Finding Petroleum

"All the non-seismic methods work"

The Direct Hydrocarbon Indicators

Getting the sequence right with non-seismic methods

Adrok - using dielectric resonance to search for oil

Polarcus - surveys with more sources

Event Report, New Geophysical Approaches, Mar 9, 2017, London

Special report

New Geophysical Approaches

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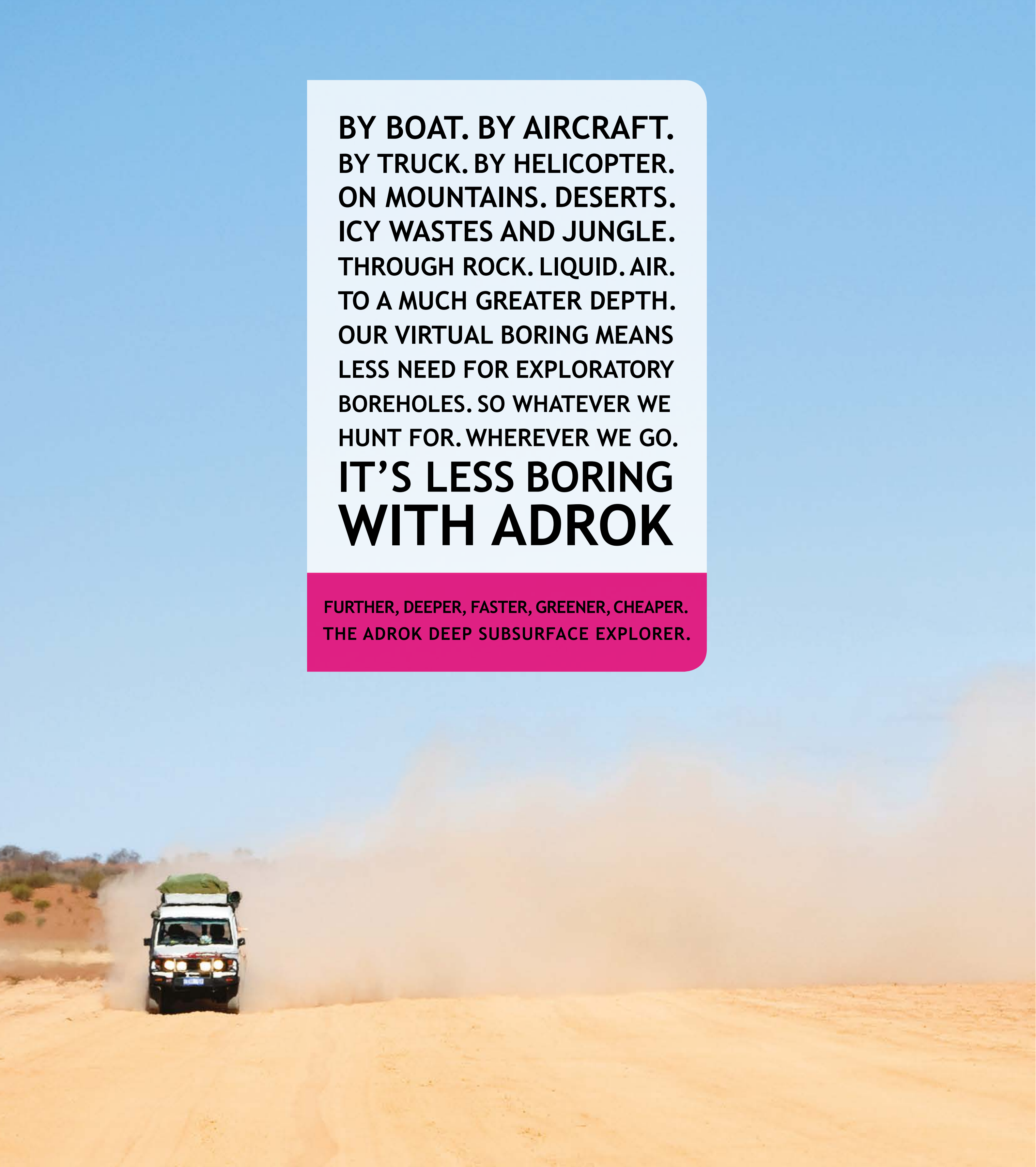

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Finding Petroleum

New geophysical approaches

Finding Petroleum's forum on March 9, "New Geophysical Approaches", looked at new ways to work with seismic – and alternatives to seismic – to help get a better understanding of reservoirs

This is a report from the Finding Petroleum conference "New Geophysical Approaches" held in London, On March 9, 2017

Event website

www.findingpetroleum.com/event/3e382.aspx

Some presentations and videos from the conference can be downloaded from the event website.

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Finding Petroleum's forum in London on March 9, 2017, "New Geophysics Approaches," looked at new geophysics approaches – other than standard seismic processing.

The conference included an in-depth look at non-seismic methods, land based electromagnetics, using multiple sources in towed streamer acquisition, advanced full waveform inversion, and using data science with geophysics.

This report covers the talks on non-seismic methods, land based electromagnetics and multiple sources for towed streamer acquisition. The full high resolution videos of these talks, and presentations, are available for download from the Finding Petroleum website at http://www.findingpetroleum.com/event/3e382.aspx

Robert Waterhouse – all the non-seismic methods work

All of the non-seismic oil and gas exploration methods work – but the question is working out how they can add value to an exploration process. Robert Waterhouse shared his ideas

The oil and gas industry largely believes that seismic is the sole tool used for exploration. But in fact there are many other techniques already used alongside seismic – and many more techniques which could be used far more, said Robert Waterhouse of Rosha Resources.

Robert Waterhouse

He was speaking at the Finding Petroleum forum in London on March 9, "New Geophysical Approaches."

Mr Waterhouse is currently involved with executive search and executive coaching work for senior management at natural resources and other companies, and was formerly involved in marketing non-seismic exploration technology

First of all, consider that companies already use seismic together with other technologies, he said.

The current success rate on frontier exploration drilling globally is 8 per cent. Now considering that companies would have used some method to determine that it made sense to do a seismic survey in that place, you can say that if they had just used seismic, they would get a success rate of much less than 8 per cent, he said.

