Petrobras is a world leader in the development of advanced technology for deep and ultra-deep water production.**

THE JUBARTE **OIL FIELD**

→ **Located 70km offshore Brazil at a water depth of 1,300m Jubarte lies in the northern Campos Basin in block BC-60. The discovery in January 2001 was Petrobras' largest since 1996, with oil reserves estimated at 600 million barrels. Though Jubarte lies in a pre-salt area, the reservoir is post-salt. In late 2012 a permanent monitoring system using PGS OptoSeis was installed over 9 km² of the field at 1,200-1,350 meters depth with plans to cover more of the 245 km² field in the future.**

"Before seismic data there was nothing – more or less just educated guesswork, based on observations of the landscape. Oil exploration was really a game of spotting the needle in the haystack. In some ways it still is but you can at least see the haystack."

Paulo Johann is among the most recognized experts in his field. He is Brazilian and loves his country and his profession. He radiates charisma, character and commitment as he talks about the history of his country and oil exploration in Brazil, and equally enthusiastically about football. With passion and persistence, amazing things are possible. On his trip to Norway, someone managed to book his ticket at the same time as the finals of the soccer Confederations Cup. Thanks to creative argument and the collusion of an equally patriotic airline captain, Paulo managed to keep himself abreast of the game throughout his flight over the Atlantic. It was worth it. Brazil crushed Spain and that's a real inspiration before next year's World Cup!

Petrobras as a marker of identity

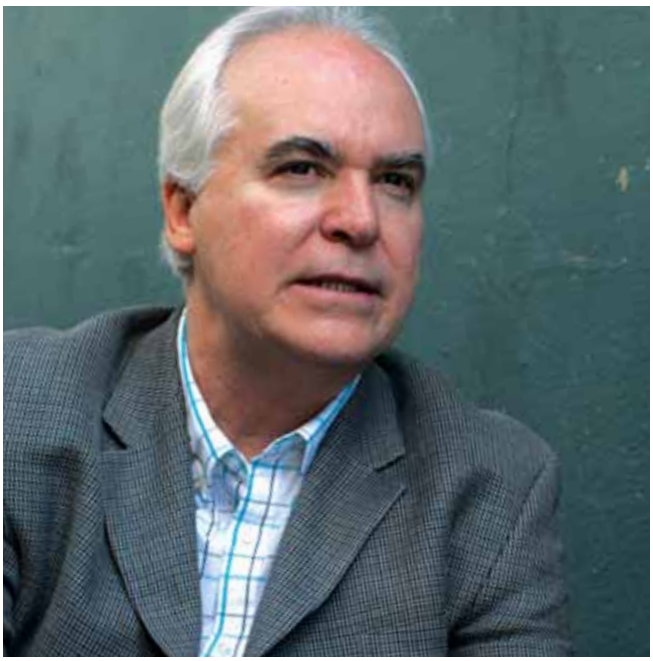
The story Paulo tells starts long before the workshop in Stavanger. It is a tale with many facets. He talks about nation building, the search for oil, the inexorable forward march of technology and himself. Paulo works for Petrobras, one of the world's largest national oil companies and an institution in Brazil. "Petrobras is more than a company," he says. "It's a lifestyle and a calling, because the company hires people for life." That's how it is. Petrobras becomes a part of your identity. It is a company that employs the best people and takes care of them throughout their lives. Petrobras fits well with the psyche of the Brazilians, who love their country and work hard for its development.

From laggard to leader

Petrobras was founded back in 1953 with a long-term vision to make Brazil self-sufficient in oil. Initially, they were regarded as laggards in the South American oil exploration business. Argentina, Peru and Chile did far better and had well-developed, land-based industries from the beginning of the 20th century. In Brazil the history was different. Certainly there were some land-based sources, but by no means enough to fulfill their vision of making the nation self-sufficient. The company therefore realized that it had to change strategy. It had to look beyond land operations and into the ocean. This was already happening in shallower areas of the Gulf of Mexico and the North Sea; perhaps it was possible here too? In 1974, the company hit oil in the Campos Basin, off the coast from Rio de Janeiro. The basin covers 11,500 square kilometers, but the real challenge was that only around 5,000 square kilometers of the Campos Basin are located in shallow water. The field extends

UNDERSTANDING THE RESERVOIR IS THE KEY TO SUCCESS.

PAULO JOHANN



into depths of up to 2,400 meters. The challenge was clear. Today Petrobras arguably leads the world in deep water exploration. It operates more than 60 fields in the Campos Basin, at over 2000 meters depths. At last in 2005, Petrobras fulfilled its vision and Brazil became self-sufficient in mineral oil.

Life-of-field lifestyle

Paulo began his career on oilfields in the Amazon, before he moved to Rio in 1984. There he worked with planning and exploration of new fields. His interest in seismology grew steadily. Almost everything he read concluded that understanding the reservoir was the key to success. Yet seismic was almost exclusively used in the exploration phase; not in recovery. He decided to go to France to learn more. There he gained a Ph.D in reservoir characterization and a love of good wine. Since then, detailed knowledge of the reservoir and its behavior has become his paradigm. In Paulo's opinion there is a very high potential for enhanced oil recovery, simply by increasing our knowledge about reservoirs. If we understand them, we can learn to exploit them better.

The devil is in the detail

"Petrobras undertook its first 3D marine seismic survey back in 1978, but due to the cost profile, 3D was not regarded as relevant for exploration. It was all about resolution," says Paulo. "With one single cable it was far too expensive to shoot seismic over large areas with sufficient resolution. Until 1994, 3D was used to map fields in production. It was like cutting the lawn with a tiny lawn mower."

The development of new technology made it cheaper and more attractive. "When PGS launched multi-streamer solutions with 8, 10, 12 cables the relative cost went down. Then 3D was increasingly used to explore potential fields, not only the promising or producing ones." Petrobras still wanted more detailed information about fields in production. Therefore they initiated projects which reduced the distance between the cables from 150-100 to 50 meters, and thereby they gained higher resolution. "It is much like a TV," says Paulo. "An old fashioned TV has 576 points per line. Modern HD TV has 1920, while 4K TV has 3840 points per line. The image becomes more and more detailed as the information in the picture is increased. Remember, the data captured raises exponentially each time the number of samples per line is doubled."

"However," says Paulo, "geological formations of importance to the oilfields often have significant characteristics that are less than 50 meters, which is equivalent to nearly half a soccer field. So that resolution might not be good enough to get the true picture of an oil field. Dual seismic sources, with cables at 50m distance, bring resolution down to 25m – but even that might not uncover the complete geological picture."

The fields they are a changing

"The problem with 3D seismic as we currently know it is that it is only a "snapshot" of reality at a given point in time. An oilfield in production has a lot of secrets, and production decisions are being taken all the time. The reservoir is changing as oil is extracted, or

water is injected elsewhere in the field. To capture more oil, more information and insight is needed. Certainly, there are many techniques used to get information. Tracer technology, for example, is used to determine how long it takes for something injected into a well to travel through the reservoir to other wells. It can be traced in the production well once the tracer has moved through the field. But then it is in many ways too late. Imagine if we could make a movie of the field, which showed changes when they happened. Not a historical perspective – but there and then. Creating that "movie", is what 4D seismic really is about," says Paulo. The vision is to provide a real-time view of what is going on in the field.

Key concepts

"There are two key concepts that are important to understand," says Paulo. "The first is 4D seismic. Basically that is to repeat 3D seismic on a regular basis, so we create a dynamic model or film of the reservoir by adding the different images above each other. The fourth D is, in other words, the time dimension. The second concept is PSM meaning Permanent Seismic Monitoring. Here the principle is slightly different, because we lay out a network of sensors on the ocean floor. These sensors monitor vibrations, pres-

IMAGINE IF WE COULD MAKE A MOVIE OF THE FIELD.

PAULO JOHANN

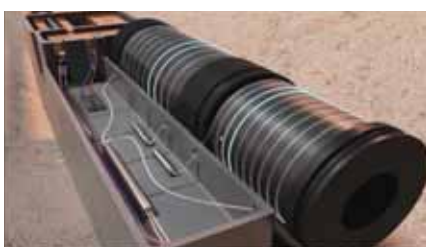
WHAT, WHY, WHERE

4D Seismic: 4D is time-lapsed 3D imaging of an oil or gas reservoir. By comparing successive images, changes can be observed. For example, these can help pinpoint pockets of oil and gas that have been bypassed. The asset team can then lead the oil to the well, or bring the wells to the oil.

Permanent Reservoir Monitoring (PRM): Seismic data recorded using sensors installed permanently on the seafloor which permit recording of both pressure and shear wave data. The PRM units measure dynamic parameters in the reservoir enabling production optimization.

