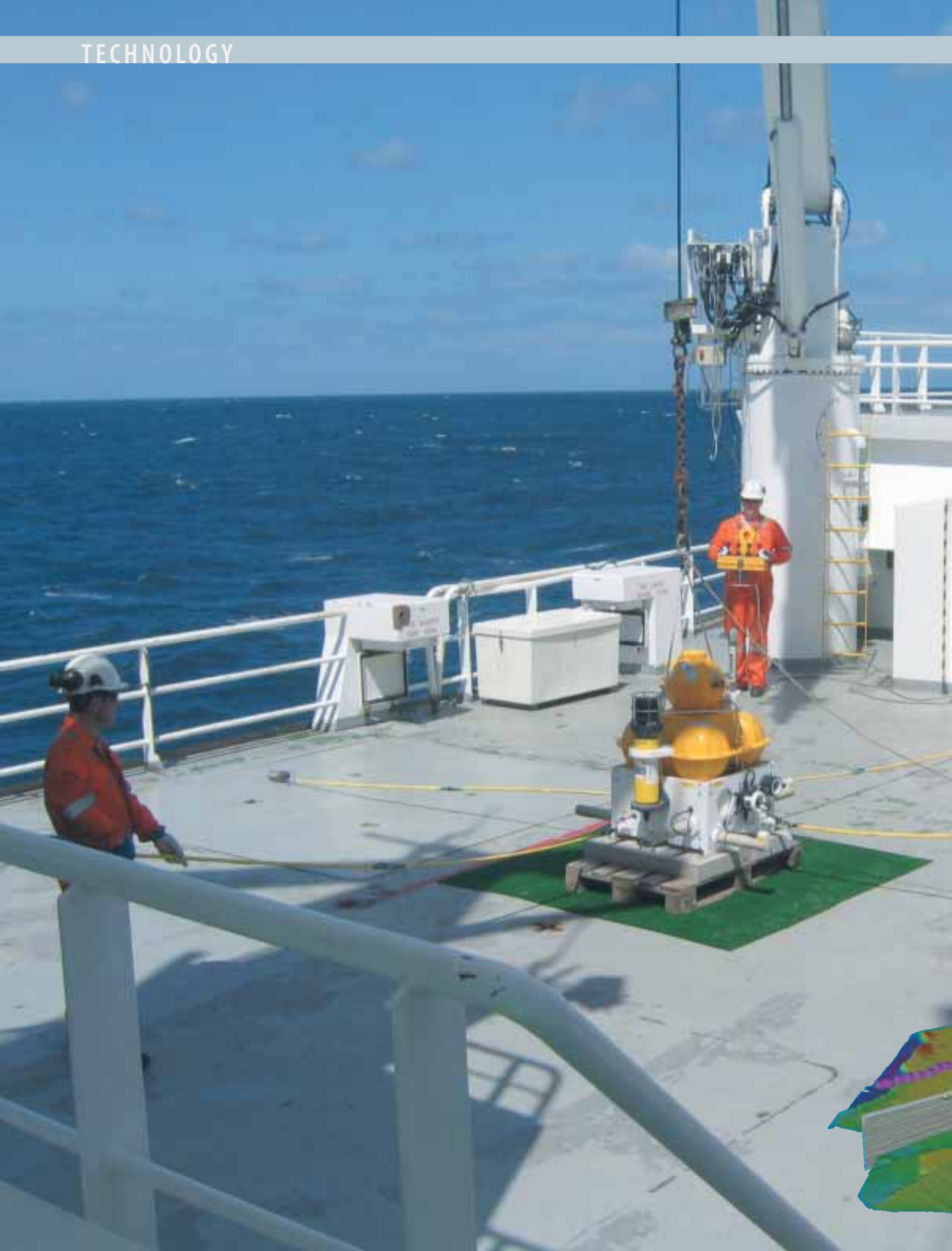


Proving the concept

Just two years after the very first commercial investigation we can confirm that the technology functions as planned. Sea Bed Logging seems to have come up to expectations achieving what was hoped for but thought by many to be too good to be true. The oil companies have, therefore, got a new means of determining whether oil or gas are present before they decide to drill.

