The digital core laboratory

By getting a better understanding of the pore structure of the reservoir rock through detailed analyses of thin sections, a brand new methodology now makes it possible to predict petrophysical properties almost without using conventional core laboratory services. The ultimate goal is to improve reservoir simulation by offering a high number of inexpensive analyses of reservoir parameters in a minimum of time.

Photo: Halfdan Carstens

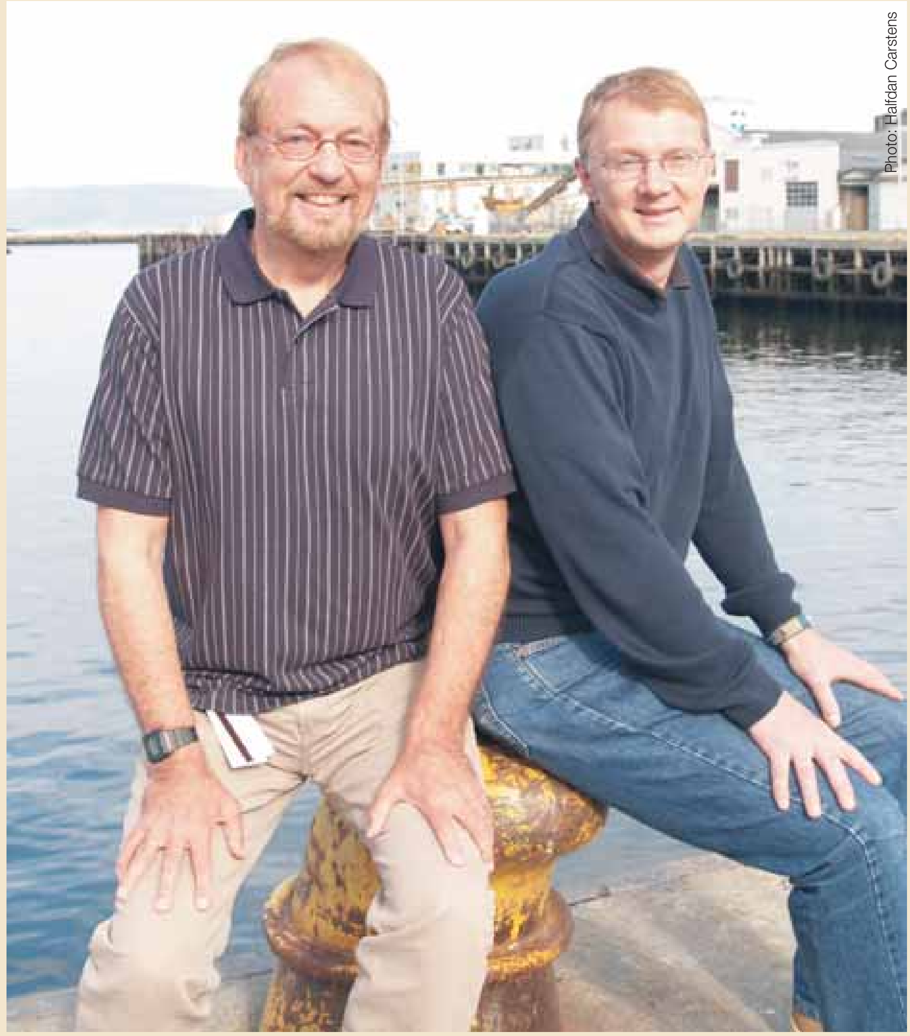
Halfdan Carstens

The new buzzword in reservoir characterisation is "e-Core technology". In short, it involves using petrographical data from thin sections to model important reservoir parameters like relative permeability, formation factor, capillary pressure, resistivity index and residual saturations, all crucial for doing a proper reservoir simulation for the purpose of planning optimal reservoir performance during production.

We are used to associating such parameters with measurements done in a conventional core laboratory equipped with sophisticated instruments and advanced analyses. And in all probability these labs will be part of our future for doing such measurements. However, the rapid increase in knowledge, technology and computer speed now makes it possible to supplement, and in some cases substitute, these with computer generated values. Numerical Rocks, founded only last year, has pioneered a technology for predicting the properties of reservoir rocks and is now ready to enter the market.

