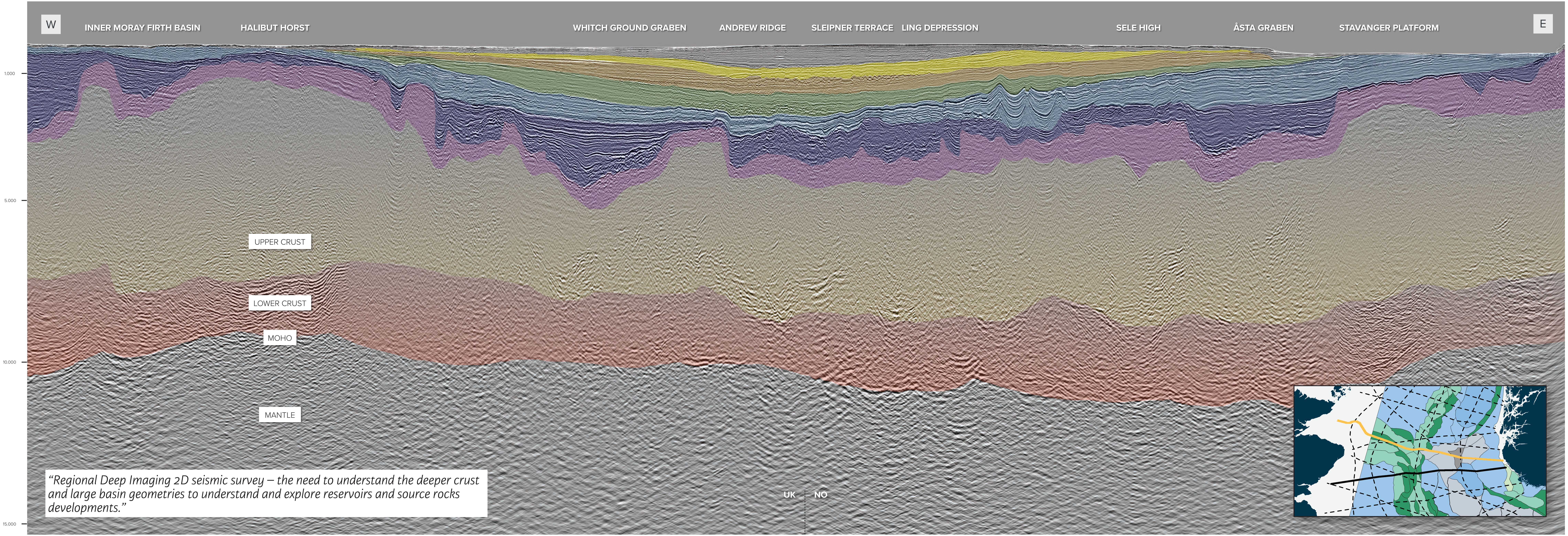
Regional Deep Imaging on The North West Europe Shelf

MCG (MultiClient Geophysical) has embarked on the second season of the Regional Deep Imaging (RDI) campaign on the NW European Shelf. In 2018 (RDI18) we were able to acquire 1,000 km in the Barents Sea and around 1,000 km in the North Sea, going coast to coast between Norway and the UK.



A Regional Deep Imaging line going from the coast of UK to the coast of Norway. Moho is seen at 10–12s TWT.

Looking through Moho

The Moho discontinuity is the boundary between the Earth's crust, both continental and oceanic crust, and the mantle. The Moho lies almost entirely within the lithosphere, except at the mid-ocean ridges where it defines the boundary between the lithosphere and the asthenosphere.

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In the late 80's, the seismic vessel M/V Mobil Search was offered to the Norwegian universities for scientific surveys. One of these surveys was conducted in the Skagerrak Sea and led to scientific papers written by Jan Erik Lie (now Lundin) and Professor Eystein S. Husebye, describing how deep seismic (0-16 s TWT) could reveal faults in the upper crustal basement (Techtonophysics 1993).

During that period, the streamer was typically towed at 7-9 meters to avoid the ghost in processing. Presently, we are now familiar with the broadband, deghosting processing which mitigates this challenge. The streamer can be towed much deeper.