Meanwhile drilling in established petroleum basins will typically see a success rate of 25 to 33 per cent. So there is something being added to the seismic data.

The process of oil and gas exploration starts with governments somehow selecting license blocks, oil companies somehow choosing blocks, and then geophysicists looking for leads and prospects, which gets matured into drilling targets. Drilling takes place, most of the time leading to discovering water rather than oil and gas.

The additional methods need to be linked into the process if they are going to be used.

There are many non-seismic exploration methods, some of which are hardly ever used. Some of the vendors claim success rates for their single seismic method is higher than those achieved in established basins (where a range of techniques are used), which seems incredible.

And also bear in mind that seismic surveys are not actually looking for hydrocarbons, it is looking at structures.

What are we looking for

As a thought experiment, you could consider how you might do oil and gas exploration if you didn't know anything about it, Mr Waterhouse said.

If we knew exactly what we were looking for, then it might be relatively easy to find reservoirs, we would just hunt for that thing.

But reservoirs come in a mixture of sizes, depths, rock types, porosities, permeabilities, fracture systems (which are often not given as much attention as they should be), trapping mechanisms, seals, levels of degradation, levels of natural loss. No two reservoirs are the same.

Hydrocarbons only exist in reservoirs due to "flukes of nature" in the first place – most hydrocarbons have leaked to the surface in the ancient past, with only a very small fraction getting trapped.

However there is one common feature of oil and gas reservoirs – they contain hydrocarbons – so perhaps that is what we should be looking for.

Black box

Another thought experiment is to consider how you might work out what was inside a container on a laboratory bench which you weren't able to open – and how each method is analogous to an oil and gas exploration method, Mr Waterhouse said.

You could ask how the container is similar to other containers you have seen before – which is broadly equivalent to geology, geophysics, rock physics and plate tectonics, comparing what you can see to something you have seen before.

You can ask if there are similar containers and do a statistical analysis, something which is also done in oil and gas.

If the container is leaking, you can analyse the leaks – which is equivalent to the oil and gas industry studying oil seeps and soil samples, doing DNA analysis of microbes. Some microbes like hydrocarbons and some don't.

You can see if the outside of the container is stained, which could be equivalent to a hyperspectral (colour) analysis, usually done by satellite – surveying land, rocks, ground, soil and plants to see if there is anything indicating the presence of small amounts of hydrocarbons. "All oil and gas reservoirs do leak slightly from the top seal, even if the top seal is intact," he said.

You might see if there is noise coming from the container, which is equivalent to recording passive seismic from an oilfield, such as listening to the noise from gas bubbles coming out of a deep reservoir.

You could look at variations in the density of the container, which is equivalent to gravity gradiometry.

You might try to image the inside of the container using a sound beam, which is equivalent to using 2D and 3D seismic. And you could do further processing on the sound beam, as the oil and gas industry does, looking for flat spot indicators.

You could also analyse electromagnetic waves coming from the container (also done in oil and gas), and X-ray the container (some X-rays are used in oil and gas exploration).

You could see how the container is absorbing heat, equivalent to thermal imaging of the subsurface, a method which is not widely discussed.

You could also make a hole in the container – which is equivalent to oil and gas industry drilling a hole.

Direct Hydrocarbon Indicators

Direct Hydrocarbon Indicators are where you actually look for oil and gas rather than underground shapes.

There are at least 10 – seeps, soil sampling chemical, soil sampling microbial DNA, bubbles offshore, hyperspectral onshore, EM (partly direct), amplitude conformance, flat spots, thermal (onshore) drilling, he said.

Most of these methods are for onshore – perhaps more DHI methods could be developed for offshore, such as seabed sampling.

Then there are many methods which can help understand structures, including gravity gradiometry and passive seismic.

"So there is hardly a shortage of non-seismic methods, and half of them are direct hydrocarbon indicators," he said.

Which of them work

The big question is which of the non-seismic techniques can add value.

Richmond Energy Partners recently did a positive study of Direct Hydrocarbon Indicators and earlier similar work had been funded by 41 companies.

The study showed for most direct hydrocarbon indicators, a positive show means that "the exploration well was virtually certain to come in".

Some other exploration methods have been claimed by their suppliers to have a 70 per cent and 93 per cent success rate. Similar figures are claimed for negative successes (when the DHI says there are no hydrocarbons there, and it turns out to be true).

These numbers are much higher than the current exploration success rates, so something funny must be going on.

Witchcraft

Meanwhile extensive use of 3D seismic is not leading to more success in exploration drilling, and the non-seismic methods are in limited use.

"I think it's fair to say some of these methods are considered by some to be almost witchcraft - some kind of black magic - people don't want to know about them," he said.

One reason is that oil companies are not able to do much of their own research, yet are unwilling to trust numbers provided by suppliers, so they fall back to 3D seismic, which "nobody got fired for using," he said.

If people drill a dry hole based on 3D seismic, the company accepts it.

The right sequence

Perhaps the key to getting value from non-seismic geophysics is getting the sequence right.

Ideally you would start looking at a broad area, studying continental shelves, margins and continents. Then you would move up to a basin and play scale, looking at satellite images, thermal images and gravity gradiometry, with data from satellites or aircraft. Then as you get closer to the reservoir location, you would look at methods like soil sampling and seismic.

The process would be different for a company which has a small exploration portfolio it is interested in doing more with. But the idea that it is important to bring in non-seismic methods at the appropriate stage still stands.

Imagine if someone shows up at an oil company and says they have a system which can say if the next exploration well is going to be successful or not. The company exploration department will be thinking, if this method shows that the well will be unsuccessful, we will have to tell our shareholders that the exploration program has been cancelled and the company no longer has an exploration portfolio. And it avoids the possibility of finding a super-giant field for oneself.

Management or technical issue?

Overall, it isn't clear whether the lack of exploration success should be seen as a management / leadership issue or a technical issue – a set of limiting beliefs and acceptance of poor results.

Not many other industries would tolerate an 8 or 25 per cent success rate.

Drilling itself is an exploration method, but a very expensive one. Companies in most cases don't have enough money to drill their way to success, Mr Waterhouse said.

