

PETROMAKS – Petroleum research in Norway

Large-scale Programme
Optimal management of petroleum resources – PETROMAKS

Large-scale Programmes

The RCN initiative
to meet national
research priorities

About the Programme

Optimal Management of petroleum resources – PETROMAKS

PETROMAKS is the umbrella for most of the petroleum-oriented research supported by the Research Council of Norway. The programme covers both long-term basic research and applied research, resulting in the development of new competence as well as innovation. This is the largest single programme run by the RCN. Insofar as possible, the programme will implement the strategy drawn up by the Norwegian petroleum industry's strategic body OG21 (Oil and Gas in the 21st Century).

Large-scale programmes are an important tool at the Research Council towards realisation of prioritised central research policy. They shall provide enhanced knowledge in the long-term national sense, with an eye towards stimulated innovation and increased added-value or generate knowledge that contribute to solving prioritised social challenges.

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PETROMAKS – A Large-scale Programme for optimal management of petroleum resources

The Research Council of Norway (RCN) has an annual budget of more than NOK 5 billion and plays a central role in Norwegian research. The mandate of the Council is to promote and support basic and applied research in all areas of science, technology, medicine and the humanities. Important goals include raising the general level of the understanding of research in society as a whole and supporting innovation in all sectors and branches of industry.

With the introduction of PETROMAKS in 2004, the Norwegian government gave a signal that strong public support of petroleum R&D was necessary. With this backing, the Research Council of Norway has an annual budget in 2007 of NOK 350 mill. for the petroleum R&D.

PETROMAKS will assist in implementation of the strategies and plans laid down by the government strategy initiative OG21 (Oil and Gas in the 21st century).

Thematic areas for research and innovation in PETROMAKS are in harmony with the OG21's targeted thematic technology areas:

- Environmental technology for the future
- Exploration technology and reservoir characterisation
- Enhanced recovery
- Cost effective drilling and intervention
- Integrated operations and real time reservoir management
- Subsea processing and transportation
- Deep water and subsea production technology
- Gas technologies
- Health, Safety and Environment (HSE)

PETROMAKS focuses on basic and applied research and technological development.



An active, growing industrial cluster is needed to maintain the petroleum sector at a sustainable level. The supply and service industry are given special attention since globalization and worldwide participation are vital to maintaining Norway's leading position. Support from the PETROMAKS programme therefore involves forging alliances, creating networks, and facilitating different types of cooperation with the world's foremost science and technology institutions.

The Norwegian Continental Shelf is characterized as a mature oil province, although the northern part remains largely immature in terms of exploration and development. A substantial amount of the world's undiscovered petroleum resources are expected to be found in this area. The Barents sea is an area of great potential, current develop-

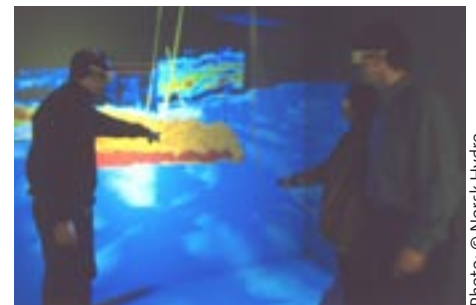


Photo: © Norsk Hydro

ments there include Norway's Snøhvit field, and the planned Russian development of the Shtokman field. Therefore PETROMAKS seeks to address R&D challenges of operations in such demanding and environmentally sensitive areas.

www.PETROMAKS.no
www.forskningsradet.no/petromaks

The ice that burns

It may be the answer to the future global energy crisis. Now, Norwegian researchers are going in search of combustible ice in the depths of the Norwegian continental shelf.

On a November's day in 2000, fishermen off the coast of British Columbia pull their seine up from a depth of 800 meters. The catch of the day is highly unusual. The sea, as the fishermen describe it, boils "like a sea of selzer".

But what have they caught? The depths of the ocean still conceal great secrets. As it happens, a fisheries observer was onboard, who had seen a National Geographic documentary about a little known natural phenomenon. He thinks out loud: "These are gas hydrates". And, as he suspects: in the seine there is no less than 1000 kg of gas hydrates.

Vast quantities of energy

Gas hydrates sound mysterious but are far more common than we think. Researchers have estimated that the energy stored in gas hydrates is twice that of other fossil energy reserves in the world – including coal.

Gas hydrates comprise methane gases trapped in a lattice of ice. It looks like ice but catches fire when ignited. The hydrates form at high pressures and low temperatures, and thus they form in Arctic area and at great depths. Consequently, conditions on the Norwegian continental shelf are perfect for the formation of gas hydrates

Norwegian researchers have recently been on an oceanographic cruise of the Norwegian Sea to start mapping out the deposits of gas hydrates on the Norwegian continental shelf. This is the starting signal for a significant investment in such surveying, and the project involves the PETROMAKS programme of the Research Council of Norway and a number of oil companies.

– But do the researchers really have any idea of what quantities of gas hydrates may be found in the deep sea on the Norwegian continental shelf?

– We have no idea. The purpose of this project is to get a general idea of the total amount of gas hydrates on the Norwegian continental shelf. We also want to gain an understanding of how the gas hydrates may be extracted, says Hafliði Hafliðason, project manager and professor at the Department of Earth Sciences, the University of Bergen.

Gas hydrates discovered on the Norwegian continental shelf

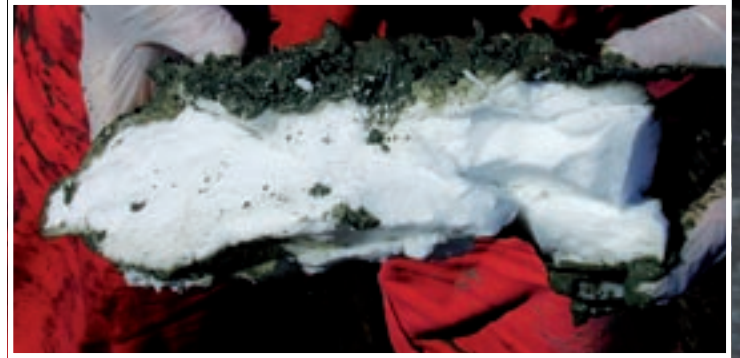
The first gas hydrate samples ever to be discovered on the Norwegian continental shelf were found ten years ago, at the Håkon Mosby volcano. This volcano spews out not lava, but clay. Last summer gas hydrates were also recovered from the deep, from the Nyegga in the Norwegian Sea.

Alberto Mancini, researcher at the University of Oslo, brought the samples of methane ice up from the seabed. He lit them, and the ice caught fire. Sporadic discoveries have since been made, but the big picture is missing.

– But how can the gas hydrates be mapped?