Statoil Innovation has been instrumental in getting Numerical Rocks to fly. "Spinning off this technology with two entrepreneurs and creating a dedicated company should ensure more focused and driven software development than keeping it in-house," explains Investment Manager Asle Hovda in Statoil Innovation. "Statoil Innovation is dedicated to commercialising the Statoil group's technology and expertise through new start-ups, and to invest in external innovative early stage technology companies. Numerical Rocks is the seventh investment by Statoil Innovation since the latter was created in 2001, and the second spin-off from in-house technology," Hovda says.

"At this stage we look at the new technology as a supplement to conventional core analysis. In the long run, however, our way of characterising the reservoir may replace some of the measurements because of both the cost- and time-aspect. Using inexpensive computers is certainly cheaper than expensive laboratory measurements, and the time we need to do calculations in the computer is only a fraction of what the laboratories need," says Ivar Erdal, Managing Director of Numerical Rocks.



Stig Bakke (left) and Pål-Eric Øren have worked in tandem for many years in spite of widely different background and expertise. They believe that the technology they now master is a result of being part of a multidisciplinary team in the Statoil research lab, where chemistry, physics and mathematics is as important as geology, geophysics and petrophysics. They have now left Statoil for the purpose of continuing developing and marketing the software to the international oil industry. Statoil Innovation is a majority shareholder in the new company Numerical Rocks.

20-year lead-time

Numerical Rocks belongs to a crowd of new companies in the petroleum service industry that has been able to establish themselves because of a rapid increase in geoscientific knowledge, technological development and data power.

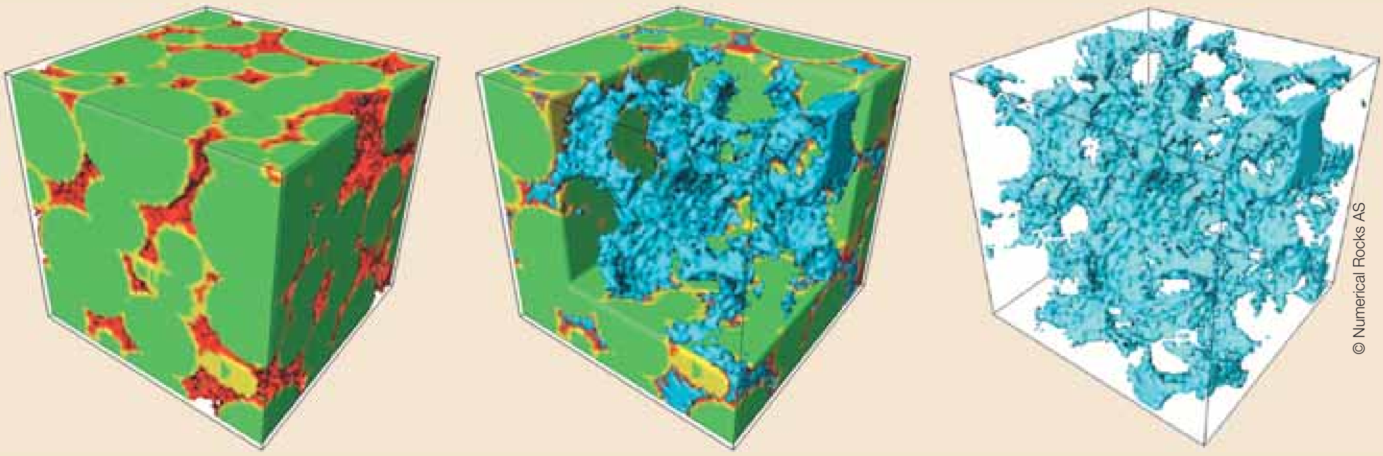
But even more important are professionals with the right ideas at the right time!

"Back in the mid 1980's we did some early thinking on how to characterise reservoir rock properties based only on thin sections. This was in line with current ideas that thin sections could be used to estimate permeability," says Håkon Rueslåtten who has now joined Numerical Rocks after a 19-year long career in Statoil.