Some companies improve their reserves by farming into other companies' successful acreage, but that does not improve performance of the sector as a whole, and it avoids the possibility of finding a super-giant field.

So the absence of an independent assessment of exploration methods and success rates can be seen as a real obstacle, he said.

"The money lost on just one major dry hole could fund substantial academic research. Imagine how much post graduate level study could be done - with the monies from one major dry hole."

They all work

One audience member asked which of the non-seismic methods actually work. "I think they all work - to varying degrees," he replied. "I don't think any of these non-seismic methods are some sort of con trick."

But more research into the track record of the various methods could be very helpful – for example to make it clear where a technique like soil sampling has actually helped find hydrocarbons.

It may be just that someone has managed to fit historic data to a model, but that is no use in actual exploration. That's similar to someone who builds a nice model which fits the data of which horse has run the last few horse races, and then tries to use it for future races, he said.

"Oil companies are always looking for some kind of proof this method works," he said. But it comes back to the first step, companies just don't have much confidence in non-seismic methods.

One audience member noted that there have been a number of exploration frauds, which leads people to be afraid of using unconventional technology. This matter is sometimes not helped by the vendors over promising it, rather than pointing out that the technology will (for example) only work with a certain sort of geology, and the success rate will only improve with a number of methods used together.

Mr Waterhouse noted that companies are losing enormous amounts of money on dry holes – and yet they don't have the staff with the competence to look at non-seismic methods. If they spent more money on staff with the right technical capabilities, perhaps they would save money from less dry holes.

The right acreage

Perhaps the most important factor in exploration is picking the right acreage in the first place. But that leads to the question of how you pick the right acreage, for example from a better understanding of the source rock.

This also includes understanding plate tectonics, which turns out to be very important in understanding where reservoirs are.

Small companies can get good at picking the right acreage to go for, as well as big ones, he said.

Testing the technology

One audience delegate, from electromagnetic survey company EMGS, said the company tries to analyse the predictive strength of its own technology, but many companies don't accept it and want to do analysis themselves. Over the past 5 years, a group of international oil companies have done an analysis and published the results in EAGE and SEG.

Mr Waterhouse said that it is typical for oil companies to say, they won't pay to use untested technology, but they will agree to test it out for free.

As an investor

Mr Waterhouse was asked about his attitude to non-seismic technology as an oil and gas investor.

As an investor, you can see that many company managers have a standard way of looking at things, which might impact their ability to explore.

You also need a great deal of caution. There was one recent example of a company that was valued at about $400m, but had invested about $1bn in oil resources and production equipment, so you can say that the value of their resources is negative or zero.

"Who is going to invest in oil and gas exploration if the outcome can be no value added?" he asked. "I think that is a very serious issue for the sector."

Adrok – using dielectric resonance to search for oil

Adrok of Edinburgh has been developing and using its 'atomic dielectric resonance' subsurface technology for 18 years – and finally starting to see some traction

Adrok of Edinburgh is making slow but steady progress with its 'atomic dielectric resonance' technology, which helps companies understand the subsurface using radio waves.


Gordon Stove

Adrok is based in Edinburgh, and over the past 7 years has gone from 4-5 employees to over 20. The company was established 18 years ago.

Managing director Gordon Stove explained how the technology works at Finding Petroleum's March 9 forum, "New Geophysical Approaches."

The basic idea is that polarised radio waves can penetrate the ground for up to 20km, or until they reach anything which conducts electricity (metal or seawater). The radio energy is also reflected back and the reflections can provide information.

Geophysics can be defined as "remote sensing of the internal structure of the earth." Various sensing techniques cover magnetic fields, density, resistivity, conductivity, radioactivity, acoustic impedance (this is what seismic is) and dielectric permittivity.

Adrok's technology builds on many physics developments in the 19th and 20th century, in particular, in Adrok's case, classical electromagnetics, invented by Clark Maxwell.

It led to work in the 20th century, including by Einstein and Charles H. Townes, inventor of the laser, and Richard Feynman, who developed quantum electrodynamics, and showed you can see through solid objects with electromagnetics.

The company Adrok was founded by Gordon Stove's father, Dr Colin Stove, who also invented the technology, and gave it the name 'atomic dielectric resonance'.

Dielectric means something which can transmit electric force without conduction. The electric charges don't flow (as they do in a conductor), but slightly shift their average equilibrium positions, creating an overall electric field.
Adrok's technology, Atomic Dielectric Resonance, uses a wide range of frequencies, sending a pulse into the ground. The return wave can be analysed to try to classify what it is saying about the materials.

Dr Stove was working as an academic in Aberdeen, and was headhunted by the UK government to do research into a technology of sensing from space. This led to a role as principal investigator from the European Space Agency, NASA, and NATO, and taking an early look at aircraft Surveillance Approach Radar and LIDAR (3D laser scanning). He also discovered that radio waves can penetrate through the ground, with a paper published at the Royal Society of London in 1983.

Radio waves in the ground

People are very sceptical that radio waves can pass through the ground, because they have heard about 'skin depth calculations', which say that only half a wavelength of a wave can penetrate the ground for X band or C band radar, Mr Stove said.

But this is only relevant to plane waves (like waves on the sea coming towards you on a beach).

Polarised waves, like the vibrations travelling along a string, can actually go into the ground.

So by using polarised waves from a satellite, you can see into the sea – there are photographs showing seabed pipelines.

There is a similar effect if sunbeams get focussed through clouds, sending vertical waves, which can penetrate through seawater.

Other researchers have managed to send radio waves through Mars, to a depth of 3.7km with just 500 watts of power.

The penetration has gone as deep as 5000m, in Egypt. "Privately we've done some in-house tests we think we've gone down 20km into the ground," he said.

"With radio waves the only thing that stops is man-made metal Geology doesn't have that in the ground. "The most challenging material for us is seawater - the most conductive material.

Comparison with seismic

To compare atomic dielectric resonance with seismic, you can say that it is sending radio waves into the ground rather than pressure pulse, you are sending multiple frequencies rather than (usually) single frequencies with seismic, and the radio travels at the speed of light rather than the speed of sound.

With ADR it is possible to stack up hundreds of thousands of traces together.

The penetration into the ground with ADR is roughly the same as seismic.