Halfdan Carstens

Sea Bed Logging was introduced to the oil industry just two years ago. The new technology, it was said, would make it possible to identify the presence of oil and gas in undrilled prospects. If correct, it would amount to a revolution in the search for new oil and gas resources.

We now know that this revolution has come a long way. Both research surveys and commercial investigations show that the technology functions as envisaged. In particular it is clearly demonstrated that geologists have got a new and valuable tool for both evaluating new prospects and for comparing undrilled prospects. But further developments are exciting, to say the least. The next may be the use of sea bed logging for monitoring reservoirs.

Well known theory

So far we have not experienced any major surprises in the use of the new technology. This is due to the fact that the theory behind it all – Maxwell´s equations concerning the distribution of electromagnetic waves – is well known and well tested. The new feature introduced is its application, says Managing Director Terje Eidesmo in Electromagnetic Geoservices (EMGS). EMGS has taken out a patent on the use of technology and now offers their services to the oil companies.

Together with Technical Director Svein Ellingsrud, a colleague of many years, Terje Eidesmo is responsible for the idea of using electromagnetic waves to identify oil and gas in undrilled reservoirs. These two now form the core in the company responsible for commercialising this technology which reduces the risk in searching for hydrocarbons. The process from idea to commercialization – at Statoil, their former employer – took several years of theoretical calculations, simulation, laboratory testing, field study and, not least, painstaking work with patent protection.

But much energy was used to defend the use of large resources for the development of innovative, epoch-making technology for colleagues and superiors. Not all supported them and at times the opposition was so strong that their work was in danger of being stopped. – Nevertheless we do not deny that Statoil has very much of the honour for the development of the technology, emphasizes Eidesmo.

After more than 40 investigations in several different sediment basins we believe that the technology functions satisfactorily. We are now working to find the limits for its use. Among other things, we are concerned about the depths to which the signals can penetrate and at the same time supply reliable data. We know the answer has to do with the type of equipment we use, which wave-lengths we send out and which frequencies we operate on. We must feel our way forward. It can still take some

Sea bed logging (SBL) is a marin operation using a vessel deploying receivers on the sea floor. The source for the electromagnetic waves is towed behind the vessel and is some 300m long. Doing a survey with one single line can take from a few days up to one week. To the right we see results from a survey on the Troll field. Also shown is seismic and a structural map

time before we finally have answers to these questions. But we are at an early stage in the development of ideas and expect to make big leaps forward in the time ahead, says Eidesmo. He believes this development can be rapid, the reason being that our experience with drill-hole logging over many years has given us much knowledge about the conductive properties of rocks, he maintains.

First a model

The theory behind the propagation of electromagnetic waves is well documented and because we have good knowledge about the electrical conductive properties of rocks it is easy to model the response from the sub-surface when the geological framework is already known from seismic studies and drilling.

The programmes for 2D and 3D modelling have been developed by EMGS. - We have had the advantage of having access to all the knowledge industry has accumulated regarding modelling of seismic data. This can be easily transferred to our problems, claims Svein Ellingsrud who is responsible for technological developments in this rapidly growing company.

Models are important for decision-taking before starting an investigation in a given area using sea bed logging. - After modelling, three possibilities present themselves. We can recommend to the customer that an investigation should not take place, we can inform the customer that in this special case we are uncertain of the response and therefore there is a chance the results cannot be used, or we can conclude that an investigation can give good results, explains Ellingsrud.

We can also foresee in advance the possibility that the method can be used with success. This will decide whether we recommend our customer to start an investigation or not. There are cases in which we have recommended that data acquisition should not be carried out, Terje Eidesmo points out. He is concerned that the customer shall have faith in the company in every single case. Only in this way can one build up trust for the future.

Good test results

The very first commercial investigation was carried out in the autumn of 2002 and since June 2003 the company has worked continually with one boat in operation. The method has so far been tried out in two different parts of the world, in Northwest Europe (the North Sea, the Norwegian Sea and the Barents Sea), and outside West Africa. Data have been collected from shallow depths (100 m) as well as from greater depths (more than 3000 m). A test has also been carried out where the sea floor topography was very uneven (over the Ormen Lange reservoir). The method has also shown its justification in cases where the reservoir has low resistivity.