Why 4D? The cheapest oil to find is what you leave behind in the reservoirs you have already located. Better knowledge about the behavior of the reservoir is the key to improved oil recovery. By increasing the recovery rate by 1 per cent, the total value of the Brazilian petroleum reserves would increase by around USD 150 billion.

Where big numbers count: The investment in PRM may look like a lot of cash up front but it promises a payback worth 5-10 times as much in increased production. Over the life of the field it could be compared to the cost of drilling one less intervention well. In other words, not that much over a 20 year perspective.



The OptoSeis system at Jubarte: Installed in December 2012, the Jubarte PRM system applies the most advanced 4D seismic techniques available for the marine environment. The system was deployed between 1,200 and 1,350 meters below sea level, making it the world's first PRM in water depths greater than 1,000 meters.

The PGS project solution is based on its proprietary OptoSeis system, a fully fiber-optic sensor array. Sensitive electronics can corrode in the salt water environment of the seabed. At Jubarte, there are no in-sea electronics. The sensors installed on the seabed use fiber optics, while the electronics are located on the topside

sure, temperature, saturation and where the seafloor collapses or rises, and more. The aim of both these technologies is to identify how the field is changing. How does this affect the flow of oil? What happens when you inject water? If geological events occur, how do they affect flow through the field? If pressure changes, should we inject more water – and which injection well should be used? Both PSM and 4D seismic aim to support better decision making by providing improved information."

How to monitor the patient?

Paulo Johann describes an oilfield in production as akin to a patient in a hospital. Using sensors and measurements, the patient is monitored on a continuous basis. Appropriate care decisions can be taken as symptoms appear – not after they have occurred and where the consequences can already be harmful or fatal. Petrobras has initiated a Jubarte reservoir monitoring pilot project with this goal in mind. They have defined an acquisition program and acquire active seismic over the field twice a year, to trace the geological changes. In addition, Petrobras also carries out passive monitoring using the same network of seabed sensors. Passive ambient noise will provide the source, coming from the natural

Appropriate care decisions need to be taken as the symptoms appear to be fully effective.

of the P-57 FPSO. The system is designed to acquire both active and passive seismic data.

Online data QC is carried out onboard the FPSO, before the seismic data is passed to the PGS data processing center in Rio de Janeiro for further processing by a team of PGS and Petrobras geophysicists.

Equipment: The opto-electronics on the FPSO include lasers, demodulators and power supplies as well as data recording and QC equipment.

A 6 km umbilical cable connects the topside to the seabed.

18 km of lead-ins get close to the desired location. The cables from the array are placed 300 meters apart with sensor stations every 50 meters along the cables, held in place with anchors.

The cables layout is designed to provide the best possible coverage while ensuring they are kept far enough away from well heads and associated subsea infrastructure like flow lines.

The system will acquire data for the life of the field: two decades or more.

Over the three years from installation PGS will acquire and process three active and four passive data acquisition campaigns.

The first active acquisition started in December 2012, covering an area of 11 by 11 kilometers using 441 sail lines and 441 shot points on each line to achieve a high fold image where possible.

The second active acquisition program commenced in December 2013.

THOSE WHO WERE SKEPTICAL WILL FOLLOW.

PAULO JOHANN

sounds from the environment, plus noise from other oilfield interventions. In addition pressure, temperature, vibration and anything that may affect the field will be monitored. The sensors are connected via fiber optic cables on the seabed. These are then collected in "hubs" which collect and transmit the information to the surface control station onboard the floating production, storage and offloading vessel (FPSO). The sum of this data should allow Petrobras to track even small changes in the field, maximizing the flow in the field and harnessing any geological changes. Though the project is still in its pilot phase, Petrobras has great expectations for the results.

The upside

Although 4D and PRM technology are now a decade old, they are still in their infancy. The next steps will draw on the valuable experience gained on the Ekofisk and Valhall fields in the North Sea, where this technology has been used successfully. Experience so far in shallow water is very positive. Results presented at the conference in Stavanger suggest that 4D and PRM can provide production improvements of 1-5%. The estimated total reserves in Jubarte are approximately 600 million barrels. So the potential benefit from this field alone is estimated to be between six and thirty million extra barrels of oil.

Investments

"All new technologies are expensive," says Paulo Johann, "and this also applies to our industry. At the same time the potential profit is extreme. Therefore it is fairly easy to make a business plan with more than acceptable ROI. To put things in perspective, the monitoring investments that are needed can be compared to the price of drilling a new injection well. In other words, the investment can be defended if it means you can drill one less well. The alternative is to drill hotspot wells for production assessment. Our goal is to extract more oil, and the more knowledge we have about the reservoir , the greater is our likelihood of success," explains Paulo.

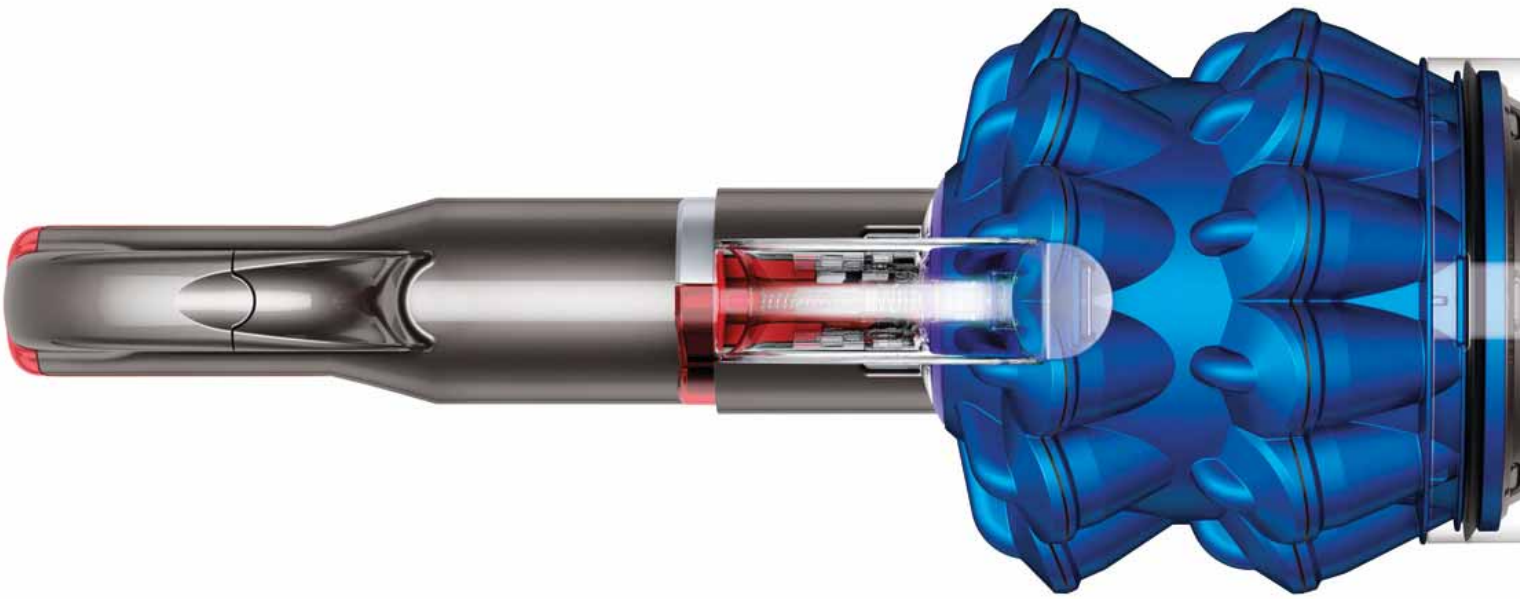
Online reservoir management

"From an historical perspective," says Paulo, "since the pioneer days seismic and reservoir knowledge have already evolved to a very high level. Initially, the technology was so expensive that it was only used where there was a high probability of finding a new reservoir. As technology developed, seismic was used to map larger areas. When 3D streamer seismic arrived, the cost rose again, but when multi-cable solutions appeared then it suddenly became possible to scan large areas relatively cost effectively. With 4D and PRM, history is repeating itself. Yes, the technology is relatively expensive," admits Paulo, "but this is the future." He envisions a scenario where oil reservoirs will be actively monitored – almost like CCTV. Using a surveillance approach, the reservoir engineer will be able to take action immediately if something happens. Investment choices are about profitability. "We need to look at the economic potential and the expectation that oil resources will become increasingly important in the future. Set against that, the cost of installing monitoring equipment is marginal compared to the potential rewards." In other words, the development will follow the same pattern as other technological innovations. "A few of us are early adopters but I am sure we will succeed. And then those who were skeptical will follow." He is persuasive and passionate in his conviction. "Active reservoir management is the future," concludes Paulo Johann. ●

Paulo Johann at the Norwegian Petroleum Museum in Stavanger

REINVENTING THE WHEEL

AND OTHER STORIES



It is always possible to improve an idea, if you have the stamina, claims *Sir James Dyson.* His reinvention approach combines form and function to create the stunning redesign of everyday objects. Some of them have rocked the foundations of major multinational companies. As a side effect, his philosophy has made him a very wealthy man.