With ADR it is sometimes possible to classify rock types in the ground and different fluid types.

Seismic surveying can't tell the difference between an oil filled or water filled reservoir, but EM can, he said.

Classical electromagnetics uses an omnidirectional electrical or magnetic wave. It has been used extensively in the mining industry, including onshore from helicopters and aircraft, looking for uranium. Many companies have used it in offshore oil and gas surveys.

Tough market

One of the biggest obstacles is still that people are sceptical about any non-seismic exploration technology. Also some service companies may see that they make more money on seismic and be reluctant to promote it.

All geophysicists have used seismic technology. Only a small proportion of those have used electromagnetics – and of those, nearly all have used offshore.

Electromagnetics company EMGS is claiming a 90 per cent success rate. "I can't find a seismic company which publicly publishes how successful they are," he said. "EMGS has been forced to publish publicly."

A Norwegian masters student, Mari Danielsen Lunde, has written an entire masters thesis on why EM has not been given a fair chance, as a case study on the company EMGS.

One of the problems is that there is also a lack of knowledge about EM in oil companies. It may make sense for oil companies to second staff to work in EM service companies for a while, so they can build an understanding about it, he said.

There has been market research on geophysics markets, the latest for 2010, showing that 97 per cent of the market is seismic, 2 per cent is remote sensing (such as gravity or satellite images), and 1 per cent is CSEM. The company doing the research estimated that by 2020, the CSEM market would double to 2 per cent of the total market, but still be very small. "This is what we're up against with non-seismic methods," he said.

Adrok's technology

It has developed technology which is very small and portable. "We realised that to be different to seismic we have to be small," he said. "We miniaturised all the electronics. It took 10-12 years of research and development to get to this point."

Adrok also has a laboratory system, which can be used to classify core samples. It works with the Royal Ontario Museum (ROM), which has one of the largest collections of rock samples in the world (120,000 samples), of which about 1000 have been scanned. It also works with the Natural History Museum in London, which has 40,000 samples. The system can be trained on different rock types.

The electronics system creates a standing wave in a transmitter, which is sent out into the ground, and resonance is received back. Raw data is collected.

It operates at a time range of nano seconds, at the speed of light.

The transmission power is low. "Conventional wisdom says that to get deep penetration using radio waves you have to use big power," he said. "We tried that, we ended up burning soil and the ground." The radiowaves are the same as those produced by a microwave oven.

"If you reduce the power you get better penetration through the ground," he said.

There are 4 different types of scan.

Adrok usually starts with a wide angle scan, similar to the seismic offset method.
Then it can do a profile or 2D cross section scan, walking along the ground moving the transmitter and receiver, with a transmission every five cm. This gives a high detail of the subsurface.

The next scanning technique is "stairs", with a fixed position of transmitter and receiver, collecting as much data as possible, and stacking up hundreds and thousands of traces. "We can get lots of high definition images of the subsurface".

This technique was developed together with a professor at the University of British Columbia, who is now Adrok's chief scientific officer. The system transmits and receives. It was used to image a lake through 350m of limestone in the US.

The final type of scan involves moving the antennas around on the ground, pointing the transmitter and receiver at one another. So you can walk around the transmitter with the receiver. That can be used to image through tunnels and see what is on the other side of rocks.

It is also possible to measure transmission leakages from the equipment, and make sure only radio waves from the system are being picked up.

Case studies

There are many case studies on the Adrok website. Mr Stove presented some of the highlights in his talk.

In Northern Ireland, Adrok could measure 1000m through basalt, and found it was getting a series of high spikes in resonance going through the rock. The basalt was drilled and cored, and it showed that the high dielectrics were happening where the core had crumbled, and there was faulting and water ingress.

Adrok can also measure the energy coming back from the ground, and how it is being absorbed and reflected, and where this is happening. This has been done next to drill holes, including for Suncor Energy in Canada, with the readings compared to downhole tool logs.

In another project Oman, Adrok captured 32 harmonics in the received wave, which is a huge amount of data. With seismic, you might get 2 or 3. In that sense ADR could be considered equivalent to playing a piano compared to a drum.

Another project was done in Australia for BG group, doing a lithological interpretation of coal, comparing it to downhole measurements.

Today the company has been an official vendor for Chevron for 5 years. It took 22 months of due diligence. Chevron first gave a 6 month contract, which was extended for a year, then 3 years, "now they use us all the time".

There was a project in California, covering a 5km2 area with 700 drilled sites.

There were some issues with small movement of the ground (earthquakes) which the company didn't understand.

Adrok did some scans, making 2D cross sections of the subsurface, and could see the sandstone layers. It also did some stair scans, which could be considered "virtual borehole logs".

"We could get some good information about where the reflective layers are." The drill logs could be used to constrain the data.

It was possible to classify the rock layers, with sandstone layers and waterways. There was a 3D model of the water table.

The Adrok data had a resolution of 10cm vertically, compared to 15m for seismic, he said.

The final output was an earth model which Chevron can use to plan a drilling program around the sands, and avoid drilling into the water.