– The gas hydrates are mainly mapped out by use of seismology or so-called BSR (Bottom Simulating Reflector). When the sound waves strike the gas hydrates, a deviation is registered, which the operator can interpret. We'll also make use of remotely operated under-water vehicles (ROVs) and retrieve samples from the seabed, says Hafliðason.

Periods of global warming in the Earth's past have been blamed on gas hydrates.



Attempts at gas hydrate production – Arctic Canada. Photo: IFM-GEOMAR



Project manager Hafliði Hafliðason

An increase in temperature may result in vast quantities of this ice melting, releasing methane gas to the atmosphere.

As methane gas has a greenhouse effect more than 20 times greater than that of CO₂, this would quickly lead to global warming. Many people also fear that gas hydrates stored in the permafrost, e.g. in Siberia, will ignite. Others speculate on whether large releases of gas hydrates may have sunk ships in the Bermuda triangle.

Is it really possible?

The experts dispute the future importance of gas hydrates. However, with the high price of oil, the oil companies are looking for new sources of energy. The question is whether there are enough gas hydrates concentrated in one location to make production profitable.

The first attempts at producing gas from the hydrates have already been made in the McKenzie Delta in Canada, which holds vast deposits. Production was maintained for two days, and then



Do not try this at home. German researchers set fire to gas hydrates. Photo: IFM-GEOMAR.

Facts about gas hydrates

- Form at high pressures and low temperatures. Can be found in Arctic areas and at great depths in the ocean (300-500 metres).
- An essential ingredient in the formation of gas hydrates is that both gas (methane) and water must seep up through the sediments. Water molecules form the lattice in which the methane is trapped.
- Estimated global resources: 1 000 trillion to 10 000 000 trillion cubic metres of gas, or 1 000 000 to 10 000 000 000 billion cubic metres of gas. By way of comparison: The Troll field contains 1324 billion cubic metres of gas.
- The ratio of water to gas in the ice structures is approximately 1:6.
- Heating allows the gas to expand by a factor of more than 70.
- Most of the probable reserves of gas hydrates on the Norwegian margin can be found at depths of less than 1200-1500 metres. In the Barents Sea, indications have been found at depths of 200-300 metres.

everything ground to a halt. And so the experts had to admit that there is still a way to go before gas hydrates can be produced in a commercially viable manner.

– But will we ever produce methane from gas hydrates on the Norwegian continental shelf?

– Yes, but it may take more than 50 years for this to happen. There are technical problems and problems related to finding deposits where the concentration of gas hydrates is high enough, says Haflidason.

– Where may we find such high concentration deposits?

– Mostly in the Norwegian Sea and the Barents Sea. The conditions are most optimal at the top of the slope. Several deposits have been discovered along these slopes, where gas seeps out from the reservoir deeper down. One aim is to identify areas where gas seeps out from oil or gas deposits in the ground. In this project, our task is to quantify and

identify. We have to start somewhere, says Haflidason.

So, in many areas of the Norwegian continental shelf gas seeps out from oil and gas deposits in the ground. Gas hydrates are often found in connection with such seeps or "wells". – Such seeps have been discovered on Håkon Mosby (a clay volcano in the Norwegian Sea) and Nyegga. The gas bubbles rise towards the surface, and we will use echo sounders to measure these gas releases.

Gas hydrates also represent a risk

Stone Age man on the west coast of Norway had a highly unexpected surprise more than 8000 years ago. A huge tidal wave almost five metres high crushed their settlements. Out at sea, an enormous slide had taken place on the margin of the continental shelf; the so-called Storegga slide.

– But what does this have to do with gas hydrates?

– Many researchers are of the opinion that gas hydrates contributed to the vast magnitude of the landslide. The warming of the oceans that followed the last ice age destabilized the gas hydrates. Consequently, once the shelf started to collapse, these unstable areas came down with the slide.

Haflidason's research project will also be important in that it will map out potential risks associated with oil production. Hot oil being pumped through a layer of gas hydrates may cause the hydrates to melt, leading to a collapse in the ground. There may therefore be a risk of blowouts, and the stability of any seabed installations such as platforms may be at risk. Gas hydrates may also trigger smaller landslides which can easily damage installations such as pipelines, cables and so on.

Typhoons in Forus

Typhoon Durian devastated areas of Southeast Asia in 2006. Gusts of over 100 km/hr were recorded and at least a thousand people lost their lives. Now a small company located in Forus, just outside Stavanger, is reproducing typhoons in a valve.

– If the Typhoon Valve can extend the lifespan of mature oil fields and increase oil recovery, it will be revolutionary, says company founder, Trygve Husveg. We are sitting in an office inside a large laboratory. Husveg turns around constantly – and with good reason. Successful test results from the valve are coming in on the computer screen behind him.



Company founder Trygve Husveg.

Purer water

A number of oil platforms are facing difficult situations. The platforms on the Norwegian Continental Shelf pump up enormous volumes of water with the oil. The oil and water are then separated using a laborious process. There are strict purification requirements and the water should be as clean as possible. This is because much of the water ends up in the ocean.

Our Typhoon Valve results in both cleaner water and cleaner oil, says Husveg. He proudly shows some data series that highlight the findings.

In the warehouse, the pipes are coiling around. They reproduce the way that oil flows in the platform's pipes. This way, they can test how the valve works. Husveg has constructed the valve and parts of the in-

stallation himself. He grew up as the eldest son on his parent's farm. He has welded and tinkered with mopeds and cars all his life. Then he was sold to science, began a civil engineering degree and sold his milk quota. The Typhoon Valve is the result of many years of PhD work. Further research and development is supported by the Research Council of Norway through the PETROMAKS programme.

Increases oil recovery

The Norwegian Continental Shelf's production is falling. Husveg aims to help slow down this trend. If the valve is successful, the oil platforms will be able to produce more profitably and over a longer period.

– Extreme instances can occur where the produced water is so contaminated that the oil company shuts down production. Several oil platforms struggle to comply with new purification requirements for produced water, he says.

– The Typhoon Valve may make the difference as to whether a well produces or not, adds Svein Tore Sivertsen, cofounder.

– Extended tail production in mature fields and the consequent increased recovery could result from improving the separation process using this valve.

– *But back to the typhoon – what exactly is the secret behind the valve?*

– We create a spin that is common in a typhoon, says Husveg. Put simply, in powerful typhoons, air masses circulate around an eye – an area of low pressure. Outwards in the typhoon, the pressure rises rapidly. Heavy items are thrust outwards by the centrifugal forces, just like a washing machine centrifuge removing water from



Husveg and Sivertsen show off parts of the valve.

your clothes. In the case of the valve, the oil remains in the eye of the typhoon, while the water is projected out to the sides. This valve ensures that the pressure drop develops as happens in a typhoon, and not by constriction, as would occur in a normal valve. The advantage is that the typhoon, however strange it may sound, is a much more gentle way of controlling oil/water flow. As a result, the oil and water are more easily separated in the process plant.