Text Stein Arne Nistad **Photo** Dyson Foundation / Rotork

DYSON SAYS: ENJOY FAILURE AND LEARN FROM IT. YOU CAN NEVER LEARN FROM SUCCESS.

THE **DYSON DC50 VACUUM CLEANER**

The vacuum cleaner that became a status symbol. Dyson's rise to fame began with the Dual Cyclone bagless vacuum cleaner. This latest model has a pivoting ball on the end. It sucks better than any other cleaner, it's lighter and it's more agile. And it's so cool that owners don't keep it in the closet.

THE **BALL-BARROW**

First, Dyson reinvented the wheelbarrow by swapping the wheel for a big plastic ball. The result added maneuverability across all terrains. It was a simple but massively effective change.

STUMBLING UPON THE NEXT GREAT INVENTION IN AN 'AH-HA!' MOMENT IS A MYTH.

JAMES DYSON

Dyson is a traditional Englishman with a talent for seeing new solutions. He was born in 1947 in the seaside community of Cromer in Norfolk. The town is steeped in history, with a Victorian pier and a 15th century parish church. Records show it has been in existence for more than 800 years.

Success is about determination

It was in these historical surroundings that Dyson grew up, as one of three siblings. At the age of nine he was sent to Gresham's, a local boarding school, founded in 1555 and the epitome of "old-school". Girls were not admitted until 1970. During his time at school Dyson excelled as a long distance runner. In his own words, he was not particularly good or talented at running. "The key was that I was just more determined than the others and therefore I won," Dyson claims.

Born in time

Though his origins are clearly well rooted in the past, the timing of James Dyson's arrival into the world made him a man of the future. When Dyson left the hallowed halls of Gresham's for London in 1965, the space race had introduced a phase of spectacular technological growth. The essence of modernism and innovation was also influencing the world of design. He spent a year at the Byam Shaw School of Art, before dedicating five years to studying furniture and interior design at the Royal College of Art. It was his final year design project, under the mentorship of British inventor Jeremy Fry at Rotork Engineering, that propelled Dyson into the world of industrial design. The Sea Truck, a flat-bottomed, high-speed landing craft went on to win a series of design prizes.

The Sea Truck (1967). Thousands of these versatile load carrying vehicles were built over twenty-five years.

ROTORK **SEA TRUCK**

A college project while at the Royal College of Art introduced Dyson to design engineering. The Sea Truck carried a three-ton load at 50mph. The chairman of Rotork, offered him a job, and in 1980 Rotork helped Dyson to develop the first prototype bagless vaccum cleaner.

Stuck in the mud

Dyson's first real breakthrough as an innovator was to solve the age-old wheelbarrow problem. Most of us who have pushed one have experienced it. On soft ground, when the barrow is loaded heavily, the wheel tends to sink into the ground, making it impossible to roll. Dyson's solution was as ingenious as it was simple. By forming the wheel as a sphere the pressure is distributed when the wheel sinks into soft ground. So the more the wheelbarrow sinks, the larger the area of the sphere (wheel) that is in contact with the ground, and hence the greater the pressure distribution achieved. In other words, the wheelbarrow appears to "float" on soft surfaces and the wheel does not sink. On hard surfaces the sphere will also actually work better, since a smaller portion of the wheel will touch the ground and thus friction decreases. As if that was not enough, the solution makes the wheelbarrow more maneuverable in general. Since the wheel is a sphere, its ability and function is unaffected by the vertical and horizontal position of the barrow. Ingenious! Dyson had radically improved one of the world's oldest tools, effectively by reinventing the wheel! By 1974

DYSON SAYS: AN INVENTOR'S PATH IS CHORUSED WITH GROANS, RIDDLED WITH FIST-BANGING AND PUNCTUATED BY HEAD SCRATCHES.

JAMES **DYSON**

- **British inventor, born 2 May 1947 in Cromer, Norfolk, England**
- **Education: Byam Shaw School of Art and Royal College of Art**
- **Famous for striking, user-focused design, with a declared mission to encourage more kids to study engineering.**
- **A college placement in 1967 with UK inventor Jeremy Fry changed Dyson's path from art and design to engineering.**
- **More about Dyson:** www.dyson.com

DYSON'S **AIRBLADE TAP**

A combined tap and hand dryer that saves space and reduces drips in the washroom. It is powered by the tiny but effective Dyson digital V4 motor, using digital pulse technology. The V4 accelerates from 0-90,000rpm in less than 0.7 seconds – five times faster than a Formula 1 engine.

Dyson had made a fiberglass prototype of a Ballbarrow. But this was only the beginning. And as most inventors discover, a prototype is not a product.

This really sucks

Dyson's real adventure began with cleaning. He bought a Hoover Junior vacuum cleaner for his house. If Hoover had known what was to come, they would probably have refused to sell it to him. Dyson was frustrated that as the bag filled, the vacuum cleaner gradually lost suction power. The reason is twofold. First, the tiny dust particles clog the pores in the bag. Then the effect is further reduced as the air inlet filters in the machine also get clogged when air is sucked through the dust-filled bag. Dyson was sure that this problem could be resolved in one way or another.

Spin doctor

The inspiration came from a nearby sawmill. In industry, it is common to remove dust from the air by separating the air particles using so-called cyclones. The principle is the same as in a washing machine centrifuge, where the water is separated from the clothes by spinning a cylinder so fast, that centrifugal force pushes the water out of the clothes through holes in the cylinder. In a cyclone the principle is the same, but here it is the air itself that is set in motion, spinning inside a cylinder. The effect is the same. The heavier particles are thrown outwards and can be extracted, leaving clean air. This is highly effective in big industrial installations. Dyson's inspiration at the sawmill was an industrial cyclone

THE **BAGLESS VACUUM CLEANER**

The first edition DC01 was launched in the UK in 1993 after a whopping 5,127 prototypes. It used Dual Cyclone technology to ensure it retained great suction even when full. The bagless design was the first of its kind.

THE DYSON **AIRBLADE**

Blasting high-pressure jets of warm air at wet hands in restaurant restrooms around the world, this 2006 innovation dries hands in just ten seconds.

that was over three meters tall. Dyson thought it might be possible to implement it on a smaller scale in a vacuum cleaner. He began experimenting with his Hoover Junior. He removed the bag and built a miniature cyclone. It worked. In fact, it cleaned the carpet better and it did not lose power, since the air was not sucked through a bag. The separated dust could be collected in a reusable container. The first bagless vacuum cleaner was born. Eureka?

Stamina and endurance

Dyson claims he learned determination from running and that innovation is about endurance. This certainly must have come in handy in his work with the vacuum cleaner. It transpired that the lightbulb of inspiration was just the starting pistol of a long race. In the period, from 1979 to 1984, before the new appliance was ready for production, he developed 5,127 different design solutions. Even then, his challenges were still far from over. The appliance industry did not share his enthusiasm for the revolutionary and effective cleaner. In their business model, the sale of a machine was a catalyst for continuous production and sale of vacuum cleaner bags. Removing the bag was not an advantage for the manufacturers. The vacuum cleaner bag market was worth $500 million in 1981. Dyson turned to Japan, where he licensed a manufacturer to produce the first bight-pink Dyson G-Force. Commercial production started in 1986, with a sales price of around US$1000 per unit. The new vacuum cleaner soon became a status symbol in Japan and won several design awards.

DYSON SAYS: THERE'S NOTHING WRONG WITH THINGS TAKING TIME.

Transparency goes international

The Dyson G-Force was not just a cleaning tool. This was a household appliance people wanted to show off. They were even happy to display the detritus it collected. The success of G-Force in Japan allowed Dyson to establish his own factory and research center in England in 1993. The UK model was equipped with a transparent dust collector. Pundits warned that no-one wanted to see household waste products. Despite the warnings, within 18 months of its launch, the model DC01 was the bestselling vacuum cleaner in the UK. The traditional manufacturers were in shock. One reportedly said they regretted that they did not buy Dyson's patent when he showed up with it, and put it in a drawer forever.

Like magic

Dyson and his company have launched a number of new products. Their solutions are mostly enhancements of existing home products, turning the banal into the beautiful and improving func-

THE DYSON **AIR MULTI-PLYER**

James Dyson pictured together with the Air Multiplyer Fan and Multiplyer Hot. By inducing and entraining the airflow surrounding the unit, it pumps 15 times more warm or cool air around a room than a traditional fan, without using any potentially-dangerous blades. Jet propelled magic.

tionality. An example is the Dyson Multiplyer Fan. Instead of the traditional rotating blades, a brushless electric motor is built into the base. This sucks air into the tube and pushes it out at high speed through a slit in the circle that makes the fan. In effect it creates a jet stream that draws the air behind the fan, creating a cool, steady air flow apparently from nothing. The sculptural design is functional and safer than its predecessors. Gone are rotating blades and with them the safety guard. Dyson claims it performs 15 times better than traditional fans.