Summary

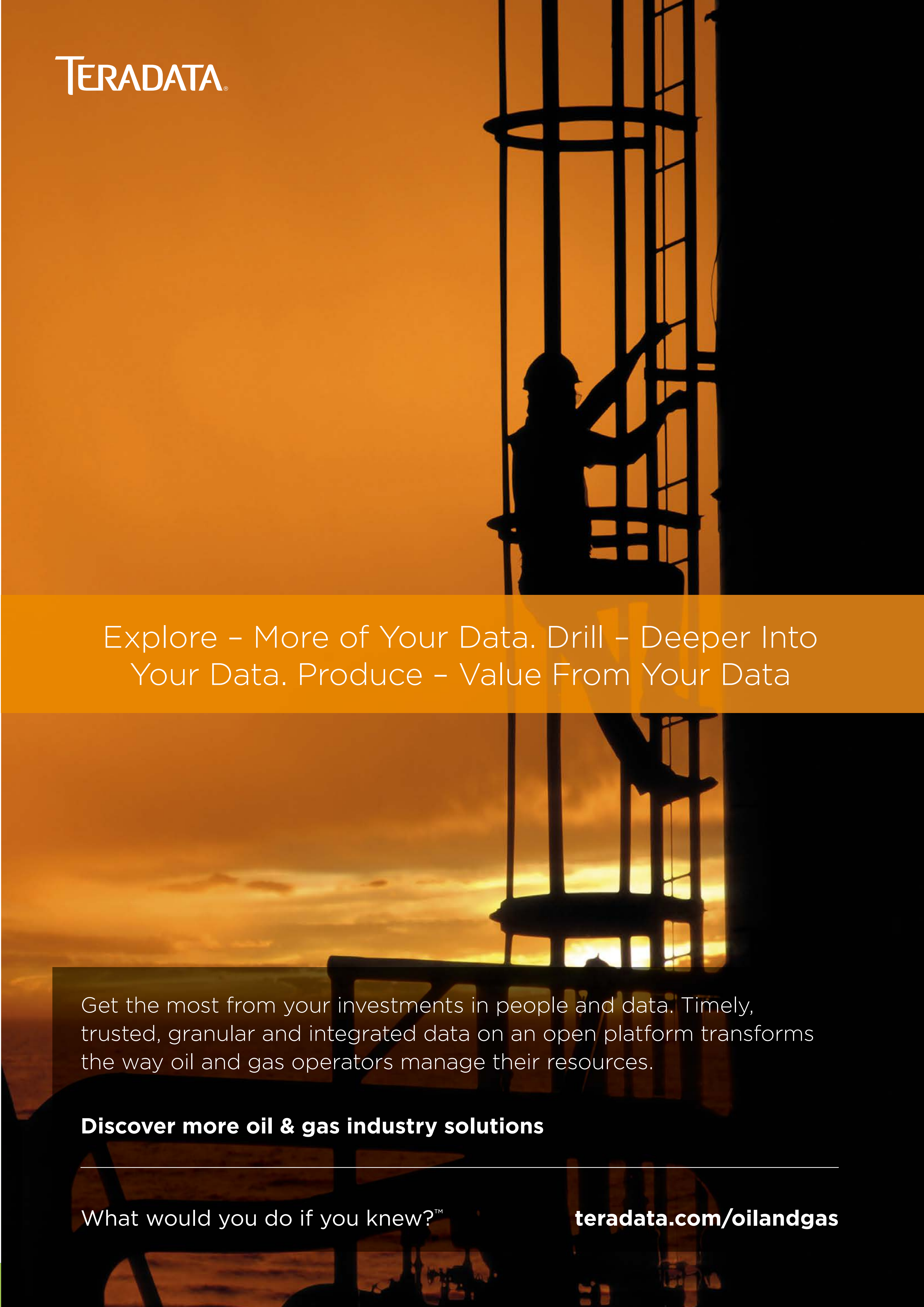
In summary, "seismic can't find everything alone," he said. "All the easy stuff has been found. We are now chasing difficult basins
You need to use Multiphysics to help you with that."

"We get 10 virtual boreholes for the price of 1 physical borehole. We can fit in any point of an oil exploration cycle."

"Our company has been around for 18 years. It is not fully accepted by oil industry yet. Average time for new technology to be accepted is 23 years."

Adrok has just started a project with the UK government, doing an onshore survey with iGas Energy, with funding from Innovate UK.

It is a feasibility study to use remote sensing to increase UK gas production.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Polarcus – surveys with more sources

Increasing trace density is a good way to get a better seismic image. But it may be easier to do that by using more sources, than having more streamers, said Phil Fontana, chief geophysicist with Polarcus

Companies have been adding more and more streamers to vessels in a kind of 'streamer arms race' over the past few decades, said Phil Fontana, chief geophysicist with seismic company Polarcus.

The aim is to increase the 'trace density' (amount of recordings which are made in the same piece of subsurface) and vessel efficiency, by using more streamer receivers.

But perhaps the same result could be achieved by having more seismic sources firing along a survey line.

A similar trend has happened on land, when companies have moved to having simultaneous sweeps from different Vibroseis trucks going at the same time.

If you record with multiple sources, you need to 'deblend' the recorded signal, allocating the various parts of the signal against a different source.

Or if you are setting one source off before the seismic from the previous one has finished arriving, then you need to work out whether the recording you are making is from the first shot (having gone deep into the subsurface and back), or time zero with the second shot Over-lapping the previous.

You want to remove the interfering energy one shot might make to another shot's recording.

Polarcus works with seismic processing company Downunder Geosolutions, which has developed a de-blending technique that does just that.

History

Over the past few years, the number of streamers on seismic vessels has been gradually increasing, Mr Fontana said.

The first offshore seismic vessels only had one streamer and one source. Then companies went to 2 sources.

When the main processing method was post stack migration, the bin fold (the number of traces in a certain 3D bin) is a critical element.

Phil Fontana

Using more sources decreased the bin fold and thus negatively impacted the quality of the data. Companies then went to 2 and then 4 streamers, and got bigger and bigger boats.

Surveys were done using converted fishing vessels and offshore support vessels with up to 4 streamers on until the early 1990s. Then dedicated vessels were built in the early 1990s which could pull 6-8 streamers. The build program has continued through to the present where vessels are built to tow 16 to 24 streamers.

As the number of streamers doubled the size of vessels got bigger and bigger and also more expensive.

As there has been something of a commodity market for seismic contractors, trying to collect more data at lower cost has been the name of the game.

Currently, many surveys are now done with 12 streamers. Meanwhile, dual sources have been the norm since the mid-1980s.

De-Blending

Seismic companies have been talking about deblending since the early 1990s, and there are many different techniques. "It is not a bleeding edge technology. We just happen to have a favourite one," he said.

All of the deblending techniques rely on some degree of 'randomisation' between shots in time and space, which makes it possible to tie a recorded signal to a seismic source.

For example with towed streamers, there is a small 'randomisation' in the time of the shots, due to small variations in vessel speed.

When you start planning a survey, you plot on a map where you want the sources to go off, so that the time between the shots is the time it takes the vessel to go from one source point to another.

Typically you can have a 100m long vessel, pulling 12 streamers, each 9km long. All of that mass can have its speed changed due to ocean currents, waves, and wind, and there are also small scale variations in speed as the gear is pulled through the water.