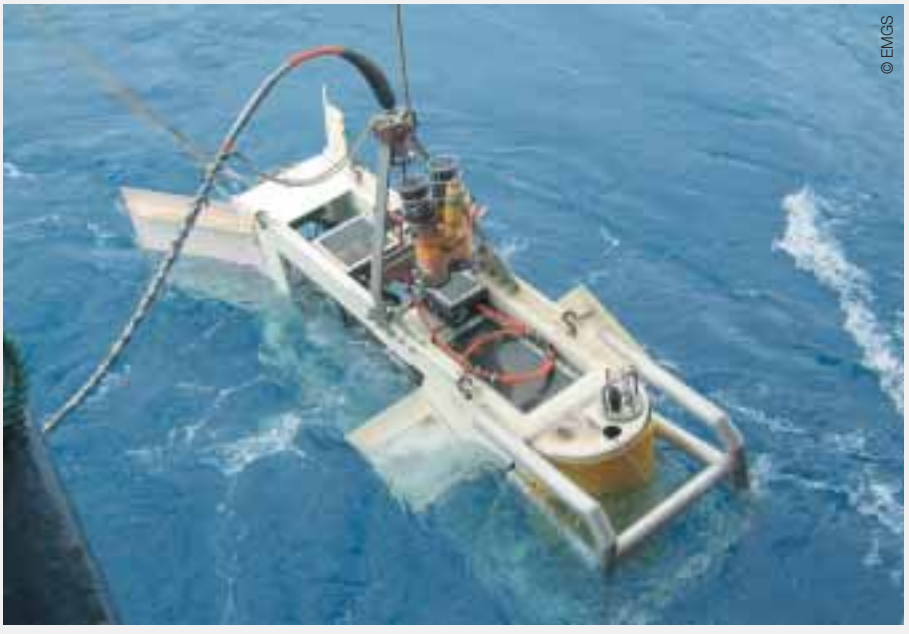
- We have learned very much in a short time span. The conclusion is that I have more faith in sea bed logging than ever before. First I believed in the theory but now we have also experience to back it up, says Eidesmo. – We have also managed to widen the area of application, he adds.

- At the same time we learn more about the limitations of the method and which pitfalls we can fall into. It is important to

Managing Director Terje Eidesmo in EMGS is well satisfied with tests carried out with the new technology over the past year or so. So far he considers the results to be very promising.

Photo: Halfdan Carstens

The fish pulls an antenne cable with neutral updrift in water. It has two electrodes which send a strong current through the water. The cable can be more than 250 m long.



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Today the vessel GeoAngler is used for the investigations. Two representatives from EMGS are always on board. They have supreme responsibility for equipment and data control, but Multiwave has responsibility for equipment. The data are processed on board and the customer can get the first results after a week, or less. It is therefore possible to give recommendations regarding enlargement of the survey area continuously if the results look interesting. The final report on the data, including quality control, takes place on land.

understand that there are other rocks than hydrocarbon-filled reservoirs which have weak conductive properties. A positive response *can* therefore be false but with good regional geological understanding it is usually possible to reduce the risk of making a mistake. One example is volcanic lava which has intruded sediments long after they were deposited, but volcanic intrusions will normally show up in seismic profiles and warn us of a possible pitfall, explains Eidesmo. – Based on these interpretations we can perform a risk analysis giving us a figure for the probability of the method functioning, he adds. There will, however, always be reservoirs where the technology does not work. Some reservoir rocks can, for example, contain clay minerals which render them conductive.

- One of the limitations focused upon at an early stage was that the method could only be used in water depths greater than 500 m. This limit is now 300 m and we have already good results where the water depth is only 120 m. We use the Troll field to develop the method and soon we shall have lowered the limit to 100 m for commercial investigations, believes Svein Ellingsrud.

The depth to which it is possible to record data was also among the uncertainties at the beginning. Today it is proven that reliable data can be recorded down to at least 2000 m under the sea floor and often down to 3000 m even though, in certain cases, only good data can be obtained down to 1500 m.

- We know that the method has its limitations but not where these lie exactly. At the same time we now have enough experience to reduce these limitations and thereby extend the applicability of the method. It is only a question of time, claims Ellingsrud.

