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App on every platform

The Norwegian Petroleum Facts app developed by the NPD and the Ministry of Petroleum and Energy for use on iPhones/iPads is now also available for Android and WindowsPhone mobiles.

Based on data from the NPD's online fact pages and maps, the app provides information about fields, production licences, companies, production and active exploration wells on the NCS.

Users can also access news stories from the NPD and the ministry.

The map function shows fields and active exploration wells, all linked to relevant background information. A search function is also provided.

In addition comes an analysis section which allows users to filter and sort data themselves. They can be stored as favourites to simplify later updating. Graphs can also be generated.

Users can chose between English and Norwegian versions. The app has been developed in collaboration with the Applaud company.

Screen images illustrating the app can be accessed at http://youtu.be/Wd1vKa3u028. An introduction is also available at http://youtu.be/4sE1wXaC6bU.

www.npd.no/en/

NORWEGIAN PETROLEUM DIRECTORATE

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Carbon catcher

Svalbard searcher
From Mongstad to the Moon
Gudrun on track

NORWEGIAN CONTINENTAL SHELF

A JOURNAL FROM THE NORWEGIAN PETROLEUM DIRECTORATE NO 1 - 2013

CONTENTS

The interview:

NORWEGIAN PETROLEUM DIRECTORATE

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FRONT COVER
Van Thi Hai Pham is the first NPD staffer to take a PhD on carbon injection.
(Photo: Emile Ashley)

LEADER

Responsibility

"It will soon be 50 years since petroleum activities began on the NCS. Activity and optimism are both high."

Optimism among players on the NCS is higher than it has been for a long time. The jobs and the challenges are piling up. It is now important that everyone concerned thinks long-term and delivers high-quality work. That will secure future revenues for the benefit of Norwegian society.

The offers made to the companies in the 22nd licensing round are extensive, embracing as they do production licences in unexplored areas – some in the Norwegian Sea and most in Barents Sea South.

All the nominations for the 22nd round and the subsequent applications show that the industry has recovered its interest in the Barents Sea. One reason is undoubtedly the discoveries which make up "Johan Castberg". At the NPD, we have always had faith in this part of the NCS, even during the years when the majority of the companies were far less enthusiastic about it than they are today.

We also expect great interest from the companies after the Storting's decision to open Barents Sea South-East. The invitation can come as early as this autumn.

The Barents Sea has been, and remains, a test of patience. Those who want to reap in the far north, must take a long-term view. The first blocks were offered in June 1979, and some 100 exploration wells have now been drilled there. Snøhvit is on stream and Goliat is approaching a start to production, but many other investments in exploration wells have yet to yield a return to society. Hopefully, some of the awards in the 22nd round will make a positive contribution to the overall account for the Barents Sea within a few years.

Our recently published report on *Petroleum resources on the Norwegian continental shelf – exploration* provides updated and valuable information for the players. Expected undiscovered resources are larger than they were when our previous resource report was published two years ago. Development of petroleum resources in the Barents Sea is still in an early phase.

We will be publishing a report this autumn which also deals with resources in the more mature areas of the NCS. Although much attention has been paid to the new areas in the far north, the work needed on and around existing fields must not be forgotten. Much remains to be done, and large volumes of oil and gas which can and should be recovered are still to be found. The companies face a challenge here which is at least as great as hunting for new far-northern resources.

The level of oil and gas exploration in recent years has been high, with 40-50 wells per year. This has yielded a good success rate, and some of the discoveries have been substantial. The same companies now awarded new licences have a big responsibility for ensuring that the development of these finds stays on schedule and to budget. Experience shows that this is a demanding business. The same applies to future projects for improved recovery.

It will soon be 50 years since petroleum activities began on the NCS. Activity and optimism are both high. Maintaining the current level of production calls for good decisions and for the industry to carry out the work it has undertaken to do. The government's job is to ensure that this yields the best outcome for the national economy.

Bente Nyland

Bente Nyland
director general

From boyhood DREAMS to adult DISCOVERIES

It smells like a petrol station when vertebrate specialist Jørn Harald Hurum gets to work on bones found on Svalbard's rugged slopes. He has now identified oil in these Arctic islands.

Bjørn Rasen and Emile Ashley (photos)

I am not in Svalbard, but hunting for the entrance to Oslo's Geological Museum – a massive stone building rather like a fortress.

The tall, wide entrance doors appear to have been created to admit dinosaurs, while their thickness seems designed to prevent such massive creatures from escaping once lured inside.

"Everything's fine," Hurum responds spontaneously when I ask how things are going with Ida. "We're still doing research on her. She's on display."

One of the two Idas in his life is his nine-year-old daughter. She has not come to work with him today, but has features in common with 47-million-year-old primate Ida, whom Hurum acquired over a drink at an exhibition in Germany.

This was something of a coup, he says, which only cost the museum NOK 1-2 million. It was not the money which kept him awake for two nights in September 2006.

When ancient Ida was imported from Germany, Hurum named it for his daughter. "That's pretty appropriate given the state of her teeth," he explains.

"The early primate had gained her milk teeth and was starting to develop permanent molars when she died. That's just how it was with my daughter at the time."

Since then, he has devoted much time to the world's best daughter and the world's best fossil – "at least, its rarest fossil, because Ida is the world's only complete early primate.

"We don't find full fossil skeletons of primates again until humans began to bury their dead. All the remains found in between are incomplete."

Those who know nothing about fossil Ida can use Google, which presented her discovery to one-two billion people and carried her logo on its front page for 26 hours. Hurum describes it as "the fastest publicised research project in history".

Time appears to have stood more than still within the museum's thick walls. Its floors are filled with the skeletons of prehistoric predators.

Some stand free in the central spaces, while others are securely locked behind glass. Although the best known, Ida is just one of many exhibits in her case.

Hurum has placed the fossils he loves best in his office. A 2.5-metre-tall skeleton looms behind his desk, and the rest of the room is dominated by skulls and other bones of every kind.

In addition come arrays of books. Many of them, including several for children, have been written by the associate professor for research and collections himself.

After five minutes in his company, I begin to wonder what Hurum actually does instead of pursuing his hobby around the clock.

"My job involves vertebrates – everything from fish to people," he explains. "I'm in charge of all fossils with bones in Norway.

"That means I can pick and choose between working on fish or land animals. But I don't bother with fish – I find them boring. They have so many bones and aren't as spectacular as mammals."

He took over his job as a vertebrate palaeontologist from Polish professor Zofia Kielan-Jaworowska, after studying for his PhD under her knowledgeable guidance.

"And now I'm here," Hurum chuckles with satisfaction, and emphasises that he also has a life and family outside work.

And where family is concerned, scientists are divided over whether Ida has human features or belongs among the lemurs – a debate Hurum directs.

He admits to inclining towards the ape theory. "She's 47 million years old, while the split between lemurs and apes occurred some 63 million years back.

"Ida exhibits features which could point in either direction. Since we lack other fossils of a comparable age, we can't reach any conclusions."

So what does a scientist who likes to stand up to his knees in mud and dig in remote places think of a Google search linking him first with Ida?

After all, he has not dug the fossil up himself but bought it at a fair. Surely the seller must have been an idle European who kept her in a drawer for at least 20 years?

"He knew what he had, all right, and that's reflected in the price," says Hurum with a laugh. "If you understand collectors, you'll know that having something unique confers self confidence.

"You enjoy it through owning it. Knowing that you have a world sensation like Ida under the bed is definitely a good feeling for a collector."

Hurum is very much a collector himself, and agrees that he can also be described as a historian. "Every fossil is a witness to an earlier time we can't travel back to and see.

"We must try to understand how the world looked then. I concentrate on the big reptiles from the Jurassic and Cretaceous periods. Plus a little excursion up to the Eocene with Ida, obviously. I couldn't say no to her."

The word "no" does not have a dominant place in Hurum's vocabulary. Life has too many possibilities for that.

He grew up with "how" and "why", and says he began to think deep thoughts about who he was and where he came from at an age of five or six.

In a children's book, he read about a boy walking along the road throwing stones. One of the stones says "Don't throw me. I'm a trilobite with a tale to tell about life before humans."

"Something just said 'click' in my head then," Hurum recalls. "Fossils bear witness to a history humans haven't experienced, and I wanted to learn all I could about them."

His grandfather advised him to wait until he started school, when he would be able to get answers to all the questions he was asking about fossils.

"On my first day at school, I asked the teacher if she knew all about fossils. She naturally didn't, so I decided to find out for myself. And that's what I'm still doing, of course.

"I try to understand the time before humans. My driving force is putting together ecosystems which nobody has done before, as we're now doing on Svalbard – everything from microfossils to huge reptiles."

He studies individual animals to comprehend them, but examines the ancient Svalbard ecosystem to grasp how the mud was deposited, what microfauna were present, and who ate whom.

Hurum cannot say whether dinosaurs and other ancient reptiles ate fish and chips, but he has studied the way they chewed their food.

This is a quite natural subject for scientific study, he maintains. "I was working on the bone-shattering dinosaur bite. Nobody had previously studied the lower jaw of these creatures."

The desolate Svalbard archipelago is Hurum's playground. "You avoid all that dreadful green stuff you find everywhere," he responds when asked to explain its fascination.

"Grass and trees cover everything that's fun, which is why geologists and palaeontologists love deserts. And Svalbard's a wasteland, of course.

"You can walk over rocks which haven't become overgrown, which let you see the geology and find fossils much more easily. You escape the root systems which keep everything in place.

"A lot of wind also ensures rapid erosion. Up to five centimetres of loose shale can be removed every year on Svalbard, which naturally brings new bones to the surface all the time. An area can change its appearance completely from year to year. Quite fantastic."

> When ancient Ida was imported from Germany, Hurum named it for his daughter. That's pretty appropriate given the state of her teeth.

The Svalbard skeletons are insulated with soft toilet paper, plastered together with gauze, reinforced with metal rods and laid on pallets before a helicopter lifts them out. "It takes up to 10 days to assemble a big skeleton," report Hurum. "That's followed by nine months of gluing at the lab, and then report-writing. It can easily take 1 000 hours before we're ready to produce the paper." The lab subsequently casts copies for distribution to museums worldwide.

You might wonder whether Hurum is unique, or whether he meets flocks of like-minded people from around the world digging for bones in Svalbard's black shales.

But the scientist is quick to emphasise that he is part of a group which includes students from various nations. The work is fun, but demanding. And many cannot be bothered.

"Working in the Arctic demands a lot of logistics," he explains. "Most palaeontologists are too lazy for that. They come, pick up a couple of rocks and go home to analyse small fossils."

His team dug 40 tonnes of shale out of a hole by hand last year. Once the bones had been removed, the spoil was thrown back into the hole. Nobody else appears to work that way in Svalbard.

"A number of people describe this approach as a form of academic suicide," says Hurum. "Eight years of collecting mean about 10 years of gluing skeletons together in the lab at home.

"This project means you devote 18 years of your life to describing some reptiles on Svalbard. And nobody has done it before or will do it afterwards. The research is likely to stand for a very long time.

"That's when it's good to have a permanent job and a bit of a thick skin, not to give too much of a damn and to enjoy the open-air life."

The Svalbard project began with a phone call in 2004 to notify the museum that part of a skeleton had been discovered on Mount Janus. "We naturally took the trip north," says Hurum.

This excursion could be combined with celebrations for the 10th anniversary of the palaeontology association at the Geological Museum.

"Twelve of us set off to excavate the first find – one metre of neck and a flipper," recalls Hurum. "We then found 10-12 skeletons in two days. That wasn't normal – something had happened here."

The team returned later to carry out further studies. During one field season, 30-40 reptile skeletons were uncovered. Major excavations began in 2007 and

> When we split carbonate rocks in old methane pipes, it smells like a petrol station.

have continued annually.

This is tough work, and Hurum agrees that it can cause problems for knees and back. Most people have had enough after a fortnight, "but we sometimes press it to three weeks, when many of us are on the verge of collapse".

The weather window at a height of 400 metres on Mount Janus is just six-eight weeks a year. Not everyone is suited to standing and digging in mud under such conditions.

Hurum selects his team carefully – some are scientists, and others are students and volunteers who can do the practical work.

"We need people in the field who've been fiddling with mopeds since they were 12 – and not just ones who sit and study. The first kind are worth having when a drill breaks down.

"And we need a big-game hunter to take care of the weapons, so that they're not full of mud when the Polar bears become too aggressive.