There is also other interference in the seismic recording, due to multiplies (when a seismic wave bounces between two reflection points several times, like an echo), and refractions (when the wave travels along an interface instead of reflecting).

Overlapping during water time

One way to do multiple source surveying is to try to only overlap the recording while the seismic wave is going through the ocean, and so nothing valuable is being recorded.

A traditional record length is 5-6 seconds, and part of that includes the time for the seismic wave to go through the seawater and back. But all of the useful seismic recording is below the seabed.

The amount of time the seismic wave is passing through water can be calculated as twice the water depth divided by the velocity (twice because the wave goes through water twice, once on the way in and once on the way out).

If the overlap in the seismic recording is the same as this seawater transit time, then you can keep the recording where the seismic is in the subsurface unblended.

Groups of gun strings

Seismic vessels typically have 6 gun 'strings'.

Traditional dual source gun arrays have 3 strings in each source, (so 3 gun strings release compressed air at the same time).

If you want 3 seismic sources, you can take the same 6 gun strings, but have them as 3 x 2 string sources.

There could be concerns that this might lead to a reduction in the amount of energy being released, with 2 gun-strings sounding at once rather than 3.

You would expect to see a drop in the signal output of about 3 decibels.

However the specific issue is not the actual signal strength, it is the ratio of signal to noise.

Polarcus did extensive testing on a survey for seismic company TGS in the West of Shetland Isles (UK) comparing three sources and two sources. The results were presented in EAGE Madrid in 2015. It showed that the quality of data from the 2 x 3 string sources "is not significantly better than 3 x 2 string sources".

The signal drops by 3 decibels and so does the noise. The same was also seen in a survey on Australia.

Another approach is to use the 6 gun-strings in alternating pairs, allowing 5 different sources (each 'source' being a different grouping of guns). In this approach there was also no "real compromise on signal to noise," he said.

Low output sources

It helps that the Polarcus sources have lower output compared to others on the market, he said. Having 24 bit electronics providing a large dynamic range allows high fidelity recording of the seismic data.

A large source does not necessarily mean that the signal to noise ratio is higher (as people sometimes believe). It is like saying, the quality of sound from a home stereo doesn't get worse just because you turn the volume down, he said.

Low seismic energy also helps with permitting, because regulators often make limits on strength of seismic energy.

Barents Sea test

Polarcus shot a high resolution 3D survey for TGS in the Barents Sea, with 12.5m cross line sampling.

If this was done in the traditional way, with two sources and 50m separation with 12 streamers, the sail line interval (gap between successive sailing lines of the vessel) would be 300m.

By moving to 3 sources and 75m separation between 12 streamers Polarcus could reduce the number of sail lines by 30 per cent, without reducing the amount of cross line sampling.

Case studies

One survey conducted by Shell in Myanmar covered 1200 km2 with dual sources and 200m streamer separation for 50m cross-line sampling. One of Polarcus' competitors said it could get a vessel out with 18 streamers, and keep 25m crossline sampling for a very similar sail-line efficiency. Polarcus could get the same crossline sampling with 12 streamers at 150m interval using triple sources.

By reducing from 18 streams to 12, there is a big advantage, not only to cost but also to risk and reducing technical downtime.

Companies have to do a great deal of small boat operations, doing maintenance and repairs to the streamers. If the streamers are 10km long, then going from 18 to 12 means taking 60km of streamers out of the water, so a big decrease in small boat operations.

Less streamers also mean lower fuel consumption, because of the drag of pulling the streamers through the water, which is linked to the propulsion power which is required. For an overall survey, moving from a 12 (streamer) x 100 (m separation) dual source configuration to a 10 x 150 triple source configuration means a reduction in fuel of about 15 per cent.

Polarcus also shot a triple source survey in Indonesia, and ran into a large amount of floating debris, including rubbish from fishing and outfall from rivers. This forced the company to come down to 10 streamers from 12 because more was too difficult to manage.

One case study is in the Cygnus field in Australia, in the Vulcan Sub Basin, where Polarcus was doing a multiclient survey. This is an area "traditionally known as difficult for imaging," he said. Previously, 3D seismic had been shot along the axis of the basin.

With triple sources, Polarcus was able to shoot perpendicular to the axis of the basin, with 18.75m cross line intervals.

There was "quite a startling result," he said. It showed up a graben, which the company knew was there, but didn't know what it looked like.

Polarcus was able to recover much of the low frequency information using deghosting (ghosts are made by seismic energy which goes from the source up to the water surface and then down into the subsurface, creating a reflection which arrives slightly after the main one).

On another survey, Polarcus decided to try with 5 sources, leading to a 6.25m cross line. It paired up the 6 gun strings to make 5 sources, with strings 1+2, 3+4, 5+6, 2+3 and 4+5.

Quadrant Energy, a company which has a deepwater block in the North West shelf of Australia, asked Polarcus if it was interested in doing a field trial using 5 sources, covering 400km2.

Polarcus did the survey using 12 streamers. After the survey, it reconfigured to the 10 x 100m spacing with 2 x 3 string sources and shot another volume right in the middle, so it could try to compare them.

In the final interpretation, it was possible to see individual allochthonous deposits (deposits which have moved), which were sized about 60 x 20m, and you could see the skid marks they had made moving down a slope.

In another example, Polarcus recorded with 8 streamers at 62.5m interval and 5 sources in a shallow water carbonate environment. It is very challenging area for seismic imaging, in a region with stacked carbonates in the subsurface, so there are many reflections and lots of noise.

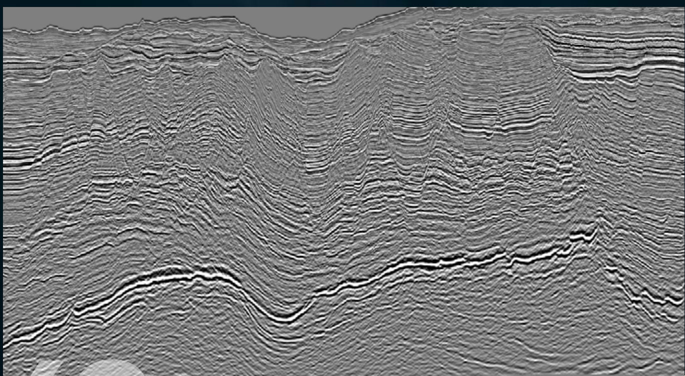
The company has done a preliminary prestack time migration analysis on the data. It is easy to see "significant channelling features in the near surface." "We're quite excited with the output," he said.