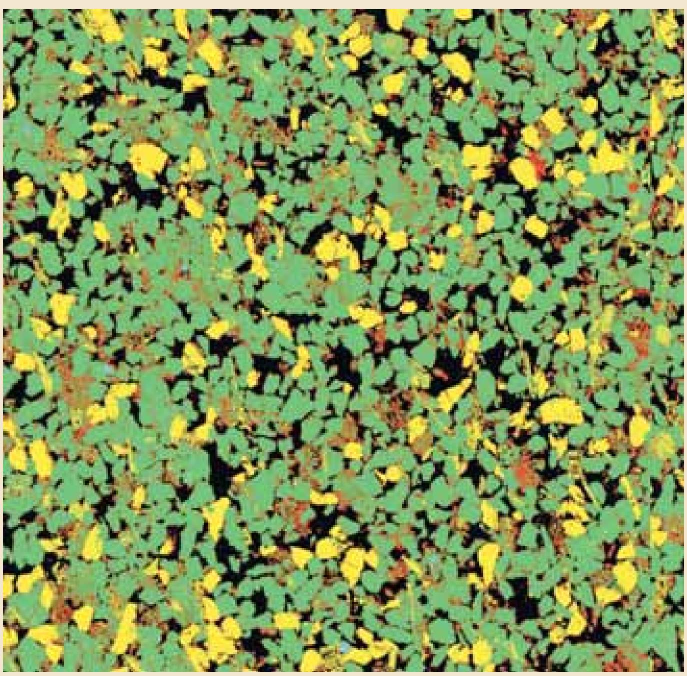
"Preliminary results were encouraging, and a few years later the project was enforced by hiring a physicist who had specialized on fluid flow in porous media. The purpose was to use the rock properties in fluid flow analysis in order to improve reservoir simulation," Håkon says.

Pål-Eric Øren, with expertise in both chemical and physical engineering, had just finished his PhD in Sydney and was ready for new challenges outside the university system. "At that time we knew a lot about how fluids move within porous media and how one fluid (for example water) displaces another fluid (for example oil). However, we knew very little about what the

Typical thin section displayed on Jurassic sandstone with ripples.



The pore space of reservoir rocks is highly chaotic, consisting of a spatial network of pores in which larger pores are connected via narrower pores (pore throats). The architecture and geometry of the pore network and its complementary grain matrix determine several macroscopic properties of the rock such as absolute permeability, relative permeability, capillary pressure, formation factor, and resistivity index.



Artificial coloured image of a thin section of a reservoir sandstone. The green and yellow grains are quartz and feldspar grains, clay coating and filling is red, heavy minerals are blue and the pore space is black

reservoir looked like, and we were for that reason not able to quantify the flow of fluids in the reservoir rocks. Not knowing the rocks pore structure was at that time – and still is – a significant limitation to the quality of reservoir simulation," Øren says. "

That may come as a surprise, considering that geologists have studied sedimentary rocks for centuries. "The fact is that we were not able to describe the geometry of the pores and how the pores connect with each other. Consequently we had no clue as to how we should make a model of the reservoir rock for fluid flow modelling," Øren explains.

Stig Bakke, a geologist who had spent thousands of hours looking into the microscope studying rocks in thin sections, and who had an interest in using computers in quantifying geological processes, also joined Statoil in the early 1990's. Stig's experience was very relevant for this project, and combining the expertise of the two proved to be the right thing.

"With information about minerals and pores from thin sections we tried to reconstruct the geological processes that formed the reservoir rock," Stig says. "Using our own algorithm, we built a 3D model with rounded grains, clay minerals and cement as well as pore space and connectivity."

And, they were successful. After a few years the small but efficient team had proved that it was possible to predict both the petrophysical properties and the flow properties of sedimentary rocks based only on thin sections, and their results were published in the SPE Journal (Vol. 2, 1997). Thin sections are easy and inexpensive to prepare, thereby making it possible to make a high number of analyses instead of analysing only a few samples in the core laboratory.

"We were now ready to try out the method on real rocks in a producing field," Øren says.

The e-Core technology

The essence of the new method is to build sandstone models that are analogues of actual sandstones by numerically modelling the results of the main sandstone-forming geological processes - sedimentation, compaction, and diagenesis. The input data for the modelling are obtained from analyses of thin section images of the actual sandstone.