Great potential

The next step is to make a full sized valve and test it on an oil platform.

– We hope to have the valve tested, full scale, on an offshore platform during 2008, says Husveg.

– *What is critical?*

– The tests show that our thinking is correct. The critical step is in carrying out a pilot, but we have great faith that it will go well.

– *What is the valve's economic potential?*

– We will secure a valve supplier and believe that this will give us annual licence revenues of NOK 50 mill. by 2015. However, the most important economic potential is the social economic one, in increased oil recovery, longer oilfield lifespans and cleaner discharge of produced water.

– So far, we have only studied the effect of the valve on the well head. However, it will also have a positive effect as a control valve in all multiphase transport upstream in a separation plant.

In theory, it will also have a positive effect on multiphase transport over longer distances and therefore has interesting potential as a sub sea choke valve.

Intelligent gel offers salvation for oil fields

This is Oil-Norway's nightmare: Oil production is diminishing. Instead of precious black gold, the pumps spew out polluted water. Fortunately, brilliant minds are working on new ways to avoid that scenario.

In 1990, the Statfjord field produced 600 000 barrels of oil and 100 000 barrels of water each day. In 2006, the field is producing 600 000 barrels of water and 100 000 barrels of oil.

The water is far from 'designer' quality, as it contains assorted chemicals and oil. As if that were not enough, the water also takes up precious platform capacity.

Now IOR Chemco (Improved Oil Recovery Chemical Company) is trying to reduce the production of polluted water, ably assisted by Researcher Arne Stavland of IRIS, formerly Rogaland Research.

Water that pollutes

– Just look at this, says Stavland from the inner sanctum of his laboratory. He holds up a bottle containing a layer of some slimy substance floating on a layer of oil. The message in the bottle is easy to read: The slimy substance was once water. Then a polymer was added, transforming the water into a gelatinous lump.

In principle, this is the same chemical process that takes place when you make home-made jam. The secret, of course, is that the polymer does not bond with oil. How does this work down in an oil reservoir?

Imagine, if you will, a reservoir divided into oil zones and water zones. When researchers inject their designer chemicals into the well, the chemicals react with the water in the water zones. Shortly afterwards, a gel is formed, plugging up the pores. Eventually, water no longer flows into the well, and water production drops.

Commercialised knowledge

– The champagne will flow if we succeed, smiles Jørn Bergeland of IOR Chemco.



Sigve Aspelund of IORChemco demonstrates the chemicals that will hopefully help boost future oil production.

The company is one result of Stavland's research.

The method has been successfully tested on the Veslefrikk field. Oil production increased in the well they tested, and 35-40 per cent less water was pumped up. Now that the NCS is in the sunset phase, produced water is becoming an increasingly more serious problem. Wells have to be closed when they produce too much water. That reduces revenues for the oil companies and the Norwegian state. The method also works with sand. Increasing amounts of sand are being pumped up from the briny deep through the wells. The gel has a binding effect, impeding the sand. This also helps extend the life span of a well.

Diagnoses of the utmost importance

The intelligent gel made by Stavland and IOR Chemco will not work on all fields.

– Doctors make diagnoses. If a diagnosis is wrong, the prescribed medicine will not help. The same applies downhole in oil reservoirs, explains Stavland.

If you have a zone where both oil and water are pumped up, the gel will be less effective. The explanation is simple: The gel will stop both water and oil from getting into the well. This presents a formidable challenge. Consequently, Stavland is currently working to further refine the method by making increasingly more intelligent gels. – We want to avoid blocking the oil zone insofar as possible, he says.

Long-term approach

The principle may seem a bit simple and mundane, but the researchers' systematic efforts have involved a lot of trial and error. – It took 10 years from when we embarked on our research until we had a commercial application, reports Stavland. – This bears witness to the fact that long-term thinking is essential when it comes to research, adds program director in PETROMAKS Erik Skaug.

The Research Council has helped support several phases of research on such polymers. – Research that turns out to be applicable is definitely a bonus, smiles the programme director, a twinkle in his eye.

Yet Stavland asserts that it is the technical process that interests him most. – I wouldn't be doing this otherwise, but it is obviously wonderful that the ideas can be used, he adds.

A badger for oil

A bright idea that dawned during Christmas week six years ago may well turn the oil world upside down. New technology can detect more oil and gas less expensively.

It happened during the last Christmas week of the 20th century. Sigmund Stokka, head of research at the International Research Institute of Stavanger (IRIS), was just about to start his Christmas holiday, but some nagging ideas kept churning around in his mind.

For nearly 15 years, he had been working on a new method to drill wells, so-called thin well holes. Sigmund Stokka got a new idea for Christmas that year. Why not lower measuring instruments into the well to find/detect oil and gas entirely without the use of a rig?

His gut feeling was that this could revolutionise the oil world. It could make data collection and the surveying of oil and gas simpler and far less expensive. In his mind's eye, he envisaged a drill bit carrying measuring instruments as it tunnelled down into the ground like a badger. He made some simple calculations. This might just work.

Investors recognise a good thing

Six years have passed. The idea is patented. The company Badger Explorer ASA has been set up and has roughly 10 employees. The company is listed on the so-called OTC list, and is currently valued at about MNOK 200.

Stokke has been awarded the Reodor Prize for his invention and the company's idea placed 2nd in DnB Nor's national innovation competition.

Development of the prototype has begun and a total of MNOK 25 in fresh research funding has been allocated by the PETROMAKS programme, as well as by the oil companies ExxonMobil, Shell and Statoil.

Moreover, in autumn 2005, MNOK 75 in equity capital was raised from different investors.

– I am proud, confirms Stokke. We are not quite finished with the technology, but the plans are in place.

High risk

Oil prices are sky-high as a result of the world's energy situation. Market demand for more oil is growing constantly, but access to new oil reserves and higher production is limited.

Accordingly, the oil companies want to step up exploration activities to find more oil and gas. One of the main problems is a lack of access to suitable rigs due to the high temperature of the market.

Many planned exploration wells have to be postponed or shelved. Badger Explorer technology can help resolve this particular problem, but there is still a long way to go. – At this point, we believe there is about a 30 per cent chance of success. We are at a critical point with a view to whether or not we will succeed, reports Project Manager at Badger Explorer AS.

The researchers have already conducted several successful tests and proved that it is possible to handle and eliminate the problem of cuttings.

Cuttings are actually one of most serious problems. As 'the badger' gnaws its way downwards, it has to get rid of all the rock in front of it, then 'leave it behind' to plug the hole.