In 2016, about 30 per cent of Polarcus' projects were triple source or penta (five) sources, in all types of environments, and that will continue into 2017. The company plans triple source surveys in Brazil and Norway.

The X-Factor

No gambling, just good geophysics.

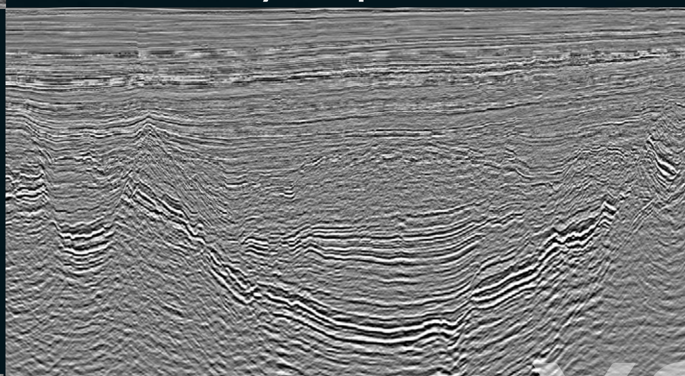
Dual Source



X2

We are excited to see more clients recognize the benefits of using the Polarcus XArray™ configurations, rather than simplistically adding excess streamers to improve productivity.

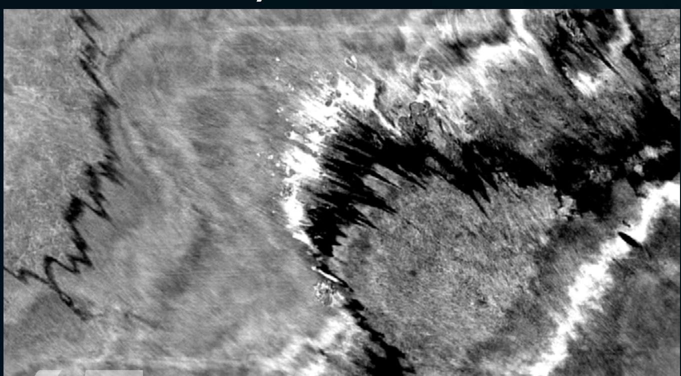
XArray™ Triple Source



X3

This innovative technique reduces EHSQ exposure of field crew by deploying less equipment in the water.

XArray™ Penta Source



X5

This also means that we enable the optimization of existing capex inventories, thus reducing financial exposure to our investors.

polarcus.com/xarray

Polarcus®

New Geophysical Approaches
The Geological Society, London, March 9 2017 Attendee list