"Many academics who visit Svalbard take to their tents in bad weather and otherwise fiddle. We go deeper – it's is a very different kind of field work, which I learnt in Canada."

This toil has yielded results, with the pliosaur christened Predator X as the crown jewel. First thought to be 15 metres long with particularly big flippers, it turned out to be two metres shorter once the vertebrae had been glued together in the lab.

"But it's the complete master – the top predator in the food chain," Hurum says. "A pliosaur ate all the other animals it had a taste for."

This sort of project yields PhD theses and scientific articles – and children's books. Hurum and his colleagues published *Monsterøglene på Svalbard* (The Monster Reptiles in Svalbard) on the day their 18 papers on the discoveries appeared.

"We communicated the whole story of our discovery to children and the scientific community at the same time," says Hurum. "I feel it's important to get across the full result, rather than publishing in dribs and drabs."

Interest in the high north is growing at many levels, including international politics, ice-free shipping lanes across the top of Asia and exploration for oil and gas. The question is whether Hurum contributes anything useful.

"In terms of oil? Hmm. One of the by-products we describe is black shale, the same Upper Jurassic strata which produces petroleum in the North Sea.

"The oil companies can benefit from our detailed studies of the stratigraphy and the sequence of deposits in these sediments."

And he has found oil in Svalbard. "When we split carbonate rocks in old methane pipes, it smells like a petrol station. That odour is even stronger when reptile bones full of oil crack.

"When we burn our rubbish on the shale, too, the rock catches fire. So it's very rich in organic materials. This liquid oil is described in the last of our 18 papers."

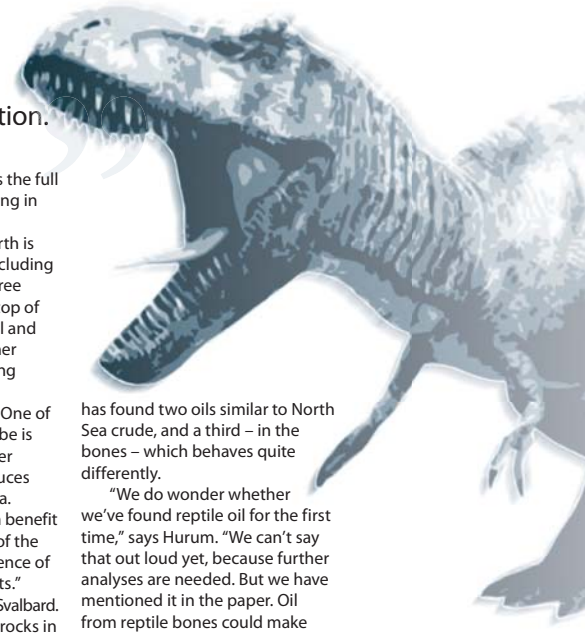
He admits that microscopic dinoflagellates provide more information for oil hunters, and that drillers seldom encounter fossil bones in a well.

But one exception can be found in the cellar at the Geological Museum – the dinosaur from the Snorre field in the North Sea. A small piece of it can also be found at the NPD.

Skeletons of ichthyosaurs and plesiosaur teeth have also been found in cores from NCS wells, without that having improved reservoir understanding.

"A few grams of black shale contains hundreds or thousands of dinoflagellate fossils, so using these for interpretation is easier," Hurum notes. "When you've 20 kilometres of mountainside to study, you don't need to think in grams."

But he hints that reptiles have also contributed to the search for Norway's oil riches. His team has found two oils similar to North Sea crude, and a third – in the bones – which behaves quite differently.



"We do wonder whether we've found reptile oil for the first time," says Hurum. "We can't say that out loud yet, because further analyses are needed. But we have mentioned it in the paper. Oil from reptile bones could make a tiny contribution to Norway's resources."

He nevertheless sees his biggest contribution as communicating knowledge to ordinary Norwegians – explaining all the interesting things he can read from stones.

That has been the way since his childhood bedroom was converted into a museum. "Everyone who visited Mum and Dad had to be taken on a tour of my little room. Now I've got a big one."

Like many others who talk enthusiastically about their subject in a way people can understand, Hurum comes in for criticism. Detractors claim that he overwhelms his audience.

He publishes children's books on the same day as his research reports are unveiled, he is present in every channel – including children's TV. Is he too keen on the limelight?

His own view is that he merely seizes the opportunities that offer themselves "and I stick to my own subject. Everything has to do with palaeontology and geology."

That held true, too, when he produced a geological survey of the district of Nedre Eiker west of Oslo with local funding and a team of academics.

Ready in five years, this books means that the local authority is the only one in Norway with such an overview of its underground assets.

"We wrote about the subsurface, mining and its cultural history, minerals, fossils and evolution," he reports. "I'm personally an active collector of geological literature."

That was followed by a concentration on the Svalbard project, before Ida turned up. "Many people maintained that I shouldn't be diverted by a primate fossil, but my boss gave the green light."

Hurum does not believe that all scientists can be good communicators. Those who are good at research but not at communication should not be burdened with the latter.

"Everyone who's been to university knows there are academics who should never be allowed to lecture or communicate. Being also able to communicate should be more appreciated.

"Writing a children's book when you're an academic is somehow bad form. I'm criticised for publishing an article or two less than the others one year, without anyone mentioning that I've also written two kids' books. Children are an important audience."

Norway should have more scientist who are also good communicators, Hurum maintains. "We have role models in skiing and football, and we have pop stars, but we need to build such models in other areas as well.

"Simply referencing a discipline is hopeless, you must show your face as well. The subject otherwise becomes too anonymous. When I was young, all the scientists doing cool things were American. I didn't know any Norwegian ones."

His subject has always interested him deeply, and he was determined to learn as much as possible. "It's got something to do with the reason why you're studying.

"I was disappointed when I started reading geology at the University of Oslo. I might just as well have studied business or law.

"My fellow students were very clever, but uninterested in the subject. They were keen to get educated because they saw a lot of money at the other end.

"So they learnt what they had to in order to get into the oil business. Opportunities for career and cash overshadow the academic element, and they're definitely not interested in a PhD. You don't get much better paid for one of those in the oil business."

Hurum's subject has always illuminated his life, including at home. He confirms a story about his honeymoon in Kirgizstan, where the newly-weds sifted five-six tonnes of sand every day.

That was great, he says. "I can't stop talking shop when I get home. If I couldn't, I might as well be single. It was absolutely essential for me to find a geologist wife."

He is still solidly married. While his holiday plans remain to be settled, he is working on a trip to Alaska – where there are these reptile footprints ...

Looking further ahead, to the next decade, Svalbard remains high on his list of priorities. He hopes to have built up a research team on the early Triassic.

"I have big plans in Svalbard to do the same as we did with the Jurassic. We now have the logistics, the camp and the knowledge of how to go about this."

The early Triassic was a time when ichthyosaurs existed which still did not look like such creatures. They were more akin to crocodiles and swam a little closer to land. Some of the earliest lived in Svalbard.

"Their remains were discovered a century ago," says Hurum. "Doing a proper job on them – five years in the field with real mud – could turn up really important finds."

Older still

The fossilised remains of a seven-centimetre-long "primate" found in China are 55 million years old – some seven million more than Ida. This finding comes from Pittsburgh's Carnegie Museum of Natural History and was reported in Britain's *Guardian* newspaper on 6 June.

Jørn Harald Hurum's daughter beneath an inflatable pliosaur. He had this created in full scale – 15 metres long – in 2008 by a US company which makes balloons for Thanksgiving and similar events. Costing NOK 130 000, it has been inflated on Karl Johan, Oslo's main street, in school gymnasiums, at oil exhibitions and at science shows.

Complete. The original of the Ida fossil (above) can be found in Oslo's Geological Museum. Visitors can also see how the creature probably looked in life (below).

Shooting for the Moon

Carbon dioxide (CO_2) must be captured and stored to keep the world from overheating. Work is now under way in western Norway to make this technology cheaper and more efficient..

| Astri Sivertsen and Marit Hommedal (photos)

Testing. Lab technician Vibeke Namstvedt analyses the amine solution from the plant.

> We test on behalf of society.
>
> *(TCM head Frank Ellingsen.)*

Halfway to the Moon. Mechanics inspect a column in the amine plant.

The "launch pad" for a programme which has been called Norway's own Moon landing project stands between the oil refinery and the combined heat and power (CHP) station at Mongstad north of Bergen.

"Catching our future" is painted in big, black letters on the administration block at the Technology Centre Mongstad (TCM), which currently embraces two different facilities.

One is based on a solution of amine and water, while the other uses refrigerated ammonia. Both capture carbon dioxide from flue gases released by the CHP station and the refinery cracker.

The ammonia plant was being converted during my visit, with only the amine facility operating. This was capturing 3.4 tonnes of carbon dioxide per hour from the CHP station, but has a top hourly capacity of 15 tonnes.

Both the facilities being tested can capture 80 000 tonnes per year, which means that the TCM currently ranks as the world's largest demonstration unit for carbon capture.

At the moment, it is concentrating on post-combustion or flue-gas treatment technology. And both capture methods being tested are based on liquid absorption.

But TCM head Frank Ellingsen emphasises that there is no reason why other methods could not be tried out, and says space is available on the site for new test facilities.

"Our strength is the availability of flue gases from two different sources," he says. "We're the front runner for testing and evaluating different technologies."

Aker Clean Carbon has designed and built the amine plant, while Alstom is responsible for the ammonia unit. These two companies also own the respective test results.

In other words, the TCM's role is not to develop technology, but to provide the opportunity for others to pursue such development.

"We conduct tests on behalf of society in cooperation with our owners," explains Ellingsen.

The TCM is owned 75 per cent by the Norwegian government through its Gassnova company, with Statoil, Shell and South Africa's Sasol chemical and energy group as partners.

They are not permitted to exploit test findings to develop their own technology, Ellingsen says. But they gain valuable experience by helping to build and run the capture facilities.

Discovery

Over the six months since it became operational, the TCM has already made an important discovery – amine concentrations released during the treatment process are so small that they have no negative consequences.

This finding has been documented in cooperation with several research institutions, and is useful because amine treatment is the most widespread method for carbon capture.

Fears that this chemical could damage health and the environment if released to the air have long been a "showstopper", according to Ellingsen.

Flue gases from the CHP station at Mongstad contain 3.5 per cent carbon dioxide, while those from the refinery hold 13 per cent – as much as a coal-fired power station.

So experience from the TCM will be transferrable to the most widespread source of electricity and pollution in the world.

Eight carbon capture and storage (CCS) facilities are currently in operation, including five in North America which all use the captured gas to improve oil field recovery.

Two of the remaining three are Norwegian and operated by Statoil, which has injected about a million tonnes of carbon dioxide below ground on Sleipner East

Smoky job. Lars Skov Olsen checks the refrigeration plant.

Writing on the wall. The global temperature cannot be kept down without CCS.

every year since 1996.

This follows separation from natural gas on the North Sea field. Statoil has also stripped carbon dioxide from Snøhvit gas in the Barents Sea for injection since 2008.

And the company is involved with BP and Algerian state oil company Sonatrach in carbon storage on the In Salah gas and condensate field in the Sahara.

Recovery

Using carbon dioxide to improve oil recovery has been considered on several occasions in Norway, including for Grane, Statfjord, Oseberg East and Gullfaks.

But all these plans have fallen through because of insufficient carbon supplies and/or because they have been considered too expensive.

Economic assessments are also the reason why no new CCS facilities have been built over the past five years, and a number of planned projects have been put on ice or dropped for good.

Carbon capture is not regarded as particularly difficult. Various industries have used parts of the commonest capture and treatment technologies for many years.

But high costs represent a deterrent to adopting these methods unless the investment can be made to pay off through such means as improved oil recovery.

A capture facility installed at a coal-fired power station accounts for 80 per cent of the price tag for a complete CCS installation.

The investment drops by almost 50 per cent for a gas-fired power station, according to Australia's Global CCS Institute in Canberra.

This organisation has also documented the obvious fact that power stations and industries with carbon emissions are cheaper without CCS than with – as long as emitting this greenhouse gas costs nothing.

The initial investment represents half the bill for a capture plant, with operation accounting for the rest, explains TCM technology head Olav Falk-Pedersen. So enhancing efficiency has much to offer.

He was involved a few years ago in investigating opportunities for introducing CCS at the Kårstø gas processing plant north of Stavanger.