Probably his best known invention is the Airblade: a hand drying machine found in restrooms all over the world. Over a narrow gap, a focused jet stream of air moves so fast that moisture is literally blown off the skin. It dries much faster and more efficiently than traditional solutions. Recent models aim to reduce the noise of this frighteningly effective device.

DYSON SAYS: YOU NEED A STUBBORN BELIEF IN AN IDEA IN ORDER TO SEE IT REALIZED.

Private commitment

Dyson runs a private company employing more than four thousand people. Despite his economic success, he has never been driven by money, he says. His goal is to ensure that the company continues to focus on innovation rather than profit. So he eschews the stock exchange. Public owners might have a short-term financial focus. Here speaks the long distance runner with his eye on the distant horizon: innovation is not a quick fix, it requires commitment and determination.

Painstaking progress

Why does he pick such dull products to start with? "When things I use annoy me, I start thinking about how they could be improved," Dyson explains. "Since I am a user I also know when we have succeeded. The passion we engage when we buy skis, surfboards and other lifestyle objects is often not present when we evaluate household products. Yet we surround ourselves with these appliances. Innovation is about improvement, but also really about frustration and making mistakes." Frustration is the starting point of Dyson's process of improvement. You have to make sufficient errors to end up with a solution that works. Dyson does not believe in a bright flash, a Eureka, where everything falls into place. Innovation can be a long process, and where the ability to look at a problem through a completely different lens or point of view just might create a breakthrough.

DYSON SAYS: I HATE SCIENCE FICTION.

THE DYSON **GROOM**

Anyone with an animal in the house will recognize the frustration that spawned this vacuum cleaner attachment. Its 364 retractable bristles remove loose hairs from your pooch, before they insinuate themselves in your clothes or the furniture.

A knight that will fight

Dyson has gained a global reputation as an inventor and he has proved he's ready to fight to protect innovation processes, patents and rights. Over the years he has filed a number of lawsuits to protect his company's patents. Indeed, he won a $5 million damages award from Hoover in 2000. Dyson is concerned that intellectual property protection is weaker today because in the global market people are getting away with copying. Copycat companies produce cheaper products because they haven't incurred all the development costs and associated risks.

"It's morally wrong, I think it's legally wrong and I think it hurts the consumers because the consumer doesn't get a choice," he said at a product launch in Sydney this year. "Intellectual property should be supported better; the law should be made stronger. It is important to protect rights and to stimulate innovation. Increasing copying and lack of respect for patents are drivers to create inferior products and stifle innovation," he said.

Eye to the future

To encourage greater motivation for the next generation he has established the James Dyson Foundation. Despite his own background in the arts, he wants to encourage young people to study engineering. "I was given a choice at school: pursue either arts or sciences. There was no happy medium on offer for a boy who enjoyed solving problems and making things with his hands. I stumbled across my flair for design engineering by mistake. 40 years on, I'm passionate about it. And I've realized what I missed out on at school."

The foundation hopes to stimulate creativity and ingenuity among young people. Over 727 schools in the UK and the USA are using Dyson's reverse engineering kit to learn more about the design process. It contains a vacuum cleaner, seven turbine head tools, a carbon fiber floor tool and eight screwdrivers. The foundation also provides a number of other resources, including bursaries and scholarships for aspiring engineers.

Science fiction?

Many people feel that Dyson's designs are like a little bit of science fiction in everyday life: less frustration, increased performance and they look neat. Sir James Dyson says he hates science fiction. He believes in functional solutions designed for users, by engineers who are ready to challenge the basic parameters of established design. His inventions teach us that none of the preconceived limitations of an established solution may be real. He preaches the importance of experience and failure in the process of invention. So, if you feel frustrated with the current solutions that surround you, and you have the persistence to persevere, it may be worth taking a tip from Dyson. Don't give up! A beautiful new solution may be just another 5,000 prototypes away. ●

THE RAMFORM TITAN

FULL FOLD CENTERFOLD

Photos PGS

The Ramform Titan, launched April 26, 2013, takes safety, efficiency and productivity to a new level. For our clients, that can mean completing an exploration program safely in one season where conventional vessels might need two. Here is what the team who know her best have to say about her.

SUNNY **FENECH**

Part Chief Ramform Titan

I tell the new guys, it's a lot of hard work but there is nothing that compares to being part of a new vessel on its first job. It's a milestone. You have worked hard and you definitely feel privileged and really proud. Of course all the Ramforms are good in their own way but definitely when the ship sails into a 40+ knot wind, with six meter seas, like now in the South Atlantic, you feel the difference. You notice the new design day and night. You work safer and you sleep better.

ANETTE **VALBØ**

Business Controller

This is the world's biggest and best seismic boat. Production statistics so far show that the design is spot on. It is amazing to consider that the distance across the deck is nearly 25 per cent greater than the entire length of our new head office. Great that this space has prioritized safety, crew comfort and productivity. And of course I'm particularly happy that it came in on budget.

ARNE **VATN**
Project Manager
Ramform Titan felt like a game changer once the concept was established. Building it will always be a great memory. This is the first vessel of this kind and we are all excited to follow the next jobs to see how she proves herself. So far she is delivering everything we hoped for. In terms of evolution, the Titan class is just as big a step from a standard Ramform as going from an ordinary boat to a Ramform.

JOHN **GREENWAY**
SVP Marine Contract
When we see customers we walk in with a Titan behind us. That's a great feeling. It shows that we've still got our mojo. We get better and better, and we still surprise people. Virtually all the major innovations in this industry over the past 20 years have come from PGS: Ramform-design, huge multi-streamer tows, massive onboard processing, broadband acquisition, multi-sensor streamer systems. They all come together on Ramform Titan.

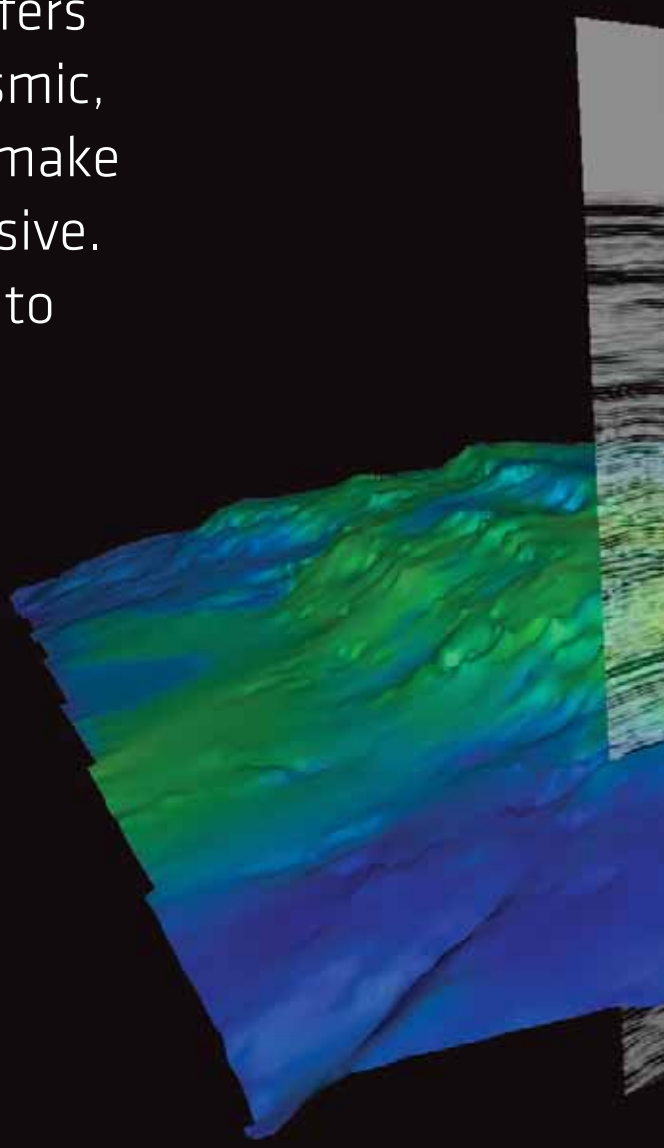
BERIT **OSNES**
Regional President, MultiClient Europe
Ramform Titan is about confidence. You know it will deliver. It is an enormously stable platform that can meet the challenges of any conditions. We were promised that it would acquire good quality data in all kinds of conditions and it did. Productivity, almost from the moment of first deployment was excellent and the data it acquired met and surpassed all our expectations. With the capacity and streamer density of the Titan class we have more flexibility in setting up new projects. And we can push the weather envelope to take full advantage of GeoStreamer. In the Norwegian Sea this summer she acquired 3,500 km² of GeoStreamer 3D seismic over 82 days.