State-support was the trigger

The Research Council of Norway was instrumental in establishing the enterprise. Badger was established after IRIS applied to the Research Council for user-driven



Head of Research Sigmund Stokka of IRIS

research-based innovation funding, but such applications are not usually accepted from research institutions.

– On that account, one condition was attached to the support: Establish a research-based enterprise. That was done, and Badger Explorer ASA was born, recounts Senior Adviser Siri Helle Friedemann of PETROMAKS.

The project would also have got off to a far slower start without support from the Research Council of Norway.

– The Research Council believed in the concept and provided a financial platform for the idea. The oil companies came on board a bit later, reports Helle Friedemann.

No lack of challenges

Notwithstanding, everyone is aware that the challenges are myriad. Many minor tests still remain, details have to be worked out, and the equipment has to be designed and calculated.

Moreover, competitors could beat them to the market with other reasonably-priced solutions, although at present there are no known rivals to this technology.

A drastic fall in oil prices could also threaten the start-up company. If they succeed, the future will be bright, and everyone who is interested in the enterprise should definitely be looking forward to next autumn. According to plan, that is when a full-scale prototype will be tested. Stokka's Christmas idea is still alive.

This is how Badger Explorer works

Badger Explorer is a patented method. The idea involves making a 'badger', i.e. a steel pipe that is 30 centimetres in diameter and about 50 metres long, with a drill bit at the end. The drilling tool tunnels downwards, gnawing its way through the sea bottom sediments on its quest for oil and gas.

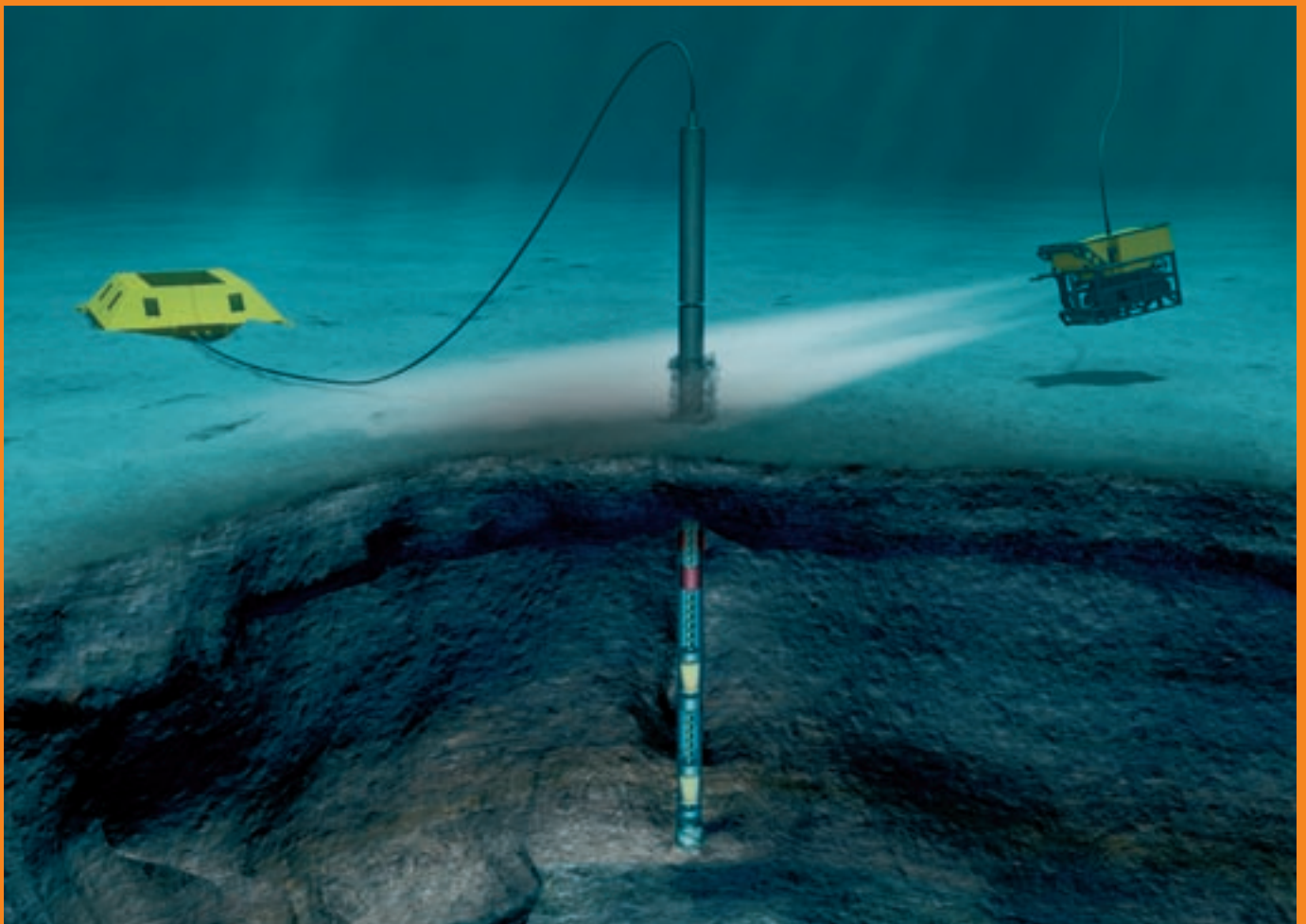
In connection with conventional drilling, cuttings are brought up to the surface by pumping drilling fluid down inside the drill string and up on the outside of the drill string.

The Badger's voyage down into the depths takes place without the help of ordinarily costly and resource-intensive equipment like drilling rigs, pipe lining and drilling fluids.

The only connection to the surface goes through a power/signal cable that is gradually uncoiled from a chamber inside the

tool as it drills its way downwards through the substratum. Power is transmitted down through the cable to operate the drilling equipment. Geological and technical data about the reservoir are transmitted to the surface through the cable as the Badger digs down through new formations. These data can then be transferred by satellite to the oil companies' headquarters for immediate and continuous interpretation of the results.

The financial rewards are one type of benefit, but the system is also easy on the outdoor environment since it does not release any pollution in the form of tailings or cuttings. The hole behind the tool is permanently plugged by cuttings and the tool remains in the substratum once the assignment has been completed.



Bacteria may boost oil production

“It is possible that tremendous amounts of oil will be left in the ground when the oil fields are shut down. As a result, we need to find new ways to boost production. Bacteria might offer one solution”, comments Sigmund Stokka, head of research at Rogaland Research.