The subsequent report from the Norwegian Water Resources and Energy Directorate (NVE) in 2006 illustrated the costs of adopting this technology.

"A modern gas-fired power station has an energy efficiency of about 59 per cent," says Falk-Pedersen. "Adding CCS cuts this to 50-51 cent, including transport and storage."

The TCM accordingly aims not only to identify the best solvents for absorbing carbon dioxide, but also to make the different capture facilities as efficient as possible.

If water and energy consumption could be reduced, power station efficiency would be increased to 52-53 per cent, says Falk-Pedersen.

"We're working to fine-tune and optimise the treatment facilities," he explains. "That's why there's so much metering equipment installed here at the TCM."

A hundred samples are taken manually at the centre every day, with 4 000 measurements carried out using the computers which monitor the capture facilities.

The TCM also benefits from its proximity to the refinery in the form of access to experienced operators used to running process systems and able to advise on doing things better.

"Uncertainties always exist when scaling up from a small test plant to a full-scale installation," observes Ellingsen. "We reduce that risk through the operational experience we acquire."

Impossible

According to the International Energy Agency (IEA), it will be impossible to reach the target of limiting global warming to 2°C without large-scale adoption of CCS.

Along with enhancing energy efficiency and renewable energy, this technology is intended to cut global carbon emissions by 20 per cent up to 2050.

That means some 100 CCS plants must be operational by 2020, and over 3 000 by 2050. Otherwise it could cost 70 per cent more to achieve the reduction targets, the IEA warns.

Chief IEA economist Fatih Birol has also said that CCS will not be adopted without financial incentives to invest in it, and that carbon emissions must carry a cost.

This has so far not been the case, and low prices for carbon emission allowances have meant that interest in building CCS facilities has been poor.

"Climate challenges rather than economics are the driving force for adopting CCS," observes Ellingsen.

Falling gas prices could mean that more power stations based on this fuel will be built. And the IEA's desire for carbon emissions to cost money could soon be a reality.

That means it could pay to be prepared for CCS, and to be ready with solutions which have proved to work in practice.

Model student

The first NPD employee with a PhD in carbon injection emphasises that her work only forms a small part of the bigger picture. Van Thi Hai Pham notes that the carbon challenge is a recent phenomenon and overcoming it has many different aspects.

Bjørn Rasen and Emile Ashley (photos)

Overview. Van Thi Hai Pham has contributed to two atlases which show possible carbon storage sites in the North and Norwegian Seas respectively. A third volume on the Barents Sea is under preparation.

Pham has a short answer when asked whether she regards the much-discussed greenhouse gas as a resource or a problem – it is both, she says.

"Excess carbon dioxide in the atmosphere is one cause of global warming, and scientists and politicians must work more closely together to reduce emissions," she points out.

"On the other hand, carbon injection could be a means of recovering more petroleum through enhanced oil recovery (EOR)."

But the big climate issues are not the focus of attention in her thesis on *Carbon storage – simulations for forecasting the effects and behaviour of injection in geological formations*.

This subject covers key issues which must be resolved when carbon dioxide is to be injected below ground for either storage or EOR.

Model

"I came up with a model for mineral trapping, which explains how large carbon volumes react with rock constituents to form stable carbonates," Pham explains.

She has been involved in the NPD's work on mapping possible sites for sub-surface carbon storage on the NCS, which has so far yielded two large atlases.

These cover the North and Norwegian Seas respectively, with a third volume, and the last planned so far, still in production for the Barents Sea.

"We're doing a thorough job to obtain an overview of relevant locations for carbon storage," she reports. "Advice on regulating how and where this might happen is also part of our mandate."

Like most other NPD employees, Pham belongs to several teams. One follows up the big Troll field in the North Sea to ensures that the licensees optimise recovery of its oil and gas.

Expertise

She also applies her expertise to reservoir modelling and simulation, and pursued her PhD work in addition to doing a full-time job.

The subject of carbon injection was chosen slightly at random, she admits. "I was motivated and like studying," she says. "The topic was suggested to me, and I latched onto it."

Her thesis comprises five scientific articles, of which four have been published and the last accepted for publication.

With the NPD since September 2011, Pham came to Norway from her native Vietnam eight years ago to study at the Norwegian University of Science and Technology (NTNU) in Trondheim.

After taking an MSc there and becoming a reservoir engineer, she went to the University of Oslo to start her PhD studies and defended her thesis in the geological faculty on 15 February.

Pham describes the transition to Norway as "a very big change. My initial impression was that the country is peaceful and a little cold. The first challenge was to decide what food to eat."

Even after eight years, she still has a lot to explore. Work on her thesis has demanded commitment every evening and a lot of weekends, "although I've had a little time off in between."

She confirms the many headlines in the press that not many Norwegians follow her example and go all the way to a PhD. "I had a lot of international fellow students, but few from Norway."

Her impression is that Norwegians have a social network and the prospect of well-paid jobs, even without a postgraduate degree.

"Most of them obviously choose that path. It's quite normal to think that way. Those of us who come from other countries are in a different position, and lack the same networks. That makes it natural to study more."

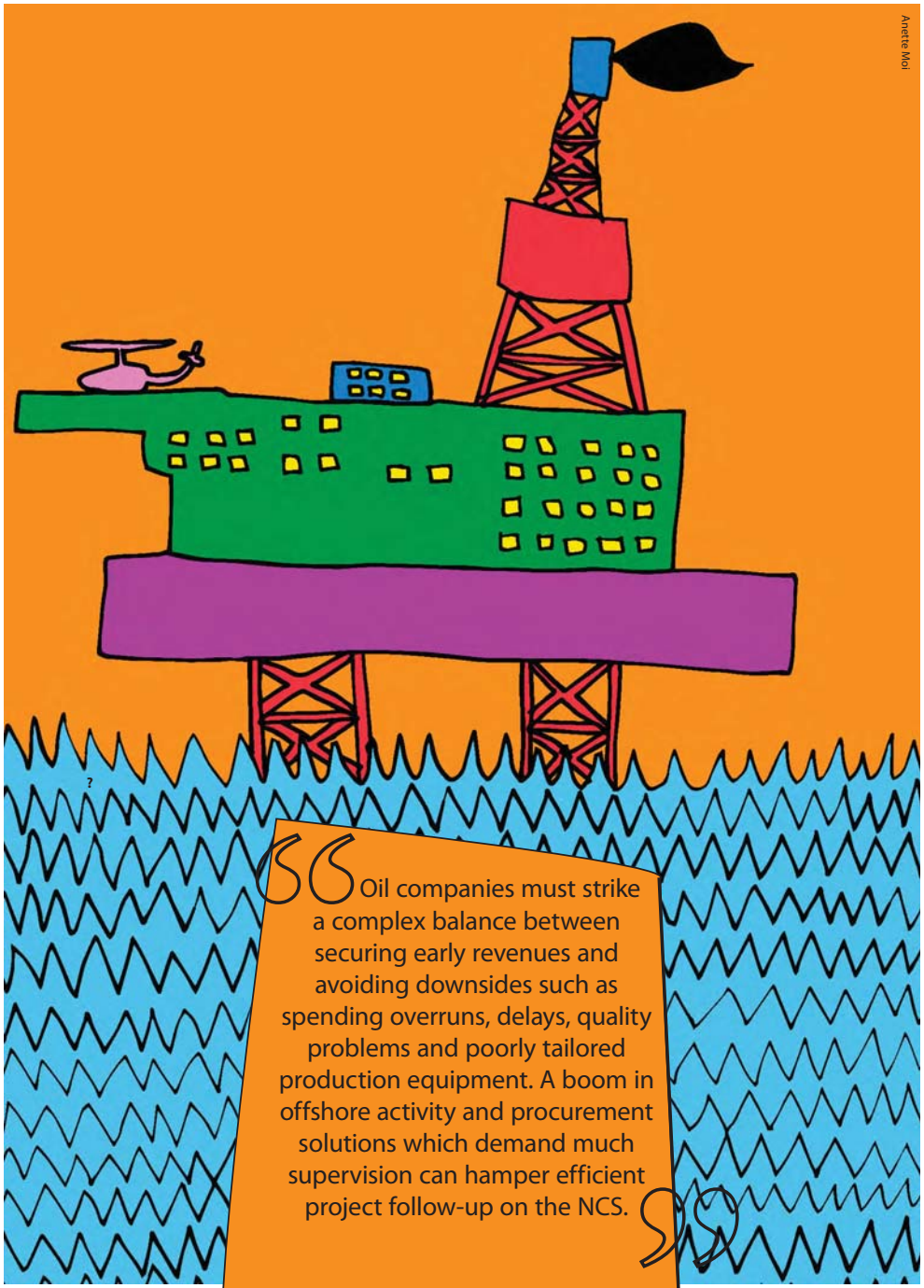
Pham is enjoying herself and has settled in well. She finds the Norwegian style "direct and honest, it's possible to say no. People respect that you want a private life."

Her advice to other foreign students is to take the initiative themselves if they want more contact, "because Norwegians are open and helpful if you only dare to ask."

She found the transition particularly hard as a woman, since the female role in her homeland is to be more passive than in Norway, "and adapting to that proved difficult."

This has not been a problem in her present job, however, and she likes the NPD model of working in different teams. "That allows me to test myself while also widening my perspective."

Respect. Van Thi Hai Pham feels Norwegians are direct and honest, a style she finds very engaging.



Haste has its price

Petter Osmundsen, professor of petroleum economics at the University of Stavanger, reviews experience with and sheds light on the economic consequences of over-hasty project execution.

Norwegian offshore investment goes up and down. At regular intervals, high oil prices cause activity to pile up and lead to associated cost-overruns and delays.

One of these boom periods is currently under way, and the negative effects are being felt even before spending has peaked. A look at past experience could therefore be instructive.

A plan for development and operation (PDO) of a Norwegian offshore field must be accompanied by socio-economic analyses when submitted to the government for approval.

These assessments include considerations related to the utilisation of existing infrastructure and coordination of fields as well as business aspects.

Oil company representatives have no problem personally admitting that everyone would benefit from a more stable pace of development.

That would secure good quality while avoiding sharp cost increases and delays. More sequential awarding of contracts would also ensure a higher Norwegian share of deliveries.

But everyone also insists that their own projects must be allowed to proceed, while those of the other companies are held back.

The market solution accordingly yields a pile-up of activity, with all the challenges that this represents. Since a planned approach creates at least equally substantial problems, it is usually not regarded as an alternative.

Are such great investment collisions inevitable? Are they rational? Questions can be raised about many economic aspects related to project pile-ups and hasty development.

Inadequate tailoring of production equipment, cost overruns, delays and quality challenges are highly relevant in economic terms.

A development with lots of parallel work can easily look good on the spreadsheet, since value will rise if revenues start to flow earlier.

In practice, however, these decisions are often taken on unstable foundations and lead on to both overruns and delays. Haste has its price.

Overruns

Spending estimates were exceeded in a number of NCS developments during the 1990s, with such overruns topping NOK 30 billion or 27 per cent in 13 projects analysed by an official investment inquiry (Norway's Official Reports 1999:11).

This study noted that the developments concerned were characterised by short implementation times both before and during project execution.

"[That] has meant a big overlap between the various phases [of] design, construction and commissioning," the report states. "This has led to a growing risk that an error/change in one phase will mean delays and increased costs in the next.

"It has also limited the opportunity to overcome unforeseen problems in one phase without knock-on effects for the next. Changes in project conditions have accordingly had big consequences for execution."

A key recommendation from the inquiry was *more quality at an early stage*. "A general feature of the projects studied in greater detail by the commission is that the decision base was weak when the development was launched and the PDO approved.

"The commission believes that a potential for substantial improvement exists here, and recommends measures ... to improve the decision base in future projects."

In its view, projects should be developed to such a stage that the cost of the various development components can be estimated with reasonable certainty before the PDO is approved.

This corresponds with international advice, which itself reflects the fact that 65 per cent of mega-projects around the world fail to meet their targets.

> A PDO for a Norwegian offshore field must be accompanied by socio-economic analyses when submitted to the government for approval. These assessments include considerations related to the utilisation of existing infrastructure and coordination of fields as well as business aspects.