ROBIN **TOMREN**
Maritime Technical Manager
My background is naval architecture and this is like nothing else out there. It's extremely inspiring to work for a company that is willing to invest in something so totally out-of-the-box. The rigging team was fantastic and made an extra-ordinary contribution to the project. The new vessels are more robust, more stable and more reliable. From an operational perspective that is a great combination.

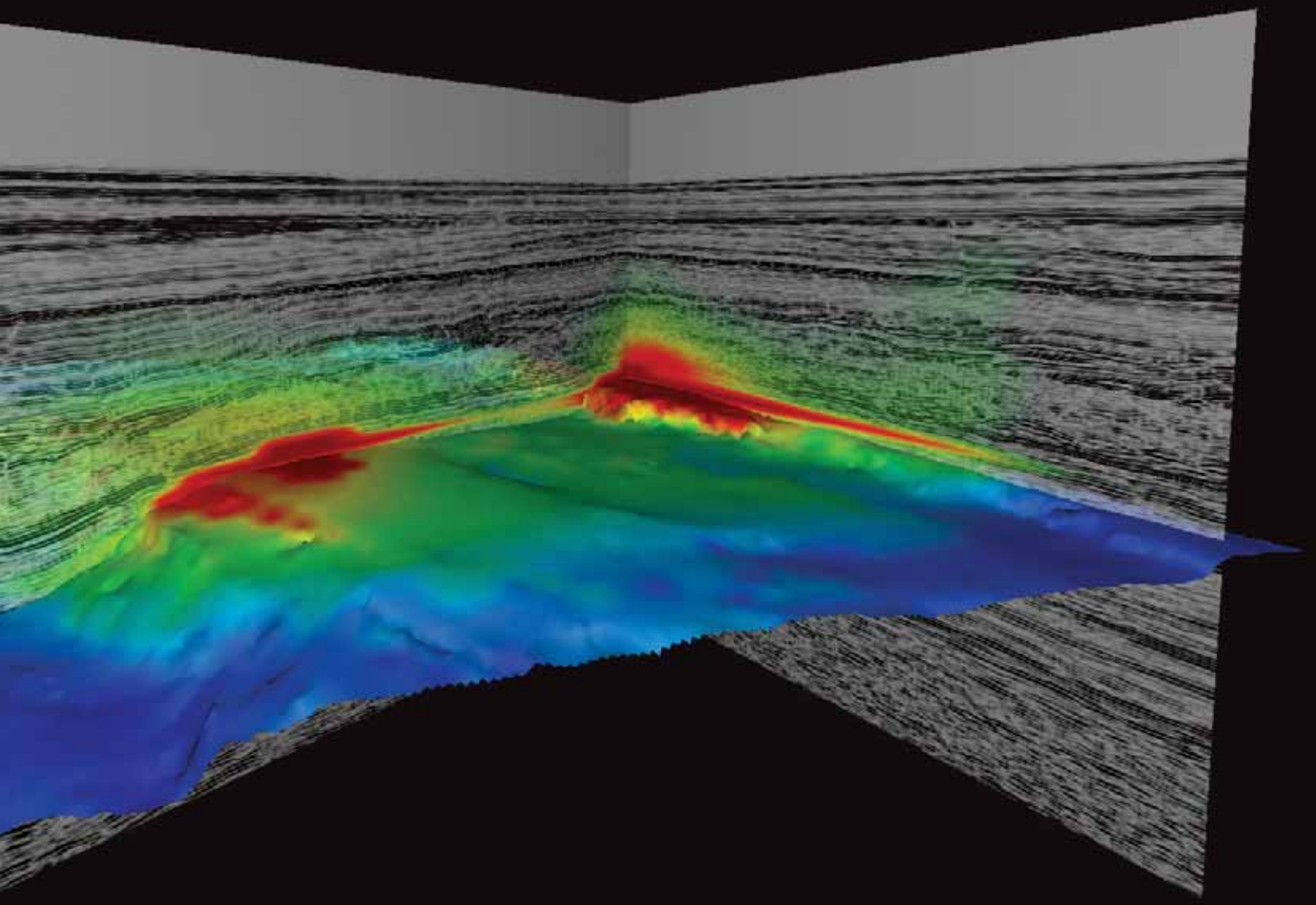
EINAR **NIELSEN**
VP Special Projects
This is the continuation of a journey we began in 1993. The Ramform has set the benchmark for nearly 20 years. The new Titan class will set the benchmark for the next 20 years.

Although electromagnetic data offers an interesting complement to seismic, node-based acquisition solutions make it inherently inefficient and expensive. Towed streamer EM has potential to change all of that.

SEEING THE **LIGHT**



Text Pamela Risan **Photo** PGS **Illustration** PGS



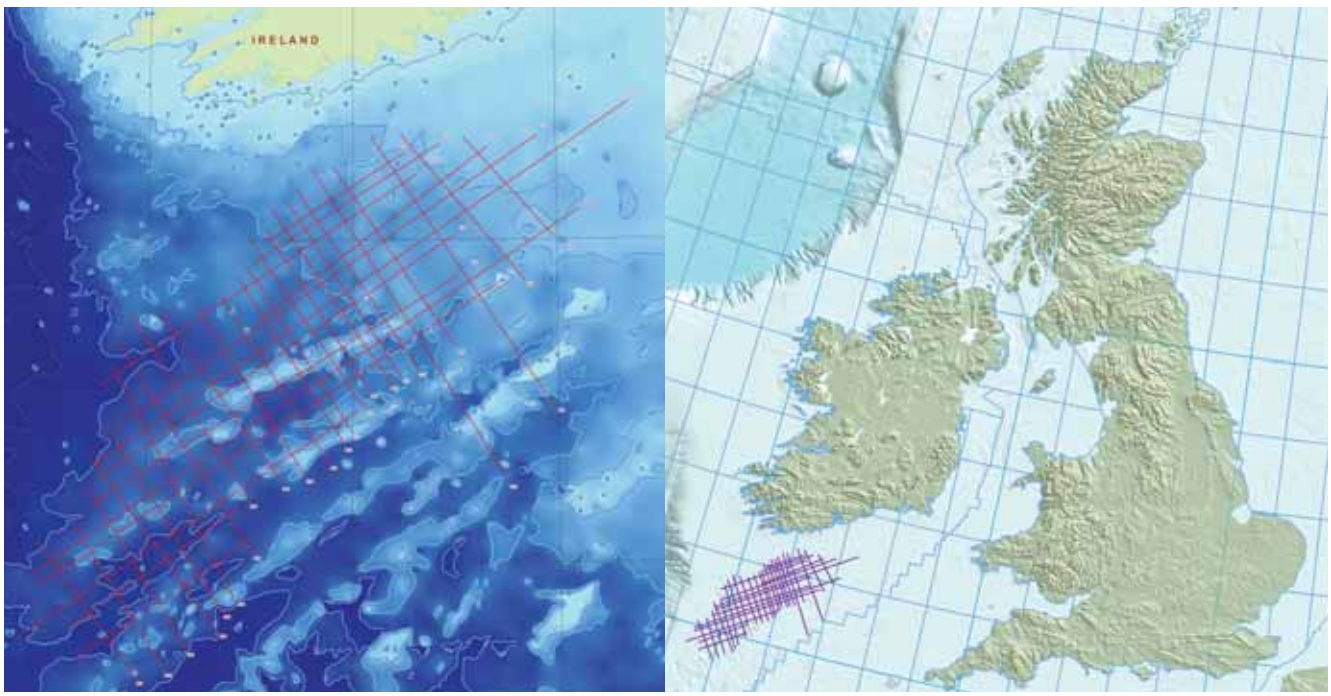
An expensive, nice to have technology. Twenty years ago that is pretty much how most people described 3D seismic. PGS was built on a vision of changing the economics of 3D seismic acquisition. We were convinced that if the economics were right, then all exploration managers would prefer to drill on 3D data. Within three years we had doubled acquisition efficiency. Within six years we doubled it again. The market grew as predicted. With increased volume came the resources to advance the underlying technology. GeoStreamer was born. EM is arguably in a similar position today. As an exploration technology EM has evolved slowly over the past ten years. Initial enthusiasm among the supplier industry has subsided, as the economics have just not added up. Few investors are interested in funding another node-based EM development. Slow turnaround, expensive operations and a limited market do not bring bears to the honey pot.

Does it have to be that way?

Despite the troubling economics, there can be no doubt that this technology holds enormous promise. For example, despite access to ever clearer seismic data, four out of five wells drilled in the North Sea are dry. Improving our understanding of targets prior to positioning the drill bit has a significant cost reduction potential.