Christian Bukovics, Partner, Adamant Ventures

Gordon Stove, Co-Founder & Managing Director, Adrok

Paul Murphy, Key Account Manager, Oil and Gas Division, Airbus Defence and Space

Geoffrey Boyd, Field Development Consultant, Antium FRONTFIELD

Joanna Wallis, Geophysicist, BG Group

Robert FE Jones, Director, Caithness Petroleum

Robert Kennedy, Commercial Director, Caithness Petroleum Limited

Jo Firth, Senior geophysicist, CGG

James Andrew, Busines Development Mgr EAME, CGG

Simon Fleckner, Geoscientist, Circle Oil Ltd

George Steel, Director, Connect2 LLC

Roger Doery, Consultant

Grahame Grover, Consultant

John Cryan, Geophysicist, Consultant

Peter Farrington, Geophysicist, Consultant Geophysicist

Charles Thomas, SEnior Vice President Africa & UKCS, EMGS

David Cleverly, Geophysicist, ENGIE

Joshua Lowe, Geophysicist / Data Scientist, ENGIE

Javier Herbas, ?Senior Geophysicist, ENGIE

Richard McIntyre, Sales Manager, Finding Petroleum

Karl Jeffery, Editor, Finding Petroleum

Avinga Pallangyo, Conference Organiser, Finding Petroleum

Jerome Foreman, Principle Geoscientist, Foreman Consultants

Simon Cushing, Research Director, Gartner

Alice Sapcaliu, Project Manager, GBC Ltd

Adrian Kerr, GdF Suez E&P UK

Richard Walker, Geophysicist & Team Leader

Norman Hempstead, Director, Hempstead Geophysical Svcs

Keely Harris, Asset Manager, Impact Oil & Gas

Neil Dyer, Independent

Neil Simons, Independent Consultant

Manouchehr Takin, Independent Consultant

Simon Marshall, Head of Events - Energy, Oil and Gas, ITE Group

John Griffith, Upstream Advisor, JJG Consulting International Ltd

Colin Clarke, Geophysicist, Lloyd's Register

Alan Smith, Director, Luchelan Limited

Geoff Chambers, Sr Geophysicist, Lukoil International

Darren McDonald, Managing Director, Moveout Data Seismic Services Ltd

David Bamford, Director, New Eyes Exploration Ltd

Helen Turnell, Principal Consultant, NR Global Consulting Ltd

Mark Robinson, Managing Director - Geoscientist, Oil and Gas Consultancy

Alex Stedman, Software Sales Geophysicist, Open Geophysical

Aoife Carr, Senior Geoscientist, Ophir Energy

Peter Dolan, Advisor to the Board of Directors, Ophir Energy

Dave Waters, Director and Geoscience Consultant, Paetoro Consulting UK Ltd

Robert Parker, Consultant, Parker

Mike Rego, Independent Consultant, PetroMall Ltd

David Sendra, Associate Consultant, Petrophysical Consultant

Tony Bell, Area Geophysicist, PGS

Lesley Auchterlonie, Sales Area Manager EAME/CIS, PGS

Stuart Fairhead, Depth Imaging Manager, PGS

Mark Seymour, Sales Supervisor Marine Contract Africa, PGS

Joshua May, Sales and Marketing Manager, PGS

Mike James, Business Development Manager, Marine Contract, Africa, PGS

Phil Fontana, Chief Geophysicist, Polarcus

David Contreras, Gegional Geoscience Manager, Polarcus

Dave Forecast, Sales Supervisor, Polarcus

Zuzana Kralova, Polarcus

Chris Newton, Sales Manager, Polarcus UK Ltd

Robert Waterhouse, Director, Rosha Resources Ltd

Martin Smith, Business Development Manager - Operations, RPS Energy

Paul Strachowski, Seismic QC, RPS Energy

David Webber, Seismic Operations Supervisor, Sceptre Oil & Gas

Robert Heath, Marketing Manager, Seismic & Oilfield Services Ltd

Alexander Chalke, Business Development Director, Simpson Booth

Oxana Bristowe, Director, Stand4More

Vibhusha Raj Sharma, StrategicFit

Andre Sharma, Petroleum Analyst, Svenska Petroleum Exploration AB

Ali Elyaseri, Petroleum Economist, Svenska Petroleum Exploration AB

Duncan Irving, Practice Partner, Oil & Gas, Teradata

John Sunderland, Retired, TGS-NOPEC

Hugh Ebbutt, Independent, Upstream Adviser

Tim Brice, Geophysicist, WesternGeco

What did you enjoy most about the event?

> I really enjoyed the Adrok presentation.

> Good range of technologies covered - excellent overview of the status quo.
> *(CGG)*

> Networking.

> The last couple of presentations and meeting colleagues.

> The geophysical focus of all the talks made for a very informative and interesting event.
> *Grahame Grover (Cumbre Consulting)*

> Phil Fontana presentation, first 2 presentations. Refreshments.

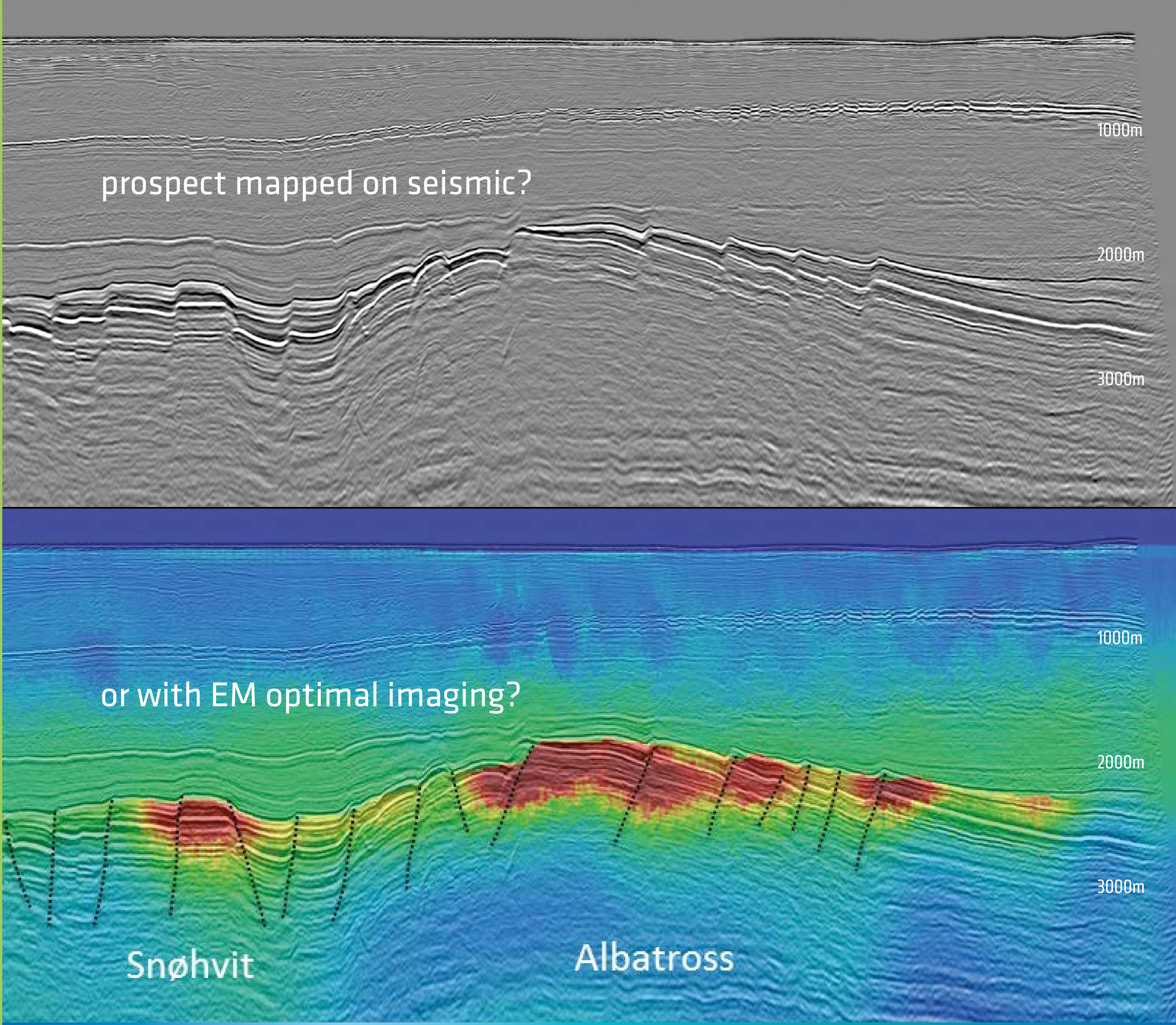
> The discussions of the new technologies, some of which I had never even heard about even after more than 30 years in the E&P business.
> *John Cryan (Consultant)*

> The content. Thought provoking.
> *Dave Waters (Paetoro Consulting UK Ltd)*

> Adrok's & Robert Waterhouse's presentations were both illuminating and fascinating. Excellent conference.

> Diverse well presented topics with opportunity to ask questions of speakers during talks or breaks. Well organised by David, Karl etc.
>
> Diversity of professional backgrounds promotes wider dialogue and insights and expands audience enlightenment during question time.

> Thought provoking presentation on novel EM methods and an excellent presentation on multi-source towed streamer operations and survey design implications.
> *Richard Walker (Independent)*



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