Independent Project Analysis Inc (IPA) offers the following advice for project execution:

1. preparation is crucial (or you are working blind)
2. establish realistic budgets and timetables (optimism is not a project virtue)
3. make goals clear and consistent (avoid ambiguities)
4. seek continuity in staffing (particularly in key roles)
5. do not be afraid to slow down (the desire to advance too quickly, particularly in the planning phase, is one of the commonest reasons for a fiasco).

Recognition

The overruns of the 1990s led to broad industry recognition that more time should be spent maturing what was known about reservoir size and drainage strategy before choosing a development concept.

Technical concepts should also be sufficiently well developed before construction begins – again to secure a better basis for a high recovery factor. That also yields a better contractual basis and consequently a clearer division of responsibilities.

Haste generally puts the developer in a weak negotiating position. They must also pay to get further up the queue for certain critical deliveries.

A more mature concept means that the design can be frozen to a greater extent, and the developer avoids expenditure on re-engineering and refabrication.

Signs can be seen in the present NCS boom that some of these lessons have been forgotten, and it is unclear whether companies are taking the time to mature projects properly.

This is particularly worrying because many of the major contracts have been awarded to foreign yards which are not good – by the oil companies' own admission – at handling changes.

The operators have accordingly emphasised that freezing the design will be crucial. That makes it even more important to mature projects adequately.

If the companies are too busy at the start of a project, they often end up making changes along the way – and these lead in turn to delays and higher bills.

Tenders from yards which have no experience of Norwegian standards thereby become a bigger risk than ones submitted by fabricators who possess such knowledge.

Statements from various oil companies suggest that they price this consideration differently from each other during the bid evaluation process.

That could reflect differing assessments of the need for follow-up, or variations between the oil companies in expertise on and capacity for exercising such supervision.

Economic analysis is concerned with flexibility on the income side, which can be priced with the aid of options. As a project continues, the developer often acquires new reservoir data which could call for adjustments to ensure the best possible recovery.

A greater degree of flexibility in project execution, of the kind offered by Norwegian yards, accordingly has a value in the form of improved resource economics. The ability of these fabricators to handle special designs may also yield better resource utilisation.

The question is whether such income options are being taken into account in bid evaluations or whether the developer's primary interest lies on the cost side.

In this context, flexibility must be balanced against the anticipated extra price tag. The cost differential may be too large in many cases, and possible delays and overruns at Norwegian yards must be taken into account as well.

Management

Distinguishing between Norwegian and foreign bidders may also be a bit superficial, since "domestic" yards often include a large proportion of work abroad in their bids. An important distinction is who will be responsible for project management.

Preserving the kind of expertise on managing major developments possessed by Norwegian turnkey contractors today is important for Norway's petroleum cluster. That also applies to the oil companies which use their suppliers as a recruitment base.

Good plans are not enough. Launching a project without competent suppliers who have adequate capacity, and without sufficient in-house resources for supervision, may backfire.

Supervising developments requires the operator to have built up control systems. Competent individuals are not enough. Sufficient human resources to follow up projects represents a challenge for oil companies new and old, large and small.

An operator like Hydro – since absorbed by Statoil – was known for good project control but also suffered big cost overruns in the 1990s when the number of developments suddenly expanded.

One problem was that it lacked enough competent project personnel to follow up such a large portfolio. That evokes parallels with today's position on the NCS.

It is widely believed that a developer must exercise direct supervision of suppliers who are new to the NCS. But Statoil clearly disagrees with this view.

"We devote some seven to 10 per cent of costs to follow-up," Anders Opedal, senior vice president for projects at the state-dominated company, told a technical journal on 21 February.

"If we build at Stord [north of Stavanger], we must have people commuting there. The same applies for Korea. We do not envisage a larger team of engineers at the latter than at the former."

Such comments are not reassuring when the scope of additional work required on facilities delivered to the NCS from Asia and other regions is taken into account. Much depends on previous experience with Norwegian requirements.

Information on the proportion of spending devoted to supervision is interesting. Combined with applicable investment plans, this makes it possible to calculate the resources which will be applied to follow-up.

By making assumptions on pay, this can be converted into work-years. A rough estimate for the NCS as a whole suggests NOK 40 billion in investment for 2013 and annual per capita pay of NOK 1 million.

Assuming that seven per cent of the costs take the form of follow-up, this means that such activities alone represent 2 800 work-years.

Various assumptions can be made here, and pay undoubtedly represents only part of the bill for supervision. Nevertheless, this calculation illustrates a big need for follow-up.

The question is whether Norway really has so many experienced and competent people for this type of work. While the world has become global, that does not always apply to labour.

How many Norwegians with experience and expertise of technical supervision and project management want to commute to Asia, for example, over several years?

This simple calculation also indicates that developers will need even more people to follow up in the event of expenditure overruns.

Cycle

Once costs do increase, a vicious cycle becomes established. Experience shows that completing an out-of-control project demands a lot more resources and personnel than one still on target.

Delays or additional follow-up can also have a knock-on effect on other developments in the portfolio. Additional resources must be allocated to the overrunning project, squeezing capacity and attention which should have benefited new ventures.

It is important to remember in this context that supervising a sharply growing development portfolio on the NCS comes on top of a greatly increased need to follow up extensive and complex investment in producing fields.

Similar demands are made by the 15 additional rigs due to be delivered to these waters. Licensees are considering owning some of these directly, which will also boost supervisory needs.

Finally, the staffing calculation must take account of new players on the NCS who will be accepting responsibility for major developments. These must allocate a number of work-years to controlling activities in fields operated by partners.

The overall need for follow-up must be viewed in relation to capacity, but the challenge is that it takes many years to train people up for such jobs.

Expertise

Petroleum investment on the NCS is growing very sharply at present, and much faster than the ability of the companies to build expertise. Many trends are similar to those seen in the 1990s, which resulted in major cost overruns and delays.

In all probability, the oil companies would benefit from a lower level of activity to ensure that projects are adequately matured and that the necessary expertise is available.

Execution strategies should be shaped to ensure that the need for supervision is in line with the companies' capacity to provide it.

Since the drawbacks of overhasty project execution are well known to the industry, it is timely to ask whether its attention is focused now on production volume rather than value creation.

The idea must be that investors give strong weight to growth in their valuation models. But they cannot live by expansion alone, and oil companies could risk underestimating them here.

Investors see right through analysts' fancy performance figures. They understand that the oil industry is very long term and demands a balanced, far-sighted strategy to create value.

The problem with analyst figures is that they are incomplete and that they change in line with the fashion of the day.

To provide any guidance, performance figures must at least be ahead of the trends. Volume has been fashionable at a time of high oil prices, but the market is now worried about high capital exposure in oil companies as a result of overheating.

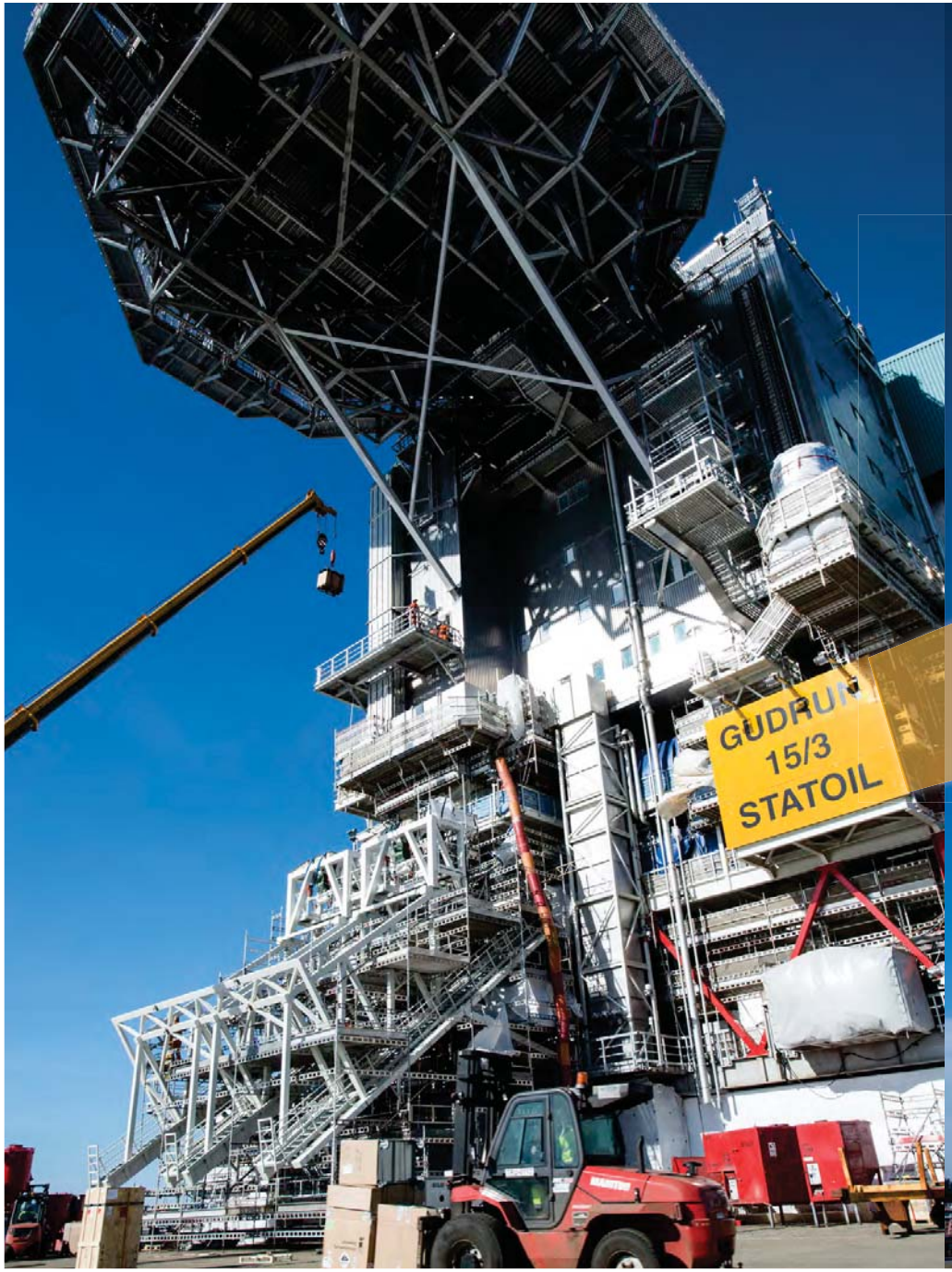
The performance figure attracting ever greater attention is "free cash flow". Many large and parallel developments do badly by this measure, with overruns and delays completely disastrous.

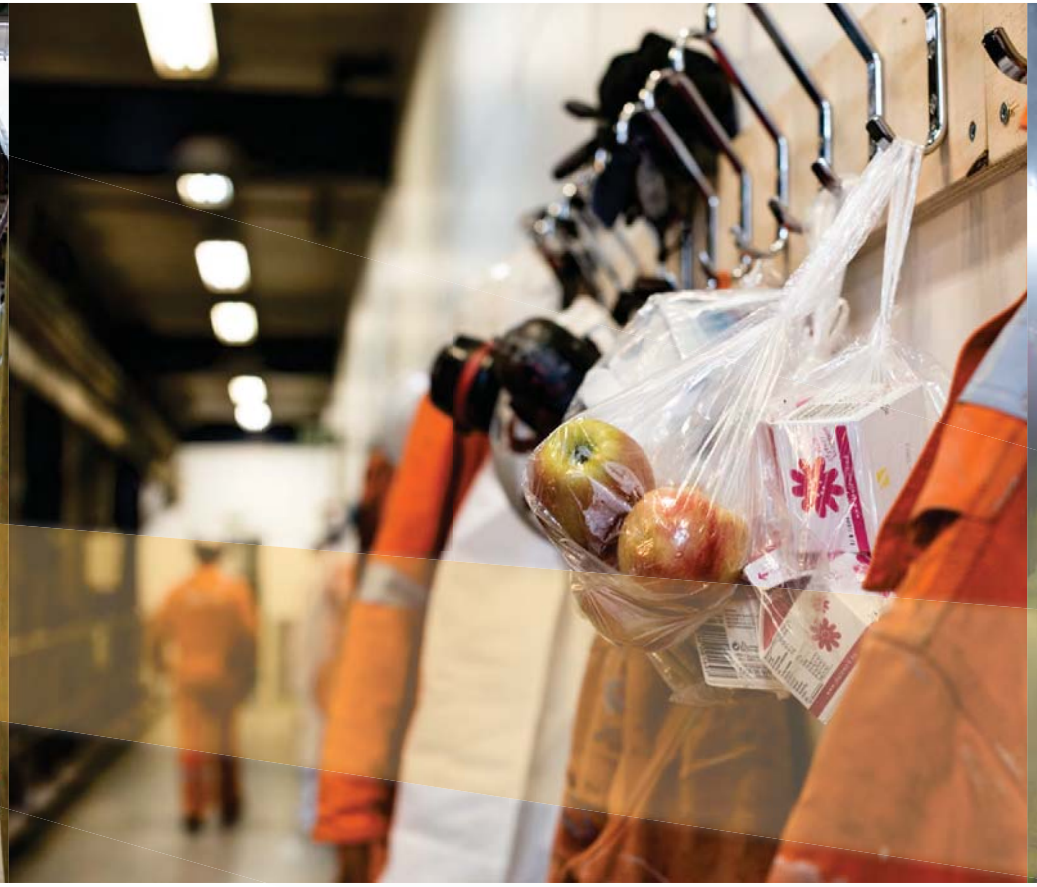
> A greater degree of flexibility in project execution, of the kind offered by Norwegian yards, accordingly has a value in the form of improved resource economics.