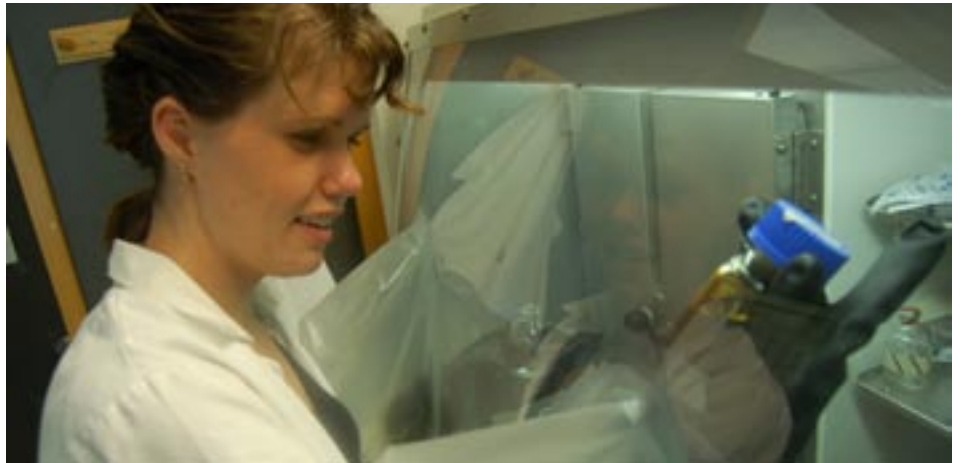
The researchers place small bottles of bacteria on a table in the laboratory at Mekjarvik just outside Stavanger. These bacteria were recovered from reservoirs several thousand metres beneath the ocean floor on the Ekofisk field in the North Sea. Although they might look small and insignificant, they may facilitate the recovery of additional oil worth billions of NOK. Bacteria are already in use to boost production on the Norne field and on an oil field in Canada.

– Many researchers are convinced that bacteria can boost production, but we lack systematic experiments and analyses of the mechanisms that apply, states Stokka.

Inexpensive and environmentfriendly

Phillips unveiled quite a surprise in December 1969 when the company discovered oil on Ekofisk. At that time, it was estimated that a mere 17 per cent of the oil in the reservoir could be recovered. Today, the figure is 46 per cent. However, ConocoPhillips is eager to extract even more oil from the Ekofisk reservoir. That was one of the reasons the company approached Rogaland Research.

– If this actually works, it will be an inexpensive and environment-friendly way to get more oil out of the reservoir, Stokka confirms. The project has a budget of MNOK 12, of which MNOK 6 has been provided by PETROMAKS. However, those amounts are peanuts if Stokka & Co. succeed. – Boosting production by just one per cent would translate into about NOK 30 billion in increased revenues, Stokka continues. The micro-organisms appear to impact the reservoir in several different ways. For example, they may increase acid



Post-graduate fellow Krista Kaster studying bacteria samplers from the Ekofisk field.

production that can enhance porosity and permeability or block pores so that injected fluids flow to new areas. That being said, Stokka has faith in emulsions or, in other words, in getting drops of oil to loosen from the rock and follow the pore water down in the reservoir.

Extreme life

One millilitre of produced water can contain up to several million bacteria. In the laboratory, researchers sustain life in the bacteria by feeding them a very special diet that includes methane, oil, vitamins and yeast. The researchers are going to use DNA sequencing to determine the following: Are there any new species? Which species are in the majority?

– I hope to find the right bacterium, states post-graduate fellow Krista Kaster as she focuses the microscope. – But how can you apply your research out in a reservoir? – Once we find out what kind of bacteria are living down in the reservoir, we can

pump down nutrients that we know will have an effect, explains Stokka. Bacteria can be dormant for several million years. Once they get nutrition, they may suddenly begin to reproduce.

Time-consuming

A 400-nm thick sheet of carbonate spheres has been fastened down. The researchers spray in microbes along with oil and water. – We want to test a number of bacteria and see how they behave in this medium, clarifies senior researcher Grethe Kjeilen-Eilertsen. The researchers also want to see how quickly they reproduce. Later, they will test the bacteria’s properties on sediment cores harvested from Ekofisk, and finally there will be a pilot test out on an oil field.

– This kind of pilot test needs to be run over a long period of time. It may take quite some time from the nutrients are injected until they have any noticeable effect, concludes Stokka.

‘Carwash’ chemicals may enhance oil recovery

Oil production has peaked on the Norwegian Continental Shelf (NCS). In response, researchers in Bergen are testing to see whether carwash chemicals can extend the lifetime of oil fields.

Half Norway’s oil resources have now been produced. Although all prognoses point downwards, hope springs eternal. One such hope is to be found in the laboratory of CIPR, a Centre of Excellence located at the University of Bergen. Scientists are trying to figure out how foam from a carwash chemical can boost recovery from oil reservoirs.

More oil

– We are trying to learn more about the fundamental mechanisms that enhance recovery, reports Professor Arne Skauge, head of a project aimed at extending the ‘Oil Age’ by a few more decades.

The project is entitled: “Enhanced oil recovery for maximising tail production”. It is supported by a number of oil companies and PETROMAKS.

The professor shows us around one of the laboratories at the centre at the University of Bergen. There, a sediment core retrieved from the briny deep through a well in the North Sea is stored in a steel cylinder. The pressure and temperature are set to mimic the conditions the core would be subject to if it were buried under 3 000 metres of sediments.

Washing the Snorre field

Two research fellows discuss viscosity and capillary number as though they were talking about their favourite team’s final football match of the season. The blackboard is covered with formulae.

The project is enabling them to examine a number of methods such as chemical flooding, foam, alternating gas and water injection, and polymers (including olefin sulfonate which is used in carwashes).

The carwash chemical has already turned out to be a success.

– The foam used on the Snorre field in the late 1990s generated extra revenues of MUSD 25 to 32, comments Skauge.

Enhanced recovery

Oil production is a bit more complicated than sticking a straw into a reservoir and sucking up all the oil. The oil is not located in big bathtub-like basins, but rather in small pores of less than one millimetre in diameter.

This means that large amounts of oil are inevitably left behind in the pores downhole. Globally speaking, the oil companies actually manage to produce on average a mere 35 per cent of the oil. In Norway, the average is 46 per cent. But we want even more!

The Norwegian Petroleum Directorate has estimated that there are roughly 180 projects currently in progress in Norway that aim to boost recovery further. Enhanced recovery should help achieve the Norwegian Petroleum Directorate’s optimistic vision of 5 billion additional barrels by 2015. That would translate into a mind-boggling NOK 1 500 billion in revenues at today’s oil prices, i.e. a whole new oil fund.

However, that will require raising mean production to 55 per cent on the NCS. This will not simply happen; it will call for significant research.

Continued success

Methods for enhancing recovery have already been introduced on a number of fields. Models have to be made first. At the pore level, however, the mechanisms for how they work are still not understood well enough.



Arne Skauge, head of Center for Integrated Petroleum Research, University of Bergen.