Recent studies by Statoil, Shell and others have confirmed that EM

FASTNET AND CELTIC SEA BASINS



PGS completed the first ever simultaneous acquisition of towed streamer EM and 2D GeoStreamer® seismic in the Fastnet and Celtic Sea Basins offshore Ireland, summer 2013.

data can add real value to exploration decisions. It seems the chances of success are vastly improved when wells are drilled on a clear EM anomaly compared to those wells drilled on a weak or on no anomaly (Hesthammer et al, The Leading Edge).

"The use of electromagnetic data in combination with traditional seismic is one of the key reasons behind the Skrugard and Havis discoveries," said Statoil's Research and Development Manager Karl Johnny Hersvik in January 2012, during a press conference.

Chief Geophysicist Tor Veggeland at Tullow Oil plc reported in a recent interview that the recent Wisting discovery in the Barents Sea would probably have been a no go project without EM data to confirm that the target visible on their seismic data was a hydrocarbon reservoir, not shallow gas (GEO September 2013).

Slow developer

EM is not new to the oilfield. Exxon Mobil experimented with electromagnetics in the sixties. Since then, various players, including the American Scripps Institution of Oceanography, have employed the method for differing purposes. In 1998 NGI carried out a survey for Statoil to determine if electromagnetic data could be used to determine whether a reservoir in substrata contains oil or water. The answer was yes, it can.

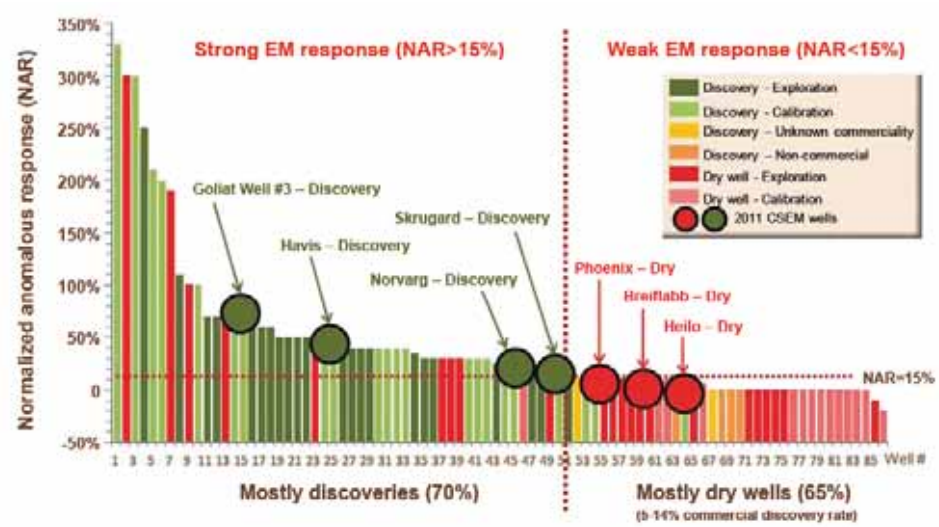
Node-based marine EM surveys have been carried out in major offshore hotspots worldwide. Since 2008 however, interest has subsided.

The unceasing, unbending and merciless imperative to cut cost in the current E&P environment has meant that EM has too often fallen by the wayside. In an era where the service industry has pulled out all the stops to optimize acquisition efficiency, EM operational efficiency has stood still for ten years.

They remain expensive and time consuming. Results can only be reviewed after the project is complete, making it almost impossible to adjust parameters without repeating the survey. In areas of short seasonal weather windows, this could mean taking several years to acquire the data.

DISCOVERIES ON NCS

Four of the five largest discoveries on NCS have been made using EM data.



Source: Hesthammer J., Fanavoll, S., Stefatos, A., danielsen, J.E and Boulaenko, M. 2010; "CSEM performance in light of well results". The Leading Edge, January, 34-41. Fanavill, S., Hesthammer, J., Danielsen, J.E. and Stefatos, A. 2010; "Controlled source electromagnetic technology and hydrocarbon exploration efficiency". First Break, 28, 61-69. Hesthammer, J., Stefatos, A., Sperrevik, S. 2011; "CSEM efficiency – results from recent wells"; AAPG conference, 23-27 October 2011, Milan.

Forget node, try towed

Increasing efficiency through towing stuff is familiar territory for PGS. Towed technology works well for seismic, so why not try it for EM? Could the same cost and turnaround advantages of towed compared to seabed methods apply? In 2009 PGS started testing a towed streamer EM solution. That was followed by surveys in 2012 in the North Sea. These early experiments demonstrated that high quality EM data can be acquired with a towed streamer.

An acquisition speed of four to five knots matches that for towed streamer seismic. As proof of this, over a three-week period this summer, PGS acquired 2,800 km of EM data in the Fastnet basin offshore Ireland, using a towed streamer. The data was recorded simultaneously with 2D GeoStreamer seismic data and onboard QC was carried out for both datasets. The first results are now available and early indicators are extremely promising.

The PGS towed EM streamer fits on a standard reel, on a conventional seismic ship. It draws on back deck knowhow gained over two decades of offshore seismic experience. The EM equipment is safe, easy to handle and robust.

Anh Kiet Nguyen is Head of EM Research and Development for Statoil. He explains why the Norwegian oil major is keen to promote this new technology:

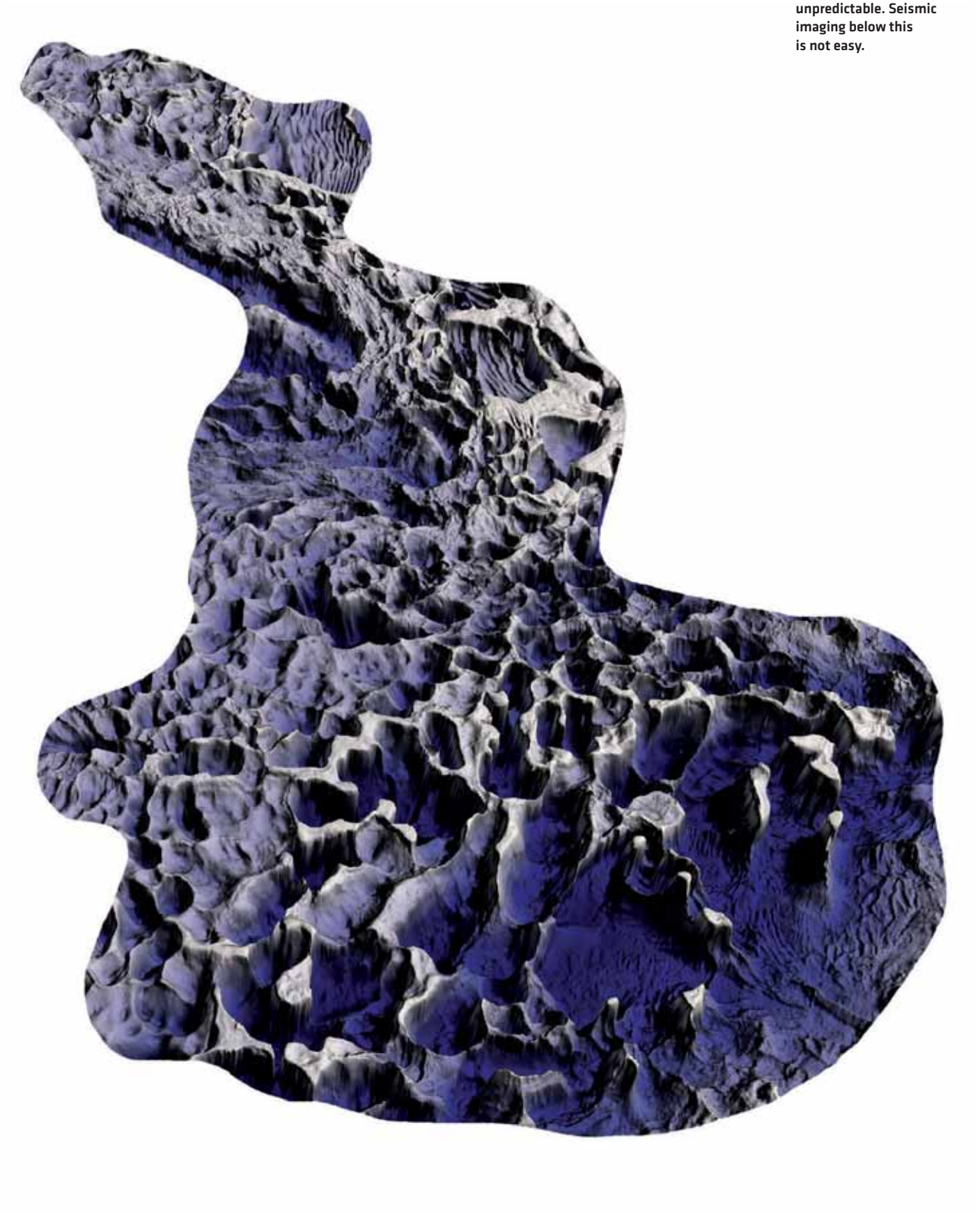
"Resistivity is an important geophysical quantity for hydrocarbon exploration since it strongly correlates with the water saturation in the formations Since its conception as a new technology for hydrocarbon exploration, marine controlled-source electromagnetic (CSEM) surveying has gone through, and still undergoes, an extraordinarily fast technological development, both hardware and processing-wise," says Nguyen.