Well timed for cost cuts

The Gudrun development in the Norwegian North Sea is on schedule and set to end up NOK 2 billion below budget. Operator Statoil and main contractor Aibel explain why and how.

Astri Sivertsen and Monica Larsen (photos)





Monks have blessed the module built in Thailand before it left the country.

Willy Strømsvold tests the escape route in one of the modules.

A total of 1 100 people were working at Aibel's Haugesund fabrication facility in late March, with most of them seeking to complete the Gudrun platform topside on time.

"Sail away is four months off," explained construction manager Askild Mokleiv with reference to the structure extruding from the huge North Sea Shop at the Risøy yard.

The mechanical part of the job had been completed the week before, leaving only coating, insulation and testing of various instrumentation systems to be done.

After tow-out, the topside will be lifted onto the steel jacket installed on the seabed two years ago. Gudrun is due to come on stream in 2014, four decades since its discovery.

Seven years have passed since so many people were employed simultaneously at the Risøy facility, when former oil tanker *Odin* was converted to the Alvheim production ship.

"On a scale of one to 10, this project is a nine," Mokleiv said, pointing to the large number of people involved and all the supervision of various yards and subcontractors required.

Aibel has an engineering, procurement and construction (EPC) contract for the three modules which collectively make up the Gudrun topside.

Pursued in Oslo, Haugesund, Thailand and Singapore, the job has taken more than 3.5 million hours. Construction has accounted for almost two million of these.

The two modules for drilling and processing were built at the Aibel yard in Thailand before being shipped to Haugesund for welding to the utilities package fabricated in Norway.

Delivered "flat-packed" from China, the helideck provided a fantastic view when Aibel's integration manager, Willy Strømsvold, took me up to it.

A local supplier of helidecks was located only a couple of kilometres away, but the Chinese structure was cheaper and therefore preferred. Price is the deciding factor.

The Gudrun project was costed at NOK 20.3 billion in the plan for development and operation (PDO) presented in 2010, but is now expected to be NOK 2 billion cheaper.

According to Statoil, that departure from the normal rule of cost overruns on offshore schemes reflects fortunate timing. Contracts were not awarded until after the financial crisis.

This was the only project on offer in 2009, says Stig Jessen, Aibel's executive vice president for field development. "So competition was razor-sharp, and Statoil got very good prices."

Concept

The Gudrun structure is a cut-down version of earlier development concepts, and lacks a drilling derrick, for instance. Vertical columns on the jacket mean a rig can get right up to the platform and extend its derrick over the topside well slots.

"Dry wellheads are very important on a high pressure and temperature (HPHT) field like this," explains principal engineer Petter Gundersen at the NPD.

Gudrun could just as easily have been a subsea project, he notes, but the wellheads would then have been wet. Interventions and workovers would be more expensive and complex. Predrilling wells also permits production to start earlier.

Statoil has already employed similar solutions on Huldra and Sleipner B, eliminating drilling facilities and predrilling wells through the jacket before installing the topside.

The same approach will also be used on Gina Krog (previously Dagny). "It's a good solution for small projects and water depths of roughly 100 metres," says Jan Einar Malmin, Statoil's project manager for Gudrun.

He explains why it has taken 40 years to bring the field on stream. "First, the HPHT reservoir presented challenges. But we're better placed to tackle these now,

Four months until the Gudrun topside leaves the yard at Haugesund north of Stavanger.

not least because of lessons from Kvitebjørn. And a lot's happened with drilling technology.

"Progress has also been made in understanding the sub-surface. At the same time, oil companies undoubtedly opt for the easiest fields first and take the more difficult ones later."

The decision to develop Gudrun was taken when the NCS presented few other choices, Malmin adds. This was one of the small fields on the back burner, made commercial by technological advances.

In addition to fortunate timing, other factors contribute to reducing the total Gudrun bill. Malmin notes that the contractors for topside, jacket and pipelines have done "a fantastic job".

Aibel was involved in every phase of the topside job, he says. Having done the pre-engineering, it was familiar with all the requirements when work began on detail design and construction.

"We've implemented the project with a minimum of change orders. That's important for keeping costs down. But it also shows we've had contractors who can deliver what we order."

Wells

Seven production wells are planned on Gudrun, but the topside has slots for 16. This will make it possible to incorporate new discoveries in the future.

The original plans envisaged developing the neighbouring Sigrun discovery through a subsea template tied back to Gudrun, but this reservoir proved very fragmented and too expensive to produce.

But another nearby find, Gudrun East (formerly Brynhild), could be developed with a well from the main field. A decision on this is expected in 2013, reports Malmin.

Gudrun was originally expected to stay on stream until 2016, but its producing life has now been extended by four years – partly because of the decision to develop Gina Krog.

This means that operating costs can be spread more widely, providing a positive income flow for longer than if Gudrun had produced alone.

Flood

Conditions change quickly in the oil business. A flood of new large developments on the NCS has been put out to tender just two years after Gudrun was the only project on offer.

The market has completely reversed, observes Jessen. "Our margins are under a great deal of pressure."

Trends over the past three years and extra costs from the short timetable for the Gudrun topside have severely affected Aibel's profits. "We couldn't actually make money on this job," he says.

To compete with the big South Korean yards, much of the company's construction work has been moved to Thailand and the Haugesund facility does more assembly than fabrication today.

Jessen says that this trend is set to be reinforced in the future, with Norwegian yards specialising in assembling big topsides fabricated in low-cost countries.

But the bulk of the engineering work continues to be done in Norway, where knowledge of local Norsok standards and various company requirements has been built up over many years.

Moreover, Jessen says that Norwegian pay rates for engineers are still competitive internationally, and Aibel made a big commitment in the Gudrun design phase.

This meant that the construction job was done correctly from the start. Fabrication profits are often hit by the need to redo things, Jessen explains. With Norwegian engineering in place, it was also cheaper to build in Thailand.

Jan Garborg, Aibel's project director for Gudrun, says that the company's engineers in Singapore

have taken an introductory course to get a detailed view of Norwegian standards and requirements.

"That means we'll be able to do the work a little faster next time," he affirms.

Aibel's parallel to the fast-track approach adopted by Statoil for many field developments on the NCS is to break the work down into "modulettes".

The company completes each module – with painting, piping and cable tracks – while it is standing on the shop floor. This ensures easy access, and enhances safety and working conditions.

"We get things into position and box them up before they're lifted," Garborg explains. The method was first adopted on Kvitebjørn in 2003, and is used both in Haugesund and Thailand.

But it demands much planning and poses a number of procurement and fabrication challenges, Garborg says. "When it works, it is good for productivity. When it doesn't, we take a hit."

Worth waiting for

Gudrun lies in 110 metres of water in North Sea block 15/3, about 50 kilometres north of the Sleipner area, and was discovered in 1975.

A depth of 4 000-4 760 metres beneath the seabed means that its reservoirs have high pressures and temperatures. They contain 70 million barrels (11.2 million standard cubic metres) of oil, six billion scm of gas and 1.2 million tonnes of natural gas liquids (NGL).

The field is due to produce until 2030, with an estimated plateau production of six million scm of gas and 75 000 barrels of oil per day.

Operator Statoil has a 75 per cent interest, with GDF Suez holding the remaining 25 per cent.

Gudrun is being developed with a fixed production platform supported by a steel jacket and powered from Sleipner. Part-processed oil and gas will be transferred to Sleipner A for final processing and transport. The platform will be staffed.

Seadrill's *West Epsilon* rig is drilling production wells through the jacket, which was installed on the field in 2011. Once the topside is in place this summer, the same rig will complete the wells for production to start in the first quarter of 2014.

Weighing 7 000 tonnes, the jacket was built by Kværner Verdal north of Trondheim. Aibel has the EPC contract for the topside, which is due to be finished in Haugesund in the summer.

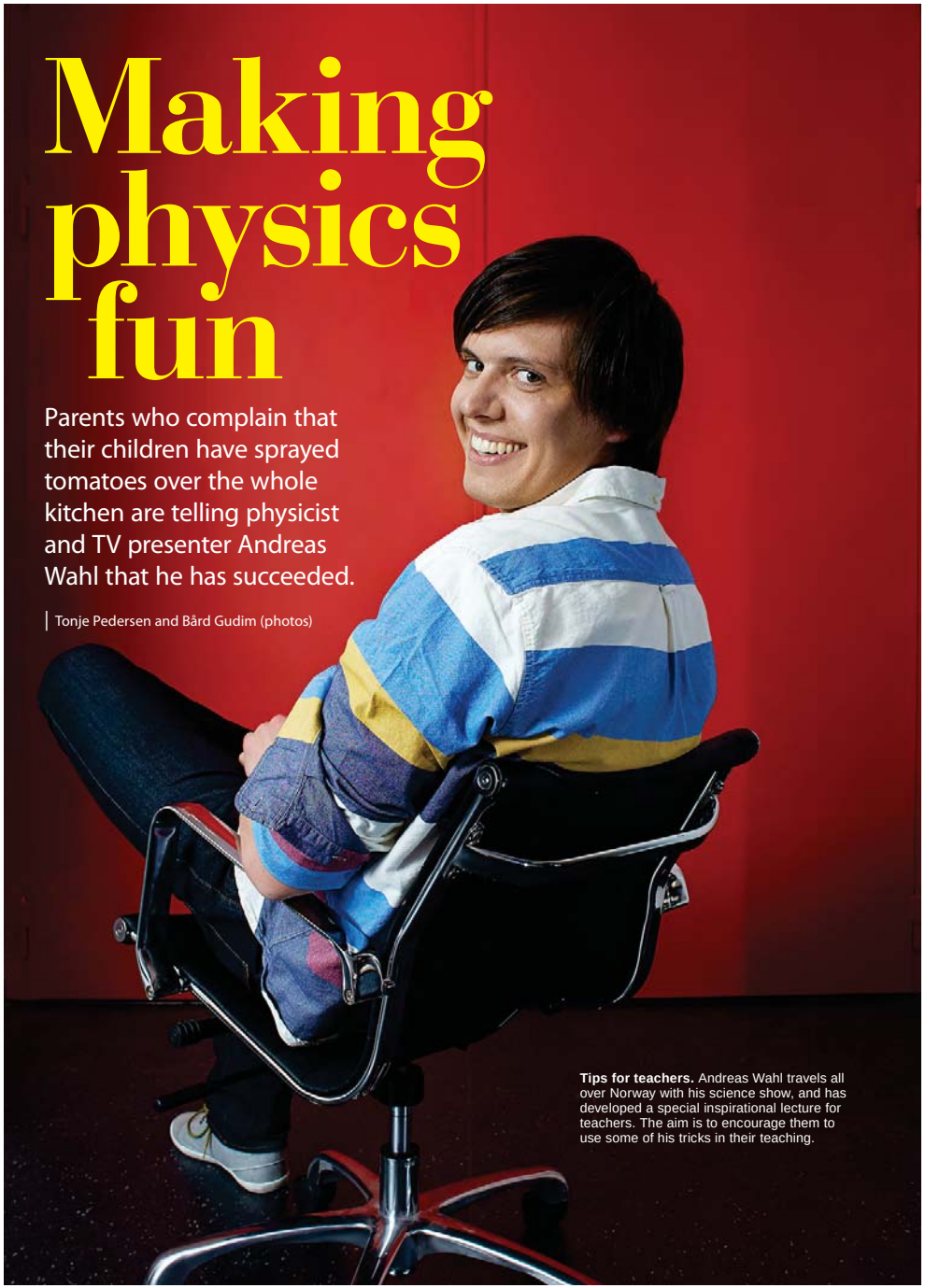
Two modules containing drilling and processing equipment were delivered from Aibel's yard at Laem Chabang in Thailand, with the third split between Haugesund and Poland's Morska yard.