The market

It is undeniable that many wiseacres were very sceptical when the new technology was first introduced. But this is a familiar phenomenon. But resistance from different experts within Statoil was not sufficient to stop the development. The volume of experience has now become so great that there is every reason to claim that the technology functions. Therefore must both old and new wiseacres come up with new objections.

- The sceptics are not concerned with limitations. They are mainly interested in testing these with a view to showing that the method is not perfect. For us it is more natural to test the technology where we know it functions and then use the know-how obtained here as a platform for enlarging the area of applicability, says Terje Eidesmo.

Fortunately, those championing development of the new technology have carried the day. – The response in the market is unbelievable though it is still a long way from the first contact with a customer until we have signed a contract. This is to be expected when the principles behind the method are still unknown for many, says Eidesmo.

A future for reservoir geophysics?

- The oil companies are positive. The challenge for us now is to tackle the expectations we have created. We do not believe that the method will always give a final answer as to whether a given basin contains oil, gas or only water. It is not that simple. Even a borehole log can give a wrong answer and here the formation is only 20 cm from measuring instruments. We must therefore ensure that the customer does not lose confidence in the method even though in some cases it does not give a good result.

- This is by no means an absolute method, and it is important that we sell this message too, says Terje Eidesmo. But in cases where modelling in advance leads to a recommendation to carry out a survey the data will, in most cases, give a fairly good indication as to whether oil or gas are present in the reservoir.

So far it has been shown that sea bed logging can be used in the exploration phase. But already speculations can be heard regarding the possibility of using

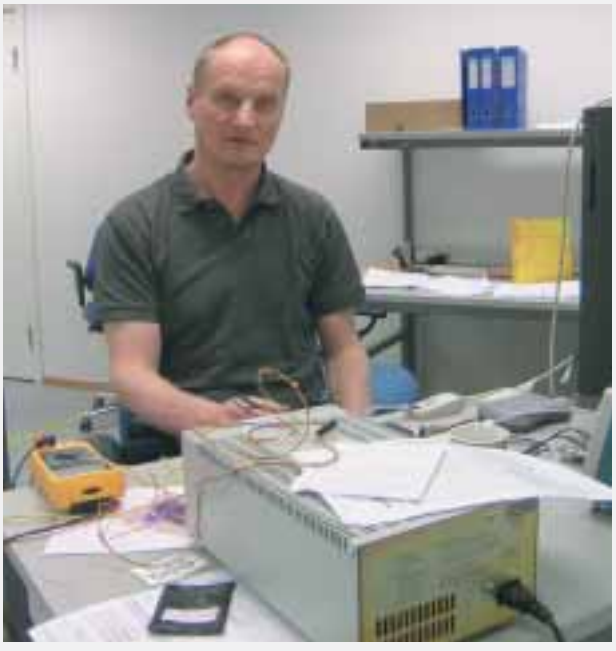
Photo: Halfdan Carstens

Technical Director Svein Ellingsrud is confident that sea bed logging will be used for reservoir monitering in the not too distant future.

Maxwell's equations

Around an electrical conductor with alternating current exist electrical and magnetic fields. In a vacuum or air (almost a vacuum) they move from the conductor as electromagnetic waves with the speed of light – 300, 000 km/s. Light consists of electromagnetic waves.

The british physicist James Clerk Maxwell (1831-1879) developed the mathematical theory for electromagnetism, and in 1864 published the theory which is expressed as Maxwell´s equations.

These equations form the basis for electromagnetic waves and radiation and can be considered as a law to understand electrodynamics. Maxwell´s equations are a system differential equations which show how electrical and magnetic fields are dependent on each other and on electrical charge and current.

the method for reservoir monitoring. I believe the method has a huge potential here. The electrical conductivity is very sensitive as regards hydrocarbon saturation. This means that the electrical resistance in the reservoir will decrease progressively as hydrocarbons are extracted. We have, therefore, already modelled and found out that electromagnetic waves can also be used in the production phase of a field, says Eidesmo.

The use of sea bed logging is currently revolutionizing the exploration for hydrocarbons. It remains to be seen if this new method will revolutionize the production of oil and gas.

The receiver measures the electrical and magnetic fields generated by the source and which have travelled through the ground.

Results from a survey over Troll shown on the Visionarium in combination with seismic and bedding in 3 dimensions.