"The microstructure of a porous medium as well as the physical characteristics of the solid and the confined fluids determine the macroscopic properties of a system. These include petrophysical and transport properties needed to characterise the reservoir. In principle, it should be possible to determine these properties from their microscopic origin," says Stig Bakke.

By "microscopic origin" Bakke is referring to thin section analysis, one of the basic geological tools used to describe rocks in detail in which a thin lamina of the rock is studied under the microscope. "Thin sections enable us to characterise the reservoir rock in terms of size and shape of the sand grains, clay particles present and to what extent the rock has been cemented after burial," says Bakke.

"Our first step is therefore to construct a numerical rock based on petrographic data. The input data include porosity, grain size distribution and mineralogy. This is done with our own software in which we fill up a cube with sand grains, clay and cement, and then remove all the solids leaving only the pore space. A 3D sandstone model and its complementary pore space is the output."

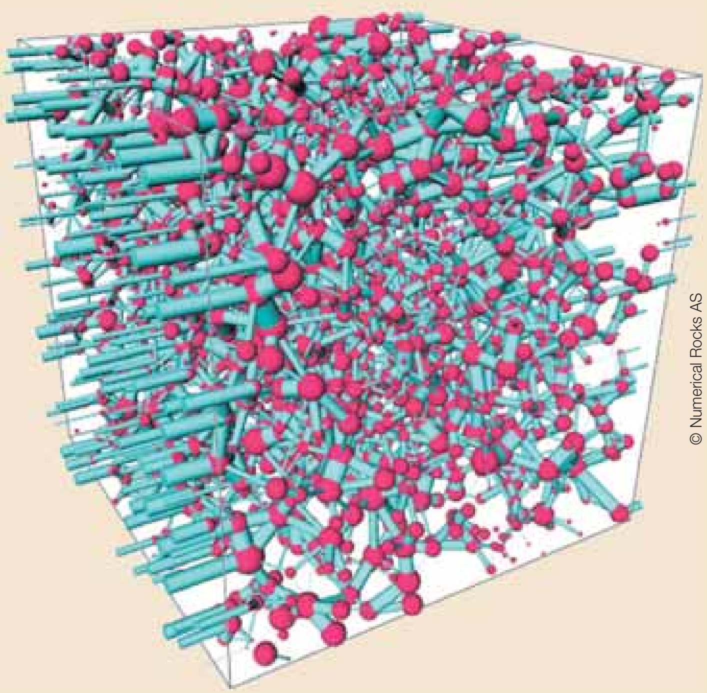
The next step is to generate representative numerical pore networks, upon which it is possible to calculate petrophysical data and simulate fluid flow directly from the numerical rock. These data include permeability, formation factor and capillary pressure. Other parameters like nuclear magnetic resonance and elastic moduli can also be estimated.

The generation of a network model makes it possible to carry out multiphase flow simulations and then to obtain macroscopic flow properties. These include relative permeability, capillary pressure, resistivity index and residual saturations.

An animation of the process can be studied at www.numericalrocks.com.

The end result based on a single thin section is a series of parameters that normally require advanced laboratory analyses. "We can get all the rock parameters that we get from the lab, with only one exception: Wettability," says Bakke.

"The product is working," says Erdal. "But up to now specialists have been required to do the preparatory work on the real rocks and to run the software to get meaningful results from the numerical rocks. That is why three computer experts are engaged in developing software that is meant to be user-friendly, which is a prerequisite if you want to penetrate the market."



A 3D sandstone model and the numerical network of a pore space with red nodes being spheres with radii equal to the inscribed radius of the pore body, while the light blue links are shown as tubes with radii equal to the inscribed radius of the pore throat.

> " Our vision is a new understanding of pore physics that enables the prediction of reservoir multiphase flow parameters."

Time is money

"There are a number of advantages in using the e-Core technology," says Erdal. "We all know that time is crucial when planning the development of a new field or when certain circumstances require a re-evaluation. While a conventional core analysis programme may take from 6 to 18 months, we can do this in a few days or weeks with the e-Core technology. That makes a difference."

"Another important advantage is that we only require a small chip of a rock to do the computations. A thin section of the reservoir rock is the only sample we need, and this we can get from cuttings, sidewall cores as well as conventional cores. It doesn't take much imagination to realise that both time and cost will allow for a high number of analyses that would have been prohibited with the traditional technology which includes coring operations and core analysis programs. Analyses can hence be made in numerous wells in which cores have never been cut," says Erdal.