The latter unit includes the living quarters built by Apply Leirvik at Stord north of Haugesund and various utilities. All three modules are being assembled in Haugesund.

Making physics fun

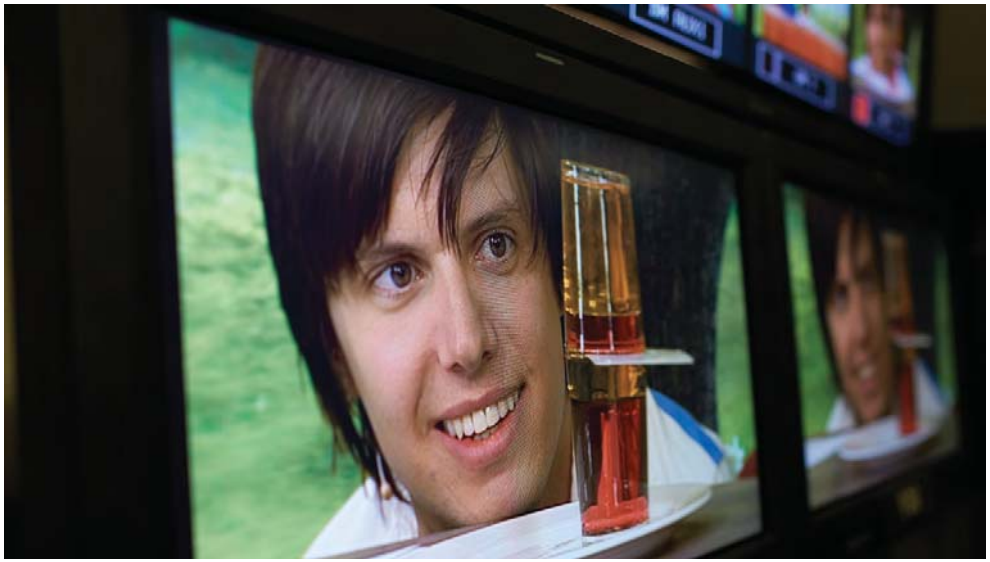
Parents who complain that their children have sprayed tomatoes over the whole kitchen are telling physicist and TV presenter Andreas Wahl that he has succeeded.

Tonje Pedersen and Bård Gudim (photos)



Tips for teachers. Andreas Wahl travels all over Norway with his science show, and has developed a special inspirational lecture for teachers. The aim is to encourage them to use some of his tricks in their teaching.

Everyday tricks. How can juice and oil be made to change places? Physicist Andreas Wahl has become well known in Norway for his entertaining science experiments. He is personally fascinated by everyday phenomena.



Sensitive seeds. Andreas Wahl hopes to inspire children and young people to continue exploring science subjects through his two TV shows.

Most people recall a special teacher – the one who did crazy things and always had a new trick up their sleeve. These are the ones who generate lasting interest in their subject, says Wahl.

The 29-year-old tries to convey the wonderful world of physics in the same way through popular lectures and his children's science shows on the Norwegian Broadcasting Corporation (NRK).

He has also written two books – *Fysikkmagi* (The Magic of Physics) and *Nært – sært – spektakulært* (Close, Special and Spectacular) – and developed an app for tricks in physics.

Boosting interest in science calls for both good teachers and entertainers, Wahl maintains.

"I have huge respect for the job teachers do, but they have to stick to learning targets and curricula. I can help to change attitudes, and believe we need both aspects."

Challenges

In his view, success in teaching physics faces several challenges. One is to get pupils to understand the kinds of careers physicists can pursue. These must be made clearer.

"Physics is not a vocational education. So children and young people find it difficult to see what they need this subject for. I want to help ensure that the next time they hear the word 'physics', they think 'Wow'."

He believes both schools and employers must get better at conveying the sheer breadth of the science. How can youngsters otherwise understand that it spans from laboratory to management, industry, programming and oil.

"We must meet physics with fresh eyes. Those who enjoy creativity choose other subjects because nobody has shown them how creative physics is, and that it's about finding answers which don't exist today."

Spin

"How can you find out whether an egg is boiled or raw?" is the sort of question Wahl likes to pose on his NRK science programme for children.

"You spin it on a table and stop it with a finger after a second or so. Halting at once means it's boiled and solid. If it keeps spinning, its contents are still raw."

This is precisely where recruitment to science studies begins, the presenter maintains during the recording of his show – at the level of children's TV.

"It's important to start as soon as possible," he emphasises. "By addressing the youngest kids, I'm hoping to sow the seeds of a future involvement."

Developing a basic interest in science is important if pupils are to continue such studies, Wahl believes. His own fascination derives from curiosity and a desire to understand the world.

His media career began in 2007 when giving a lecture. A journalist from Oslo tabloid *Dagbladet* was taken with the committed physicist, leading to a video series on science tricks.

His reputation was further enhanced through participation in several popular TV programmes, and his schedule has been tight-packed ever since.

Through his own company, Vitenwahl, he travels around Norway to deliver his two popular-science lectures *University in 42 minutes – a science show* and *We are all stardust*.

Teachers are a target audience, and he has produced a special inspirational lecture for them. His argument is that getting the message across becomes easier when physics is down-to-earth. When physics and entertainment meet, the result is magic.

Encounter

"Making physics entertaining means that the audience has a rather different encounter with the science," says Wahl. "I kill the myths that this is boring stuff.

"Today's scientists aren't dry and boring. They play in rock bands during the evening, for example, and do sport. With the aid of simple tools, we can get the subject to be exciting."

With a wood in the background, he emerges from the TV screen in his own youthful and engaging manner. This is not somebody with big glasses and bushy white hair – or who writes boring and incomprehensible formulae on the blackboard.

On the contrary, he is a charmer who comes across well on TV to do more than attact the girls. With expertise and the ability to communicate, he spices his shows with fun tricks from physics.

One example is the way he explains on-screen how to get a glass of orange juice to change places with a glass of oil.

"Bring the two glass together, separated by a piece of plastic," he says. "Make a small hole, and the oil will rise while the juice sinks. That's because one is denser than the other."

His producers feel he combines charm and knowledge with the ability to put himself at the audience's level, and Wahl acknowledges that meeting children is great fun.

"At the same time, it's a little dodgy because they obviously feel they know me very well. That makes it pretty demanding to fulfil their expectations of who I'm going to be."

Explanations

Baking powder, vinegar, juice, eggs and tomatoes – the tricks are the same, but their explanation varies with the audience Wahl is addressing.

Whether visiting a centre for the elderly, at a primary school or giving a lecture to companies, he uses the same methods. The laws of nature are just as interesting whoever is listening.

"Working with a live audience is very special," he says. "What happens between people gathered in a room can be magic. On stage, I'm hunting for such moments.

"You can quickly establish a dialogue with young people after showing them the tricks. It's fascinating to see when they grasp what you're saying, become enthusiastic and take part."

Wahl has an MSc in physics from the Norwegian University of Science and Technology (NTNU) and a one-year course in educational theory and practice.

He is fascinated by everyday phenomena such as why transparent water can become white when divided into small droplets, as in a cloud, or how clean water and soap combine to create white foam.

The examples he demonstrates are culled from the internet, books, former teachers or viewer suggestions. He adapts them and seeks to make them his own. "I steal from others, and hope they steal from me."

Future energy source?
Producing gas hydrates off Japan. Photo: Japan Oil, Gas and Metals National Corporation (Jogmec)

Icy interest hots up

The first planned output of gas hydrates has begun in energy-short Japan. This forms part of an urgent search for alternatives to nuclear power after the Fukushima reactor accident two years ago.

Astri Sivertsen

Deposits of gas hydrates – methane packed into a lattice of ice crystals – off the Japanese coast are probably sufficient to meet national energy needs for several hundred years.

So trial production by state-owned Japan Oil, Gas and Metals National Corporation (Jogmec) is also being closely followed internationally.

Looking like ice but catching fire when ignited, hydrates form under high pressure and low temperature. They are accordingly found in Arctic regions – including tundra – and deep water.

Half the output from Messojakha in Siberia, the world's biggest gas field, has been provided by the melting of this hydrocarbon ice since 1970.

But the hydrate deposit was not known when the discovery came on stream, so the pilot project off Japan can claim to be the world's first planned production.

Some researchers have estimated that gas hydrates could contain twice as much energy as all existing fossil fuel resources put together, including coal.

But the size of these deposits is uncertain, and they have to be very concentrated before extracting and utilising them becomes worthwhile.

Unstable

One disadvantage of hydrates is that they are chemically unstable, and methane is a greenhouse gas with about 25 times the warming effect of carbon dioxide if emitted to the air.

"These deposits are unique," explains Bjørn Kvamme, professor of petroleum and process technology in the department of physics at the University of Bergen. "Each is different from the rest."

Hydrates melt on contact with heat and minerals, he adds. Their properties depend on local groundwater flows. That makes the picture far more complex than for oil and gas reservoirs.

But Kvamme notes that producing them is much simpler than extracting shale gas, for instance, where the rocks have tiny pores and low permeability.

"The oil industry has been sceptical, and has regarded hydrates as rather mystical. But it's only a case of modifying technology already available."

Research on hydrate production has largely been pursued by geoscientists, Kvamme explains. But this work has been short of expertise on physics and flow dynamics.

Together with fellow professor Arne Graue, Kvamme has developed a technique to replace the methane molecules in hydrates with carbon dioxide through injection.

This makes the gas more stable and the methane easier to produce, while providing a carbon storage solution for this problematic greenhouse contributor.

Tested

The method has been tested in Alaska and Canada in cooperation with ConocoPhillips and Jogmec – and with good results. But interest fell once shale gas made the USA self-sufficient in gas.

However, Asia remains very keen. Kvamme and Graue do not know if the pilot production in Japan uses their technology. Big carbon deposits in this part of the world would make it natural, though.

Gas from the Sleipner area of the North Sea contains about 10 per cent carbon dioxide, and this high proportion represents a problem.

The greenhouse gas is accordingly stripped out and stored in an underground formation. By comparison, gas from the huge Natuna field off Indonesia is 70 per cent carbon dioxide.

Indeed, hydrocarbon reserves throughout south-east Asia contain extremely high carbon proportions. But the region lacks potential storage formations with good capacity and sealing properties.

"A market clearly exists for this technology in Asia, where some countries have few energy resources but a huge demand," observes Graue.

In addition to Japan, Malaysia, Indonesia, South Korea and India are making a heavy commitment to research into and pilot output of gas hydrates. If they succeed, much could be different.

Big reserves in far north

The Barents Sea probably contains big gas hydrate deposits. Discoveries indicate, for instance, that these are found in the topmost 600 metres of the sub-surface around Skrugard and Havis.

This information comes from professor Jürgen Mienert in the department of geology at the University of Tromsø, who heads the Centre for Arctic Gas Hydrate, Environment and Climate (Cage).

Named one of Norway's national centres of research excellence last November, Cage is working on methane hydrates as a potential energy source.

It also seeks to identify the role methane in offshore reservoirs and the seabed in Arctic regions might play with regard to tomorrow's oceanic environment and global climate.

According to Mienert, a rise in sea temperatures could cause large volumes of gaseous methane to be released to the atmosphere.

Cage plans to map possible gas hydrates in north-eastern Svalbard, close to the Norwegian-Russian boundary in the Barents Sea. Seismic surveys are to be shot there, probably next summer.

And Mienert believes that the continental shelf north-east of Greenland could also be interesting, but sea conditions in these waters make access difficult.

Landslide

A five-metre-high tsunami washed over the west Norwegian coast more than 8 000 years ago, unleashed by the massive Storegga submarine landslide on the NCS.

Scientists believe that gas hydrates which had become unstable as the seas grew warmer at the end of last Ice Age contributed to the vast extent of this event.