– We are working on modelling tools that can predict the effect of these methods out on the oil fields, continues Skauge. The laboratory also accommodates some slabs of limestone imported from Spain that are going to be filled with water and oil, then tested with all kinds of chemicals and fluids.

The resultant knowledge may have a crucial impact on future production on the NCS and on other oil fields the world over. Oil production is diminishing on the NCS, which means that future must be ensured through even better recovery.

In any event, the chances of making major new discoveries on the NCS grows less with each passing year of exploration so more oil must be recovered from existing oil fields.

– There was not so much focus on enhanced recovery in the 1990s because oil prices were too low to provide sufficient incentives. These days, the oil companies are far more interested, but the industry lacks expertise, reports Skauge.

Success story

Hopefully, this success story will continue, and increasingly more oil is being recovered. On the Ekofisk field, recovery has been boosted from 17 to 46 per cent.

It is expected that no less than 70 per cent of all the oil will be recovered from the reservoir on the Statfjord field. Norway’s ‘Age of Oil’ still endures, and research can help ensure that it endures a little bit longer.

– Enhanced recovery is one of the programme’s main focal points, confirms Erik Skaug, programme director for PETROMAKS.

The programme is currently supporting no fewer than 32 projects aimed at exploring different ways to extend fields’ useful economic life by enhancing recovery.

– We hope this research will help boost wealth creation on the Norwegian Continental Shelf, concludes Skaug.

Searching for oil in the Barents Sea

The Barents Sea features in all of Norway's national strategies - and at the centre of the debate sits geologist Jan Inge Faleide, the man trying to find out where the oil has gone.

260 million years ago: Coral reefs curl around the prehistoric Barents Sea like a picture from a Caribbean tourist brochure.
220 million years ago: Rivers meander across a vast plain where dinosaurs graze.
10 million years ago: An endless, barren landscape is exposed to wind and erosion. In the north, huge ice masses threaten. The land sinks, the water encroaches and the Barents Sea is created.

January 2007: Professor Jan Inge Faleide from the University of Oslo talks about PETROBAR - the research project that may help reveal the secrets that lie deep within the Barents Sea.

– We will provide geological knowledge about the Barents Sea so that the oil companies can make new discoveries more easily, says Faleide. He is leading the project to which the PETROMAKS programme pledged NOK 17 mill. in June of last year and which will receive a further NOK 8 mill. from Statoil. Researchers will undertake large scale mapping of the area and study the geological development of the entire Barents Sea. This will provide valuable knowledge to the oil industry, which itself often has to undertake detailed studies.

An expensive discovery

The Barents Sea was a promising oil territory in the early 1980s. Then came a series of disappointing results, with exploration wells that did not contain sufficient oil. As time went on, geologists began to suspect that something devastating must have happened in the last ice ages. They realised that natural events during the last ice ages had led to the depletion of what could have been valuable oil reserves for Norway today.

– The Barents Sea rose and fell during the last ice ages. Sediments several kilometres thick were scraped off. Gas deposits underneath expanded and the oil was forced out of the reservoirs, says Faleide. Doubts and scepticism spread throughout the oil companies and many turned their backs on the Barents Sea. As geologists say, – The drilling should have been done 10 million years ago. However, after a promising additional discovery in the Goliath field and increased oil prices, optimism and interest in the Barents Sea has returned.

All is not lost

Faleide presents a seismic event on his monitor. – Here is the Snøhvit field (the “Snow White” offshore gas development). When it was raised up during the ice age, all the oil migrated to the Goliath field, says Faleide. – Traces of oil are found all over the area – enormous amounts of oil are generated in the Barents Sea. The question is whether some areas were spared from the rise, and where the oil that migrated is hiding itself, continues Faleide.

– The Barents Sea is an enormous petroleum pool. There are many layers of source rock and several possible reservoirs. The challenge is to find the right combination, as happened with Goliath.

The Government is also hopeful of further discoveries. The Norwegian Petroleum Directorate estimates that around a billion cubic metres oil equivalent may be found in the Barents Sea. At today's oil and gas prices, this represents around 350 billion US dollars.



Mr Barents Sea

– Part of my mind is always in the Barents Sea, says Faleide, who has worked with the area for over 30 years.

– You have been called “Mr Barents Sea”?
– Yes, maybe I am.

– What motivates you?
– It's like constantly putting together a jigsaw puzzle and there is also my own curiosity. You never quite reach your goals. The knowledge we obtain is also vital for other people, he continues.

– How do you feel about the fact that your knowledge may contribute to new discoveries, developments and also, perhaps, environmental spills in the region?
– The debate is very black and white. The spills from the drill rig Eirik Raude in 2005

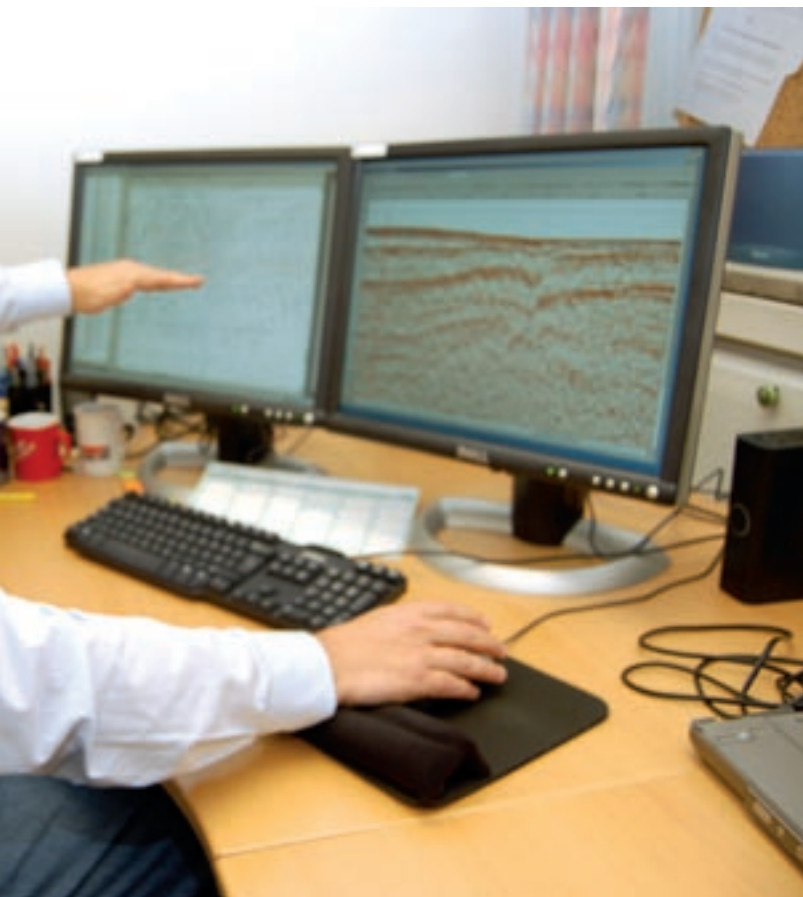


Foto: Torgny Skogsrud

Oil discoveries in the Barents Sea

Around 65 exploration wells have been drilled in the Barents Sea, but these have resulted in very few significant discoveries. The first exploration well was drilled in 1980 and the first successful well was Snøhvit in 1984. Goliath was discovered in the autumn of 2000 and has reserves of 60 million barrels. In 2005/2006, another well was drilled and reserve estimates grew to 250 million barrels of oil equivalent. The Stockman field on the Russian side, which contains around 3.2 trillion cubic metre oil equivalents, was discovered in 1988.