The odd couple

Coupling EM and seismic acquisition adds a further dimension. In addition to a radically improved level of acquisition efficiency, towed EM delivers advanced online QC of data, and, when acquired simultaneously with seismic data, may provide a rapid tie between fluid distribution and stratigraphy. The benefits of effective acquisition will remain unchanged.

So far the PGS towed streamer EM solution is relevant for relatively shallow water – with operational depths of <400m meters. Approximately 25% of the seismic projects PGS acquires annually are within those depths. However, the ball is rolling. With a growing take up of the technology, it may yet progress into deeper waters. As the rate of data acquired increases, so will the geophysicists' understanding of the data and how best to exploit EM.

At the moment towed EM is still limited to relatively shallow water but with what we have seen in the seismic world and the pace of recent development in towed streamer EM, who would bet against towed EM becoming the premier electromagnetic acquisition method of the future? ●



The surface of a salt sheet is rough and unpredictable. Seismic imaging below this is not easy.

PASS THE SALT, PLEASE

We used to do everything we could to get rid of them. But now they are being harnessed to help unlock the secrets of the pre-salt. The dreaded multiple has finally become our friend.

Text Andrew Long **Illustrations** PGS

20 years ago, Philips, Anadarko and Amoco found oil in the Mahogany well offshore Louisiana. The sub-salt era was born, and with it a seemingly endless search for the ultimate technology to crack the sub-salt imaging challenge. Salt is a cypher, the ultimate form of signal encryption. But what if, instead of removing the white noise it creates, we reversed the logic and used it instead?

Rough and noisy

Seismic imaging below salt is not easy because the strong velocity contrast between rugose salt morphology and surrounding sediments leads to irregular and incomplete sub-salt illumination, and the reflection and transmission of complex coherent noise types such as prism waves and multiples. However, geophysicists have found an unlikely ally in one of the strongest and most pernicious seismic noise types that has been plaguing us for years: free-surface multiples. We have found that these can actually be used to improve seismic imaging below and around complex salt structures. Indeed, the petroleum industry and academia has spent the last 30 years or so obsessed with multiple removal in seismic data processing, including dedicated journals, books, workshops, conferences, academic consortia and so on. PGS tipped that perspective on its head when it first published the basis of Separated Wavefield Imaging, or "SWIM".

As illustrated with synthetic seismic data imaging in Figure 1, the "illumination" of the subsurface geology is very different when considering the traditional pursuit of primary reflections (seismic energy that travels a relatively simple path from the surface source to each point in the subsurface and then back to the associated subsurface receivers) versus surface multiples (any reverberating path from the surface source to various points in the subsurface, includ-

SEAM SYNTHETIC SALT MODEL

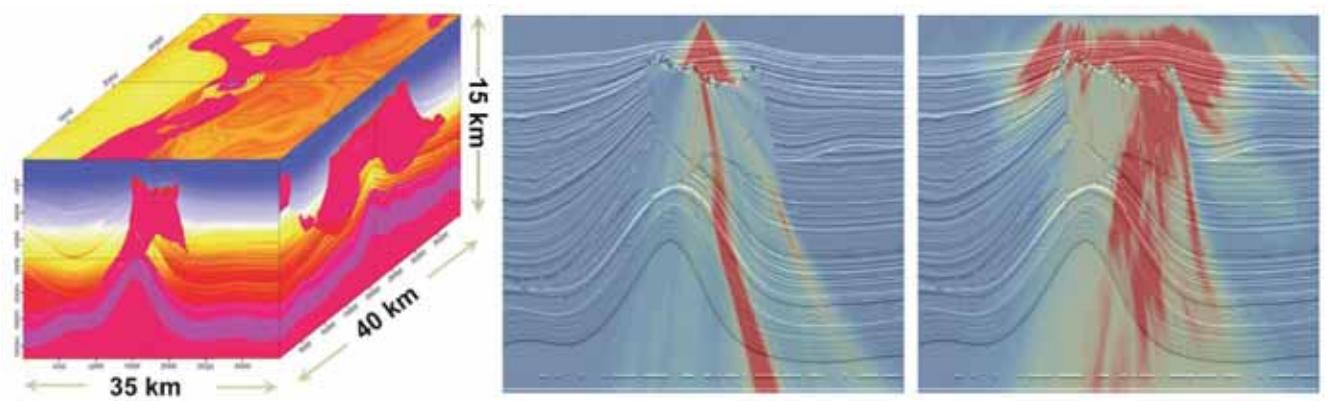
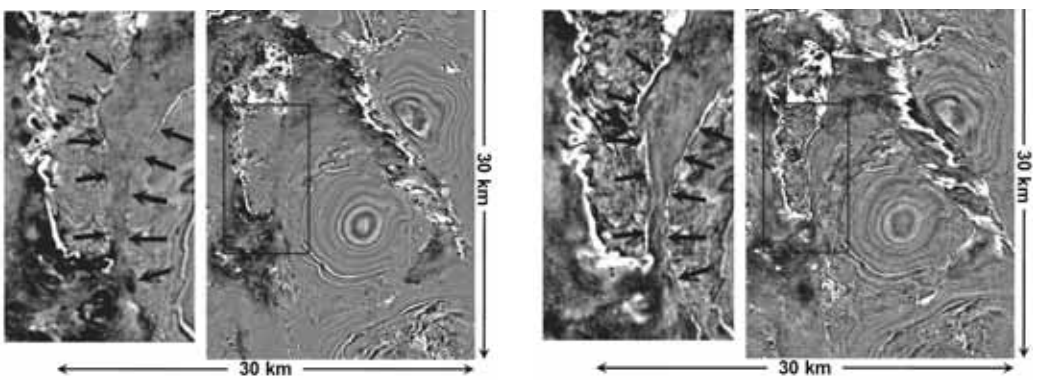


FIGURE 1: Synthetic salt model (left) with single shot illumination provided by primaries (center) compared to multiples (right). Note how multiples illumination contributes significantly greater lateral information above, within and below complex salt bodies – even for a single shot gather recorded during seismic acquisition.

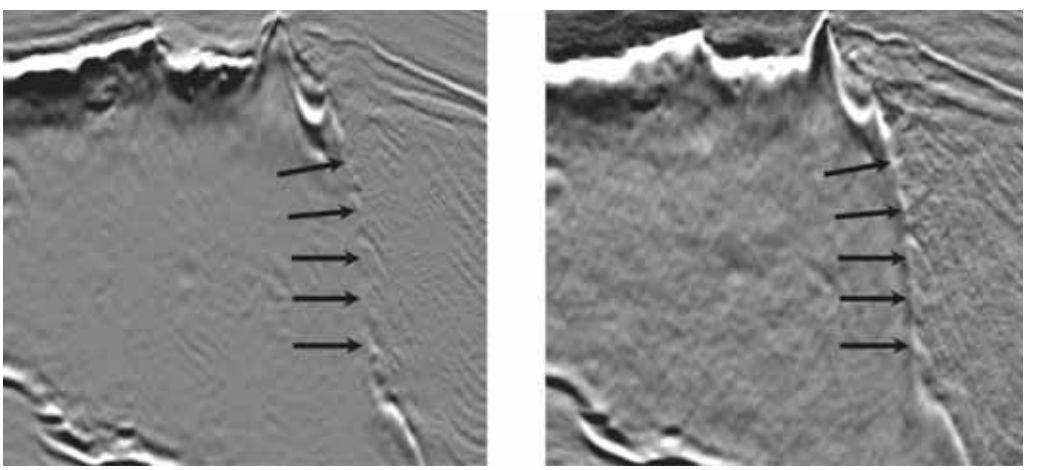
SUB-SALT/BASE SALT GEOLOGY

FIGURE 2: Imaging of sub-salt/base salt geology, including ambiguous salt/sediment boundaries: PSDM with primaries (left) vs. SWIM with multiples (right). Each image represents a horizontal depth slice near the base of salt.



POTENTIAL DRILLING TARGETS

FIGURE 3: Imaging of potential drilling targets sealed by salt body flanks: PSDM with primaries (left) vs. SWIM with multiples (right).



WHAT WAS ONCE PERNICIOUS "NOISE" HAS NOW BECOME AN INVALUABLE SIGNAL.

ing at least one reflection from the ocean surface, and then back to the associated subsurface receivers). Surface multiples typically comprise the strongest component of the overall seismic wavefield.