When the continental shelf began to give way, the areas containing such destabilised deposits were sucked into the landslide

Rock-solid resource

Studies. The core store and display room are much used by NTNU students, according to senior research Atle Mørk (left) at Sintef Petroleumsforskning and professor Mai Britt Mørk (right) at the department of geology and mineral resources engineering. Behind them are students (from left) Kristoffer Solvi, Ane Andrea Svinth, Turid Haugen, Even Nikolaisen and Gareth Lord.

A total of 6.6 kilometres of shallow stratigraphic cores from the NCS are stored behind walls more than three metres thick in a former submarine pen in Trondheim. The NPD took over this facility in February.

Bente Bergøy and Emile Ashley (photos)

Ownership of the store was acquired from the Sintef research foundation after it had been managed for many years by the museum at the Norwegian University of Science and Technology (NTNU).

"We have an overall responsibility for administering geological materials from the NCS," observes NPD director general Bente Nyland.

"We also make provision for scientists, students and oil companies to study these resources. So we're very pleased to have secured this collection."

The cores were obtained from shallow wells drilled in 1982-93 by the former Continental Shelf Institute (IKU) – now Sintef Petroleumsforskning AS.

During the period, one-three expeditions were staged annually with drill ships. Parts of the NCS were mapped using shallow high-resolution seismic surveys and stratigraphic drilling. Most of the wells were drilled in the Norwegian and Barents Seas.

The NPD's rock store in Stavanger contains cores and drill cuttings from virtually all the exploration and production wells drilled on the NCS.

But most of the cores hail from reservoir rocks. Geologists would prefer many metres of cores from a well rather than simply cuttings, but that would be too expensive. Each metre of core drilling can cost several hundred thousand kroner.

"We drilled full cores from the seabed through both source and reservoir rocks," explains senior researcher Atle Mørk at Sintef Petroleumsforskning. "So they provide useful information on the sub-surface."

This work was funded by a number of oil companies through various projects, and the collection comprises cores from more than 90 wells on the NCS.

The latter were drilled in waters depths of 100-1 500 metres, with the shallowest driven only a few metres into the seabed and the deepest going down to almost 600 metres.

While each expedition as such cost roughly NOK 20 million, the total bill – including processing – came to almost NOK 500 million.

Drilling locations were determined on the basis of detailed seismic surveying, and analysing the samples yielded very useful information.

"We chose sites where interesting strata were not far beneath the seabed, and where they could be followed down to deeper structures of interest for oil exploration," explains Mørk.

In the modern display room at the Trondheim facility, core sections cast in epoxy are presented from virtually all the stratigraphic cores collected.

The remainder of the cores from each well are held in the storage area, neatly organised in boxes.

"We began with ordinary bits until we reached the bedrock, and then continued with diamond bits," says Mørk. "We brought up three metres of core each time we retrieved the bit to the drill floor."

He knows more than most about the cores in the IKU collection. Not only was he involved in the bulk of the drilling expeditions, but also analysed the samples afterwards.

Results from this drilling and the subsequent work have been documented in a number of reports and publications. And the material remains relevant.

The geological samples from the shallow wells are used in research and teaching – primarily in connection with courses, projects and MSc theses at the NTNU.

Measuring five-seven centimetres in diameter, the cores have been split vertically and provide a quick overview of rock types and sedimentary structures.

They can be used for research in a number of areas, such as sediment types, stratigraphy, deposition environments and climate variations.

The age of the samples ranges from the Ordovician period about 450 million years ago to the late Cenozoic era as recently as 2.5 million years ago.

"We make much use of the core store and the display room," reports professor Mai Britt Mørk at the NTNU's department for geology and mineral resources engineering.

"We've run a series of courses in sedimentology for geology students, for example, and a number of students have drawn on the cores in their MSc theses."

Oil companies also study the material in connection with exploring the NCS and hunting for petroleum. It was extensively used, for instance, by companies preparing applications in the latest 22nd licensing round on the NCS.

Plans call for the cores to remain at the Trondheim store, and an agreement has been reached between the NPD and Sintef Petroleumsforskning on sharing lease costs for a decade with options for extensions.

As the main user for courses and student work, the NTNU will be responsible for practical operation of the store.

Squid. Limestone containing many mussel fragments and the cross-section of a belemnite, a fossil squid.

Sections. Even Nikolaisen and Turid Haugen study display sections.

Cores. Sections cast in epoxy from virtually all the stratigraphic cores collected are presented in the display room.

New opportunities, old challenges

Becoming chief executive of Petoro makes Grethe K Moen responsible for a third of Norway's oil and gas reserves as manager of the state's direct financial interest (SDFI) on the NCS.

Bjørn Rasen and Per Lars Tonstad. Photo: Emile Ashley

> We can't achieve anything without decisions in the licences, and must convince our oil company partners that this is sensible to do. And what's profitable? Those who're going to make the investment determine that.

Moen has previously been Petoro's vice president for mature areas, and still sees this as a priority area. She will also be giving full attention to the development of new discoveries and opportunities along the gas value chain.

But she is not willing to make any programme declarations just a few days after taking over as president and CEO from Kjell Pedersen, who had run Petoro since it was founded in 2001.

Asked what she regards as the major challenges on the NCS and which opportunities look attractive, however, she starts with her former area of responsibility.

"I still regard improved recovery from the mature fields as a priority job. And we must take decisions on measures now, or huge assets will be left behind on the NCS."

Moen also sees the great opportunities offered in other parts of the business.

"We're now getting new major developments, such as Johan Sverdrup in the North Sea, several years after we thought it was all over for 'elephant' discoveries.

"It was almost more than we had dared to hope for. And the Johan Castberg field has confirmed the Barents Sea as a new oil province. The far north is highly interesting."

She emphasises at the same time that "we're taking with us our best expertise and our best practice in the area of health, safety and the environment."

Moen has earlier headed HSE work in Shell's European upstream business – while simultaneously leading the Anglo-Dutch oil company's exploration and production activities on the NCS.

She is also looking forward to working on the gas value chain – another area where she has previous experience. As a new recruit to Statoil, she worked in the mid-1980s on the big Troll sales agreements which truly launched Norway as a gas nation.

Major changes currently under way in the gas market bring with them considerable uncertainty. Moen sees the challenges, but would prefer to concentrate on the opportunities facing Norwegian gas.

A pertinent question is whether she is satisfied with the commitment of the companies to squeezing more out of their mature oil fields – and whether she feels that the regulator and the state-owned company must find new ways to cooperate in securing the recovery of these huge assets.

"That's a very interesting idea," she acknowledges. "But we have different roles – the NPD as a driving force and regulator, and we as the commercial prime mover.

"We can't achieve anything without decisions in the licences, and must convince our oil company partners that this is sensible to do. And what's profitable? Those who're going to make the investment determine that."

Deeds

Moen amplified her view that deeds must follow words on mature fields in an interview for the *Petoro Perspective* magazine published by the company last autumn.

The main features of this interview are reproduced here, with the first question put to her being whether oil companies will prioritise mature fields when new projects entice.

"We don't see the same commitment to mature fields as with the big new finds," Moen admits. "Everyone says they want to maximise oil recovery, but hang back when it comes to decisions and deeds."

Petoro's 10 largest fields on the NCS currently account for about 80 per cent of its output and will continue to do so in 2025, she adds.

As a driving force for maximising the value of Norway's mature fields, the company wants the pace of production drilling stepped up and profitable producing life made more robust.

"Necessary action must be taken now", says Moen, who fears that long-term and capital-intensive measures are being given a lower priority and that the moment has already passed for some mature fields.

"If we wait longer, it could be too late for a number of them. That could cost society very dear," she declares. Nor is anyone likely to be held to account for failing to take decisions soon enough. "The wasted opportunities to make giant revenues will be forgotten unless we continue to focus attention on these fields."

Commitment

Moen emphasises that improved recovery from mature fields can be achieved by a conscious commitment and prioritisation.

"The companies need their best brains here, people with experience and insight. This is complex and demanding, and management must take the lead in showing that it has a responsibility to recover more from the mature fields."

Production from a number of fields is reaching a critical point. Installations are aging and drilling rates declining drastically because rigs are deployed for other jobs.

More maintenance and updating – or redesign – are needed to ensure that reserves can be recovered within the producing lifespan of installations.

Investment required to achieve this must be made while remaining reserves are large enough to ensure solid overall profitability.

"Costs will be high," Moen says. "As reserves decline, the water cut steadily rises and more gas must be injected to maintain pressure and production.

"Water-treatment capacity needs expanding, which demands conversion work on installations. More chemicals must eventually be added to boost recovery.

"This all has to be paid for, and production must yield enough cash flow to make such spending acceptable. If the commitment to mature fields is postponed, investment risk could become too high because profitability is marginal."

Positive

Moen emphasises that the wil-

lingness to make a continued commitment to mature fields definitely exists. "And much that's positive has happened.

"A lot of good work has been done to tie satellites back to existing fields. Standardisation provides a sound basis for extending production.

"Reservoir understanding is better than ever, too. New technologies like four-dimensional modelling and permanent seismic arrays on the seabed can tell us much more about the way fields develop over time. That improves the basis for investment decisions."

A commitment to mature fields calls for agreement between operator and partners. Moen says that Petoro will carry out detailed work to document technology and systems which can improve recovery from such fields.

Experience from the UK continental shelf, which is a decade ahead of the NCS in this area, will be utilised.

Moen draws a parallel with marriage: "New love offers intoxication and adventure, enthusiasm and drive. When you've lived together for 20-30 years, life is mostly dull by comparison.

"Partners must struggle more to retain the spark. Mature fields need the same 'guts' as new lovers. Johan Sverdrup will be developed regardless."

Drilling

The pace of drilling on the NCS has declined dramatically, with the number of producers drilled from fixed platforms probably halved over the past five years.

At the same time, drilling costs have exploded. Production wells drilled today are more complex and time-consuming than before.

"Rigs are also used for a lot of purposes other than drilling," Moen points out. "That includes well workovers, improvements and maintenance, shutting down and plugging old wells, and measures to boost short-term production.

"These jobs must be done, but don't provide access to new parts of a reservoir. It may be possible to do them in different ways and with equipment other than rigs.

"Getting the drilling rate back up again is very important, and we're taking steps to secure our own units and simpler rigs. Wellhead platforms should also be considered more often as a means of radically increasing the number of production wells."

A positive feature in her view is that the industry has identified a number of possible future wells on mature fields over the past year.

"But I'm not sure we'll manage to drill them all before the fields shut down. Estimates for both drilling pace and producing life could be too optimistic. This must be clarified before we choose measures."

Moen fears there is a great risk that cost and price trends make it unprofitable to commit to a lot of wells in a field's late life.

In her view, the companies may have to drill more at an earlier stage to get the number of boreholes needed to recover the available oil.

"We can secure a large part of its value for future generations by acting now," she concludes.

More confident outlook

The biggest change in the Norwegian petroleum industry since 2011 is a higher level of optimism than has been evident on the NCS for a long time, according to the NPD's latest resource report.

This overview of petroleum resources on the NCS is published by the directorate every other year.

"After the government adjusted its exploration policy about 10 years ago, which included opening up for new companies on the NCS, the number of participants has almost doubled," says Sissel Eriksen, the NPD's exploration director.

"This has contributed to a high and stable level of exploration activity, and many new discoveries have been made."

The report presents analyses which show that medium-sized companies are strengthening their position on the NCS. They appear to be taking over the place held by the international integrated oil companies on the NCS since activities began there almost 50 years ago.