TRACES: Geologist Jan Inge Faleide presents a seismic map showing Snøhvit and Goliath. The oil has moved because the area was elevated during the ice ages. Photo: Reidar Müller.

that produced so much hysteria were so insignificant that they could have been hidden under this table. But I stay true to my principles when I undertake exploration research in the north.”

The hot Grey-Zone

Faleide moves over and points at the map to show the so-called “Grey-Zone” in the Barents Sea, between Norway and Russia. – This disputed area is hot. There are large geological structures in the area that may contain oil and gas. Collection of new data in the area is not permitted, but the geology has no boundaries. Through PETROBAR we will also obtain a better understanding of the region, says the professor.

One number circulating currently is that there are 12 billion barrels of oil in the area – an oil mass that makes any attempt to

solve the 30 year old dispute between the two countries more difficult. The boundary line of the Grey-Zone was also a topic for discussion when Jens Stoltenberg met with Vladimir Putin in November of last year.

– We will obtain a better understanding of both the Russian and Norwegian sides of the Barents Sea, with Russian cooperation, states the head of PETROBAR. There are also other motives for Barents Sea research, as better understanding of the regional geology may also expand the Norwegian deep sea territorial border.

Hot Political Topic

This year, the Research Council of Norway (RCN) and the Government both launched Arctic region initiatives. The Government initiative “Barents 2020” will take on the research challenges of the northern petroleum industry. In RCN’s budget, it is

proposed that NOK 330 million will be used to strengthen the Arctic region initiative. Of this, a total of NOK 86 million will be directed towards petroleum, of which NOK 20 mill. will go to PETROMAKS .

However, without new oil discoveries, Northern Norway may as well give up any plans of building its own “oil Mecca”. Faleide may be someone who can help.

Taking the Earth's pulse

Norwegian research groups are helping Americans understand their earthquakes. The researchers' knowledge has come from the North Sea.



It's 5am on 18 April 1906. A violent earthquake, measuring 8.3 on the Richter scale, hits San Francisco. At least 700 die. 100 years later, Americans are waiting anxiously for the next big quake to strike. But when will that be? This year? In 100 years? Researchers at NORSAR will help American researchers understand these earthquakes. To do this they will use expertise gained from measuring small earthquakes on the Ekofisk oil field.

Drilled through the earthquake zone

The San Andreas Fault is a geological fault in the earth's crust that effectively slices the American continent in two. The fault is where the Pacific and North American tectonic plates converge and slide sideways

against each other in opposite directions. This meeting of giants gives rise to the enormous earthquakes that have shaken California. Americans are desperate to avoid the devastation of a new earthquake, and one of their initiatives is to invest in more research. They have therefore drilled a hole, 4 kilometres deep, through the fault and placed geophones in the hole. The geophones will be the researchers' "ears" down in the fault and provide valuable information about the earthquakes - and this is where the Norwegian researchers come into the picture. They will be involved in collecting information on the very smallest quakes along the fault, so called micro-earthquakes.

– We hope to find out how large earthquakes develop. Do they start off as small earthquakes that grow? Or are small earthquakes fundamentally different from large ones? This is a topic that is much discussed in research groups in this field. We may also be involved in finding out whether there is some sort of stress build up that triggers larger earthquakes. This could be useful for earthquake warning, says Volker Oye, a researcher at NORSAR, the geophysics and seismology research foundation located in Kjeller, outside Oslo.

According to Oye, we are still a long way from being able to predict an earthquake.

– However, we can become better at finding out where a new earthquake is most likely to occur.

The NORSAR researcher's last visit to California was a year ago, not far from the small town of Parkfield, where the boreholes are located. The project SAFOD (San Andreas Fault Observatory at Depth) is a collaboration between the US Geological Survey and the State of California.

– We managed to identify very small earthquakes or movements along the fault. Our software has also helped to localize the small quakes down in the earth's crust, says Oye.

The seabed is sinking

The knowledge that the NORSAR researchers use in the SAFOD project was collected from the Ekofisk oil field in the North Sea. The seabed at the Ekofisk platform has sunk six metres since the early 1970s. When oil is pumped up, the seabed sinks down. The production of oil therefore creates small earthquakes and cracking

down in the reservoir. The NORSAR researchers wanted to find out more about these quakes and developed a method for this with the support of the Research Council of Norway's PETROMAKS programme.

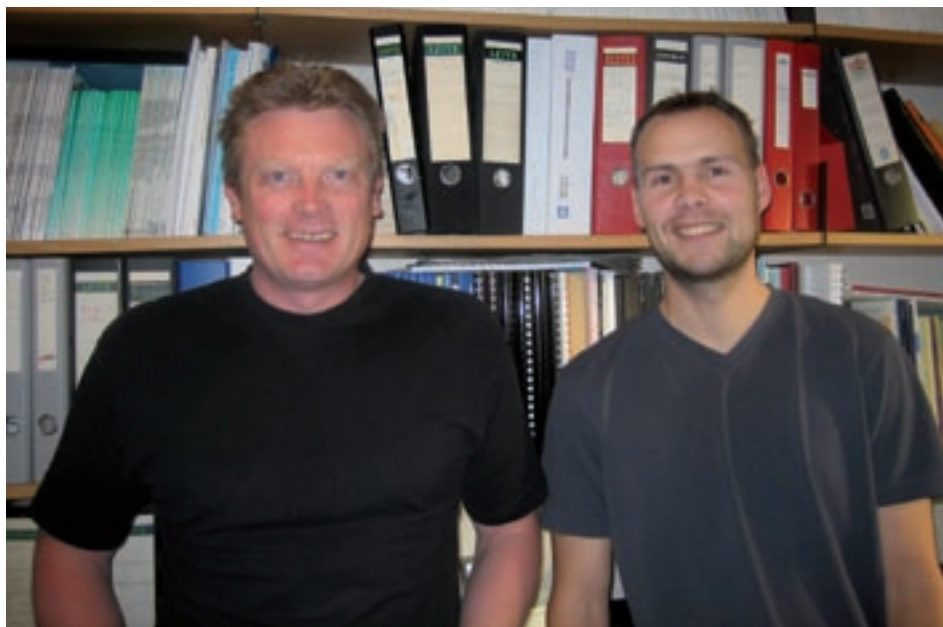
– The cracks can change how the oil moves around down in the reservoir, which is important for recovering as much of the oil as possible. There is also a safety concern: the measurements are taken from small geophones placed in the oil wells, so that the researchers can listen to what is happening down in the reservoir. Small tremors underground are transmitted as sound waves that are captured by the geophones. The sound waves are then interpreted and analysed by the NORSAR researchers. This work in itself is an entirely separate science.