"From an oil company perspective easy access is also good news because the database has the potential to increase multifold without increasing cost. Instead of scattered data points made from an incomplete core record, wells can now be analysed for reservoir parameters centimetre by centimetre."

However, he is eager to ad that the new technology by no means replaces conventional core analysis. Rather, it is a supplement that may increase the need and the market for reservoir characterisation. The long time required in the laboratory to get meaningful results may in fact have hampered more extensive use of such services.

New applications may also result because of the reduced cost. Håkon Rueslåtten, who is responsible for business development in Numerical Rocks, envisages a library of reservoir rocks with thin sections from each lamina, with associated simulation results that can provide important information in connection with for example exploration play models.

Håkon Rueslåtten was instrumental in developing the original idea of using thin sections in reservoir characterisation and has joined Numerical Rocks as Business Developoment Manager.

"The proof of the pudding is in the eating"

Numerical Rocks is now investing heavily in generating the necessary software to be able to offer their services with a streamlined product, and by next year they expect to approach customers who are eagerly waiting for a time- and cost-efficient tool that may ultimately give significant improvements in simulating fluid flow in the reservoir.

Before that, however, they also need to prove that the e-Core technology is more than theory. They need to show cases in which their new innovations have worked.

"The e-Core technology has been successfully tested and verified on both outcrop rocks and on different reservoir rocks, and reconstruction of the rock microstructure has been verified by quantitative comparisons with micro-CT images of the actual rock that give detailed 3D images," says Bakke.

"In the late 1990's we generated sedimentary rocks in the computer and predicted their properties on several Statoil operated fields in the North Sea and the Norwegian Sea, including Gullfaks, Statfjord, Veslefrikk, Kristin, Heidrun. We were asked to do more, but were constrained by the lack of time and resources. Without proper software we had to do everything ourselves. We were the only ones who could use the software and get meaningful results."

"It is still a bit early to conclude to what extent we can use the e-Core technology, but we have now gained considerable experience after testing the technology on fields in the Norwegian Sea," says Odd Steve Hustad, reservoir engineer with Statoil. "First of all, we can get the necessary data very quickly. But, we also generate a lot more information with this technology compared to doing measurements in the laboratory. The result is that we have a consistent and detailed database for early use in reservoir modelling, and that is very useful."

"The aspect of low cost is also very attractive," Hustad adds

Adding all this up, it is no surprise that the Statoil team wants to continue testing the technology. "The technology may turn out to be particularly useful for projects related to "increased oil recovery" that require a lot more detailed information, which can prove tedious to obtain through laboratory measurements," Hustad says.

The e-Core technology has been successfully tested on the Heidrun field.

Ivar Erdal accepted the position as Managing Director of a company based on digital core analysis after more than 15 years in a company that succeeds in conventional core analysis. So far Numerical Rocks have only seven employees, three of which are dedicated to making the new software user-friendly.

A nice ambition

Today, Numerical Rocks is modestly staffed, but it is easy to envisage that they are in the need of a large marketing and service delivery departments if their ambition is to conquer the entire petroleum world.

"We are not in a rush," comments Erdal. "We have to do this without going too fast. You therefore may have to wait a couple of years before you find an office of ours in Abu Dhabi or Houston."

Erdal has been in his new job as Managing Director a few weeks only. But he is no newcomer to the petroleum industry. His last position was General Manager of ResLab (Reservoir Laboratories) Norway who specialises in core analysis and who has gained a reputation for doing excellent work (GEO ExPro No 2-3, 2005). He is therefore well-positioned to predict how the new technology can add to value creation in the petroleum industry.

"Access to an increased database of reservoir parameters may ultimately result in a better understanding of the complex process by which oil and gas fields produces fluids, they being oil, gas or water. Also, more knowledge will assist the petroleum engineer in evaluating the effect of gas- or water-injection and other methods used to maximise recovery," Ivar Erdal says.

"We believe that the e-Core technology has the potential to optimise the production and by that improve the overall recovery."

That's a nice ambition for a company that is in the process of entering the market with a brand new product.