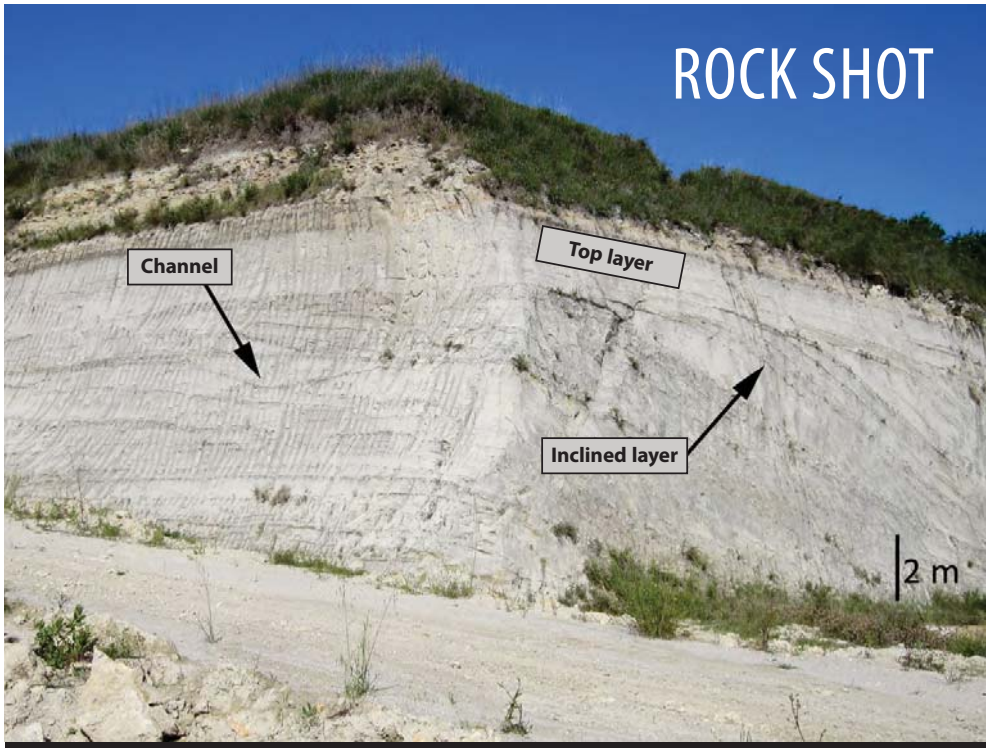
The big recent discoveries have not reduced estimates for undiscovered resources – quite the contrary, according to Eriksen.

"This is primarily because new knowledge encourages greater confidence in opportunities for further discoveries. A lot of oil and gas remains to be found in all three parts of the NCS – the North, Norwegian and Barents Seas."

An expansion occurred to the NCS two years ago, when Norway and Russia signed the final treaty on maritime delimitation in the Barents Sea. The NPD has recently mapped the Barents Sea South-East area, which could be opened to the industry as early as 2013 if the Storting (parliament) gives its consent.

In addition, the NPD is mapping Norway's continental shelf around Jan Mayen, with the work due to be completed in 2014. In addition to providing knowledge of potential petroleum resources, this mapping could contribute to increased knowledge of the geology in the deepwater areas west of the Norwegian Sea.

The resource report can be found at *www.npd.no*.



Delta details

Rivers carry huge volumes of sediment, but the amount of gravel, sand, silt and clay they can hold in suspension declines once they meet non-flowing water. These materials are accordingly deposited – but not all in the same place.

As a river flows into the sea, its energy steadily falls and its sedimentary load gets deposited. The smallest particles separate out when the water finally comes to a standstill.

River-dominated deltas containing coarse deposits such as sand or gravel are known as Gilbert deltas, and are constructed with clearly defined top, inclined and bottom layers.

Taken in Sardinia, the photograph shows the top layers which defined the water surface during deposition. Inclined layers can be seen, which were deposited in front of the delta and point in the direction of flow. Their grains are rather smaller than in the top layer.

The finest sediments were deposited as bottom layers, further out in deeper water and not visible in the picture. The small crescent-shaped structures on the left are former river channels on the delta plain.

Knowing how sediments sift out is interesting because sand and gravel provide permeable deposits where oil and gas can migrate or accumulate. Finer silt and clay are virtually impermeable, and can prevent hydrocarbon flow.

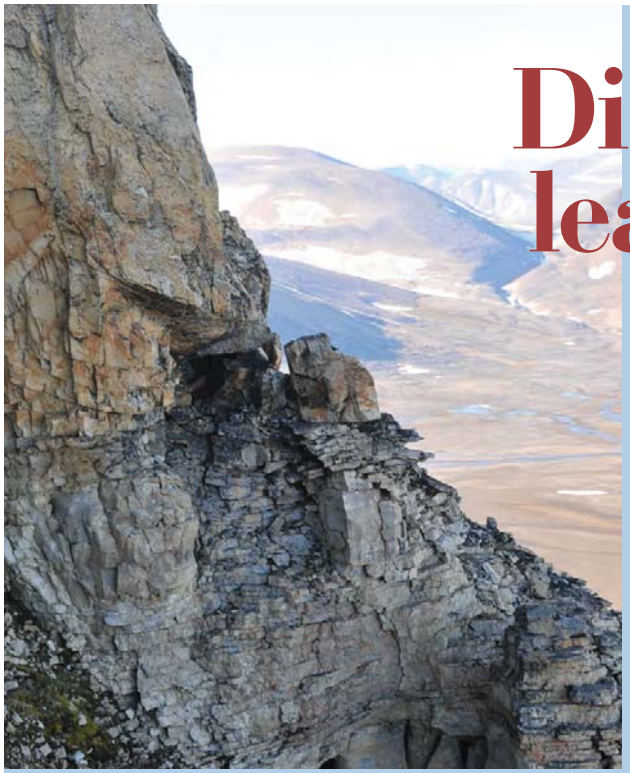
The river which deposited the delta on Sardinia in the Miocene epoch has long since vanished. This Mediterranean island has subsequently been uplifted several hundred metres, and the former delta now provides local building materials.

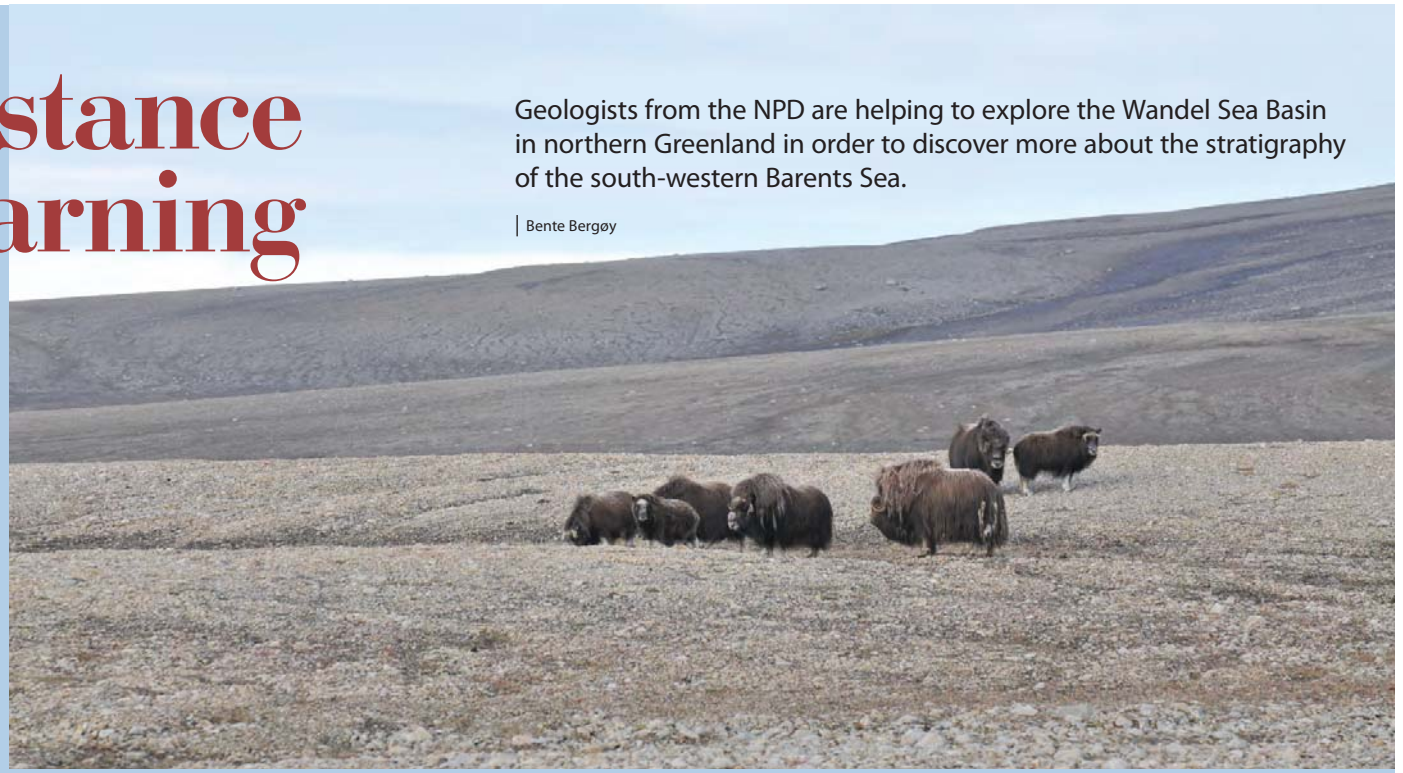
Terje Solbakk (text) and Espen Simonstad (text and photo)

Distance learning

Geologists from the NPD are helping to explore the Wandel Sea Basin in northern Greenland in order to discover more about the stratigraphy of the south-western Barents Sea.

Bente Bergøy





Wild and beautiful. The geology of the Arctic desert in northern Greenland has features in common with the south-western margin of the Barents Sea.

Fauna. Musk oxen can be found in northern Greenland. (Photos: Hans-Ivar Sjulstad)

The logic behind this work is that these two regions were geographically close to each other before seabed spreading in the North Atlantic accelerated 65 million years ago.

"As the northernmost sedimentary basin exposed on land, the Wandel Sea Basin is off the beaten track – to put it mildly – and little studied," says NPD project manager Hans-Ivar Sjulstad.

"We're due to study stratigraphy and structures at a number of locations in this area over three summers."

Field work began last year, and is due to finish next summer. Sjulstad and his colleagues will then compile palaeogeographic charts for several geological periods. These will focus in detail on the south-western margin of the Barents Sea.

Palaeogeography is the science of geographical conditions in earlier geological periods, and applies mainly to the study of former landforms.

Sjulstad explains that the previous field campaign in the Wandel Sea Basin was more then 30 years ago, but that the National Geological Survey for Denmark and Greenland (GUES) is now at work in this inaccessible area.

"So we took the opportunity to join forces. We're working independently as a separate team, but collaborate in such areas as using transport planes and helicopters. We also lease camp and depot equipment from GUES."

Plans call for him and fellow NPD geologist Hilde Krogh to be in northern Greenland from 10 July to 9 August before spending a few days at Longyearbyen in Svalbard.

They will then head for the South Cape/Horn Sound area in the Arctic archipelago to continue geological field work for another two weeks until returning home on 28 August.

A local Danish military facility serves as the base camp for northern Greenland. The two are due to investigate a number of sites from three camps, all about a hour by helicopter from base.

That means living in tents between 81-83°N, among musk oxen and Arctic foxes. But Sjulstad says they are well prepared, with safety and first-aid courses and thorough weapons training.

"This part of Greenland is virtually an Arctic desert, where a tough landscape features much ice-shattered rock as well as unconsolidated sediments deposited by meltwater and glaciers," he explains.

"There's also a good deal of snow and ice. During the summer, the temperature usually fluctuates between -2°C and 6°C."

He and another NPD geologist, Harald Brekke, spent two and a half weeks in the area last year,

Basic. Two sleeping tents and one for cooking in the NPD's summer camp at Owlet Valley during 2012. Geologists Hans-Ivar Sjulstad and Hilde Krogh will be leading the same simple life this summer.

when they scaled three mountainsides which form the main features around Owlet Valley.

In addition to producing detailed sedimentological field logs, the pair worked on large-scale structural geology and took samples.

The expedition provided much new knowledge, with all the geological formations studied proving to have different deposition environments than had been assumed in earlier literature.

That represented essential new information for the palaeogeographic maps which are to be produced, Sjulstad explains.

"Exposure there is fairly good. The deposits form big sandstone formations which represent potential reservoirs for oil and gas.

"These structures could extend into the south-western Barents Sea, which increases the probability of discovering good reservoirs there."

He and Brekke explored the Mesozoic era (250-65 million years ago) in western Greenland, while this summer's expedition will primarily look at the second half of the Palaeozoic (360-250 million years back).

The 2014 expedition will be heading for Bear Island midway between Svalbard and the Norwegian mainland, where both Palaeozoic and Mesozoic formations will be studied.

Most of the oil found in the Barents Sea lies in rocks 245-160 million years old – in other words, from the first half of the Mesozoic. But a number of relevant Palaeozoic plays also exist.