– In the North Sea, we have gathered our knowledge by measurements in the wells, and how the tremors are localized down in the reservoir. This is useful information that we have transferred to the SAFOD project, says Michael Roth, a researcher at NORSAR. The earthquakes measured on the Ekofisk field are mainly from minus two to plus two on the Richter scale. You don't often hear about minus figures on the earthquake scale, but in fact these quakes happen all the time, without us noticing.

Oil wells of the future

The NORSAR researchers now want to move forward with their research. In the future, oil fields will consist of installations with permanent seismic sensors. These will be used to measure data from seismic guns and vibrators, but they will also measure the naturally occurring and unexpected quakes in the ground.

– We have no control over these sources compared to other sources of sound. This is demanding but it also provides more information that can give valuable knowledge about the reservoir. This can be an important contribution to reservoir management, well planning, production optimization and can reduce accident risk, says Roth.



Researchers Michael Roth and Volker Oye at NORSAR.

In the new project, the researchers will develop new processing strategies for large passive seismic data sets, event localization and waveform analyses. They will also develop interpretation methods for passive seismic data that may give information about the composition of the subsoil.

Danger of rockslides

Michael Roth carefully places his geophones down the mountainside at Åkneset, in Western Norway. The fjord glistens several hundred metres below.

The NORSAR researchers are also using their technology on mountain slopes that are vulnerable to rockslides, such as at Åkneset. Åkneset is an area that has received a great deal of media attention lately. Some researchers fear that a massive rockslide, equivalent in size to 200 of Oslo's tallest buildings (or 40 million m³) could tumble down into the fjord. The rockslide would create a 6 metre high tsunami that would devastate the villages of Hellesylt and Stranda along the coast.

– The sensors will give us information about how the mountain slides. The geophones are very sensitive. They register rain, hikers and rock falls, says Roth.

The NORSAR researchers' comprehensive use of oil knowledge is a great fit for PETROMAKS, which supports petroleum research.

– It is very positive that oil knowledge is creating synergies", says Erik Skaug, Programme director of PETROMAKS.

The project "Active Use of Passive Seismic" will be carried out by NORSAR and NGI (the Norwegian Geotechnical Institute). It is supported by PETROMAKS, and also by the oil companies Total, Norsk Hydro and Statoil. Funding was allocated to the project in June 2006.

OG21 – Oil and gas in the 21st century

In order to meet the challenge associated with efficient and prudent petroleum activities, OG21 – Oil and Gas in the 21st century – was established on the initiative of the Ministry of Petroleum and Energy in 2001. The objective was to unite the oil and gas industry in a common technology strategy.

The goal of OG21 is to:

- Increase the value creation on the Norwegian continental shelf
- Increase the export of Norwegian technology

In this period OG21 has succeeded in getting oil companies, universities, research institutes, the supplier industry and the authorities to join forces and support

a national technology strategy for petroleum.

Declining production from existing fields shall be compensated through increased R&D resulting in value creation through increased recovery, development of new areas, better utilisation of gas resources and the resulting export of new technologies.

The OG21 strategy

To meet OG21 vision of a sustainable petroleum industry for the next 100 years through joint efforts concentrating on knowledge and technology, eight Technology Target Areas have been identified. The TTA groups are led primarily by oil companies (Lead Parties) to ensure the commitment of the industry.

Implementation of the strategy

The tools for implementing the OG21 strategy are the Research Council of Norway (RCN) programmes PETROMAKS and DEMO 2000. PETROMAKS is a programme supporting basic and user driven research, while DEMO 2000 is supporting pilot qualification of technology. PETROMAKS and DEMO 2000 have to be aligned with the OG21 strategy to ensure a collective national approach.

Organisation

The OG21 work is managed by a secretariat reporting to a Board appointed by the Ministry of Petroleum and Energy.

More info at www.og21.org



DEMO 2000

The Demo 2000 program is directed towards three main objectives:

- Continued cost-effective development of the Norwegian Continental Shelf (NCS) using new technology
- Improved confidence in cost and schedule during project execution
- Development of new Norwegian products for a global offshore market

DEMO 2000 was initiated jointly by the oil industry and the government, realising that a major co-operative effort was needed to bring new products and systems into a market of rapid change and with increas-

ing emphasis on reducing cost of new field developments.

The role of DEMO 2000 is to accelerate the uptake of new technology in the industry, by bridging the gap between R&D projects and implementation.

DEMO 2000 focuses on qualification of new technology and solutions in a close collaboration between suppliers/contractors, research institutions and oil companies through prototype development and testing, deployment and pilots.

Since its start autumn 1999, a total of 380 million NOK have been awarded through 8 application rounds within reservoir description and interpretation, drilling

and well technology, seabed/downhole processing and multi-phase transport, deepwater technology and gas utilisation.

To date more than 130 projects have been approved by the Steering Committee. The DEMO 2000 support has triggered supplementary funding from oil companies and from the contractors themselves to a total funding in excess of NOK 1,8 Bn.

More info at www.demo2000.no



INNOVATION NORWAY

Innovation Norway promotes nationwide industrial development profitable to both business economy and Norway's national economy, and helps release the potential of different regions by contributing towards innovation, internationalisation and promotion.

Innovation Norway's target groups are entrepreneurs and SME's with an international growth potential. Innovation Norway support more than 7000 projects with 4

billion kroner annually. Half of this is loans, guarantees and support to almost 4000 innovation projects.

Innovation Norway assist Norwegian oil and gas suppliers in Norway through the 19 district offices, or internationally through 37 offices worldwide. Support is provided from the early stage of start-up and securing patent rights, through provision of funds through the IFU – or industrial research and development scheme – to

assistance in gaining access to international markets.

More info at www.innovationnorway.no






Photo: Norsk Hydro.





About this publication

In this brochure you can read about some of the exiting projects in the PETROMAKS portefolio. The articles are written by advicer Reidar Müller in the PETROMAKS programme, the Research Council of Norway.



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