Covering all the angles

The vessel geometry simulated in Figure 1 is a large multi-streamer spread with the shot placed in the center of the streamer spread. Note this necessitates a multi-vessel or wide-azimuth (WAZ) approach in practice.

Full length feature

Whilst PGS is excited about the potential benefits of SWIM in pre-salt areas, the greatest benefits may lie in combining it with various other approaches. Simultaneous Long Offset, SLO acquisition uses two or more vessels towing conventional length GeoStreamer® dual-sensor streamers to deliver ghost-free data with source-receiver offsets up to 20 km. This method is operationally attractive as it reduces the risk of streamer tangles and survey downtime associated with very long streamer towing.

Those long offsets can be further complemented by wider azimuths. WAZ acquisition has become standard in salt-affected areas such as the Gulf of Mexico, deepwater Brazil and West Africa. Taken to its full potential, such multi-vessel configurations enable full-azimuth (FAZ) sub-salt illumination and seismic imaging. The multi-vessel geometry enables more complete sub-salt illumination with primary reflections. What might it achieve if we were to include imaging using multiples?

Alphabet soup – with salt

The Triton MC3D survey in the Garden Banks area of the Gulf of Mexico is shot using five vessels in SLO + WAZ configuration to tow 20 GeoStreamers, delivering FAZ seismic data with 16 km maximum offsets. This combination delivers one of the most complete sub-salt illumination products ever attempted. And that is just in terms of primary reflections. Adding in SWIM promises a further spectacular new improvement.

The left side of Figure 2 shows a pre-stack depth migration (PSDM) of traditional streamer data using primary reflections associated with deep sedimentary and salt geology. Two key pursuits are the efforts to establish the true three-dimensional morphology of the various salt features, thus identifying wherever sediments truncate against salt flanks and base, and as a consequence, building accurate velocity models of the contrasting salt and sediments. The various wave propagation challenges to salt imaging mentioned above often necessitate expensive imaging solutions. Velocity model building is an arduous and time-consuming task that despite lasting more than a year, may still deliver ambiguous or wrong salt velocity models, and exacerbate errors in seismic imaging.

Surfing the separated wave

The right side of Figure 2 shows contrasting SWIM imaging of wavefield separated data (made possible by the dual-sensor design of GeoStreamer), demonstrating a remarkably clearer and less ambiguous seismic image. When WAZ and FAZ acquisition geometries are used, SWIM can exploit the dramatically improved sub-salt and base-salt illumination associated with surface multiples – what was once pernicious "noise" has now become an invaluable signal.

Figure 3 shows how SWIM clearly images the truncation of (porous) sediments against the (non-porous) flanks of a salt feature. Drilling candidates such as this can be more clearly resolved around and below salt bodies using SWIM. Note that Gulf of Mexico salt features can span many tens of kilometers, thereby providing "illumination barriers" to primary reflections. Exploiting surface multiple illumination offers the best chance of getting past the salt.

A flavor of what's to come

This is another perfect example of the multiple manners in which GeoStreamer, thanks to its dual sensors and separate wavefields, is revolutionizing broadband imaging. One such opportunity was the ability to robustly image seismic multiples. SWIM has challenged the way we think about everything we have done for decades. Now another long-term headache, seeing through salt, may in turn be on the cusp of being resolved. ●

GLOSSARY

of technical terms

4

4D seismic Time-lapsed 3D imaging of an oil or gas reservoir. By comparing successive images, changes can be observed over time. These can help pinpoint pockets of oil and gas that have been bypassed. The asset team can then lead the oil to the well, or bring the wells to the oil.

B

Broadband seismic Seismic signals which contain a range of frequencies significantly higher than conventional data both at high and low frequencies.

C

CSEM An offshore geophysical technique, employing electromagnetic remote-sensing technology to indicate the presence and extent of hydrocarbon accumulations below the seabed.

CSEM uses a dipole source that is towed just above the seafloor to transmit a time-varying electromagnetic field into the earth. This field is modified by the presence of subsurface resistive layers and these changes are detected and logged by an array of receivers (see EM data).

Cyclone An area of closed, circular motion rotating in the same direction as the Earth where the primary vertical motion is upward. In a Dyson cyclone cleaner the air stream shoots around in a spiral exerting a powerful centrifugal force on the dirt particles. These are whipped outward and extracted, without using any sort of filter, at the bottom of a cylinder.

D

Depth slice A horizontal slice of the selected seismic data model at a given depth.

Digital motor The Dyson DC4 is a brushless DC motor with integrated electronics and an onboard microprocessor that controls voltage and power efficiency over 6,000 times a second.

Dual-sensor streamer Marine seismic recording system that records both pressure variation and particle velocity.

E

EM data Electromagnetic data is a measurement of the electrical resistivity of rocks. Porous material filled with hydrocarbons exhibit significantly higher resistivity than other similar rocks.

F

FAZ seismic Full azimuth seismicis designed to illuminate a subsurface target from all directions. That means the geology is sampled from all directions at all required offsets to give an optimum data set to image complex structures.

J

Jet stream Fast flowing, narrow air currents formed between hot and cold layers in the atmosphere which move weather systems around the globe. Scientists are investigating ways to harness its wind energy.

M

Multiples Seismic signals that have been reflected more than once.

O

Offset The horizontal distance from source to receiver. Offset creates a delay, or moveout, in the arrival time of a reflection that can be corrected before stacking and can be used to determine velocity. Long offsets are used to record the wide aperture reflections which can occur around salt bodies.

P

Passive monitoring Tracking reflections generated by background acoustic energy which is not triggered or controlled by the seismic crew, but which nonetheless can be used for seismic surveying in some way.

Permanent Reservoir Monitoring Commonly referred to as PRM, or Life of Field Seismic, refers to the recording of seismic data using sensors installed permanently on the seafloor around producing fields with the aim of optimizing production.

Pre-salt reservoir Hydrocarbons trapped in very deep sediments that were laid down before a salt layer accumulated above them. This was especially common off the coast of Africa and Brazil during the breakup of the Gondwana supercontinent. It is thought to represent a significant fraction of world oil reserves.

Post-salt reservoir Hydrocarbons that have been laid down more recently than the formation of the salt layer, or those which have leaked from the earlier pre-salt layer and subsequently been trapped.

Pre-stack depth migration (PSDM) A complex and computer intensive data analysis which aims to reconstruct the real shapes and positions of geological bodies from the recorded seismic data.

Primary reflections Seismic energy that travels a relatively simple path from the surface source to each point in the subsurface and then straight back to the associated subsurface receivers.

Prism waves The rough structure of salt bodies can cause double bounces of seismic energy, rather like the multiple reflections of light beams inside a glass prism. These create ambiguous seismic features during seismic imaging.

S

Science fiction A genre of fiction dealing with imaginative content such as futuristic settings, futuristic science and technology, space travel, time travel.

SEAM The SEG Advanced Modeling Program (SEAM) is a partnership between industry and the Society for Exploration Geophysics that was launched in March 2007 to advance geophysical science and technology through the construction of subsurface models and generation of synthetic data sets.

Separated Wavefield Imaging (SWIM) Making use of the dual sensor properties of GeoStreamer to create two discrete recorded wavefields for further processing.

Simultaneous Long Offset (SLO) An acquisition method using both combined source and streamer vessels, plus source only vessels. Used to record offsets significantly greater than the physical length of the streamers, with simultaneous source activation.

Sub-salt imaging Imaging beneath salt is hindered by the fact that salt bodies dramatically distort the wave paths of seismic signals. This aims to reconstruct these wave paths in order to decipher the geology that lies beneath the salt.

T

Time slice A horizontal display of 3D seismic data, representing points with a shared arrival time.

Triton A mythological Greek god, the messenger of the sea. The largest moon of the planet Neptune, discovered 1846. A full azimuth, deepwater MultiClient project in the US Gulf of Mexico, employing GeoStreamer technology and SLO.

V

Velocity model Numerical model that estimates the thicknesses of layers in the Earth and the speed with which seismic waves travel through each layer. Used to predict the depth to a formation of interest. The accuracy of the velocity model is critical for all time or depth imaging.

W

Wide-azimuth (WAZ) Term describing a survey design where separate source vessels are used to record seismic reflections from areas out to the side of the recording spread.

LET US **KNOW**

If you would like to suggest any additional terms for the glossary, please feel free to contact us at info@pgs.com.

IN THIS **ISSUE**

GRAND DESIGNS

A lot of the time improving what we already have is sufficient. But that's not a vision. In this issue of Reflections we look at ideas that lift everyone's game. Let's salute the big ideas.

WAKE **UP**

It is not the wake behind the Ramform Titan that is significant, it's the 70 meter wide area of calm. Ideal for deploying the industry's largest seismic spread.

EXPLORE REFLECTIONS **BACK ISSUES**

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