Inspired by this, Jan Erik and Lundin, did many tests with SeaBird's M/V Harrier Explorer in 2015 on different streamer depth and configurations, such as straight/slant/undulating streamer depths. These towing tests proved you could tow the streamer well below the 'noisy' sea (typically 3 times the wave height) into the deeper, significantly quieter water and actually record and detect, after deghosting, the weak, low frequent, deep reflectors all the way down to the Moho.

Encouraged by these results, Lundin (as well as Cairn and Edison) sponsored a regional multi-client 2D survey in 2016 in the Norwegian Barents Sea where the streamer had a depth from 15 to 60 meters. Resulting in the successful imaging of Moho!

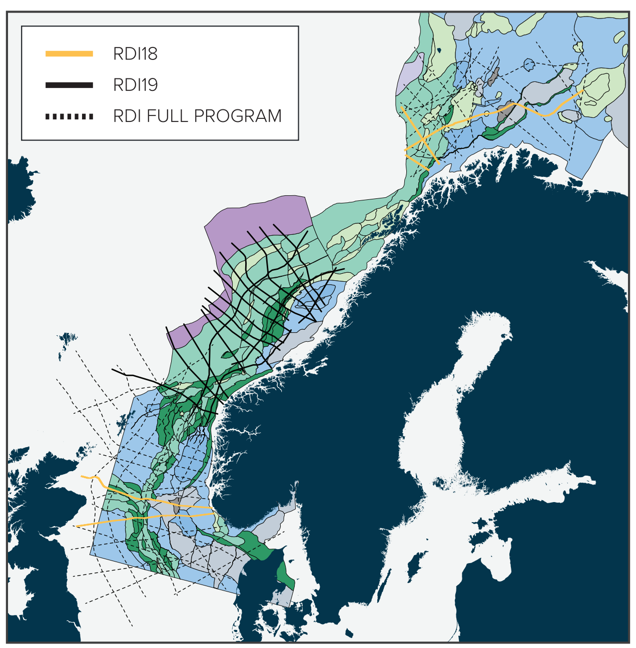
In 2018, a new and more ambitious Regional Deep Imaging (RDI) campaign was initiated. The idea was to cover the NW Europe shelf from the Barents Sea, the Norwegian Sea and the entire North Sea from coast to coast in areas open for exploration, with a consistent deep imaging 2D seismic survey. This would provide the explorers with a much better understanding of the regional basin geometries and structural evolution. The RDI does not see the borders between the different countries but the boundary between the crust and the mantle!

Lundin also play an important role in the RDI campaign, being responsible for the processing which is performed by DUG. Due to late arrival of both seismic vessel (again the M/V Harrier Explorer) and sponsors, but consistent work from Toril Leite (former SeaBird) and MCG, we were able to acquire three lines in the Barents Sea, one of which runs from the Russian border to the very western Norwegian Barents Sea, and two lines in the North Sea which run from the Norwegian coast to the UK coast.

The seismic line on the previous pages shows one of the lines from the RDI18 in the North Sea, running from the Stavanger Platform in the east through the Southern Viking Graben and into the Inner Moray Firth Basin in the west. The line shows that the RDI18 campaign successfully imaged the top and base of the crust as well as giving a regional understanding of the mega-sequences deposited from Devonian/Carboniferous to Recent.

The main focus in the processing has been to enhance the image of the crust, but also to image the deposited sediments which is a challenging task. The section shows how the Moho is successfully imaged between 10 to 12 s TWT and that there are deep seated faults and differences in the thickness of the crust across the North Sea. This is perhaps better illustrated in the 'crust enhanced' display on the opposite page. The influx of sediments from both east and west into the basin can also be easily recognized.

To obtain an even better control of the main structural elements and the depth to the Moho, gravimetry and magnetic data were also acquired. These have been processed by CGG and modelled by Mats Andersson from Envision. Andersson's interpretation shows the preliminary results of this modelling. The colours show the density contrast while the numbers show magnetic (susceptibility) contrasts. There is indeed a good match between the observed and the modelled anomalies. The individual sediment sequences do not have a major impact on the gravity and magnetic modeling results.



Map showing the acquired lines in 2018, the RDI18, in yellow, the current RDI19 campaign in solid black line and the remaining RDI20 campaign in dashed black lines. Underlying is the geological feature map from NPD.

The crust itself is divided into the Upper and Lower Crust. The Lower Crust has no magnetic susceptibility due to the relative high temperature. While the Upper Crust magnetic susceptibility varies quite a lot, this is probably due to different compositions of the basement rocks.

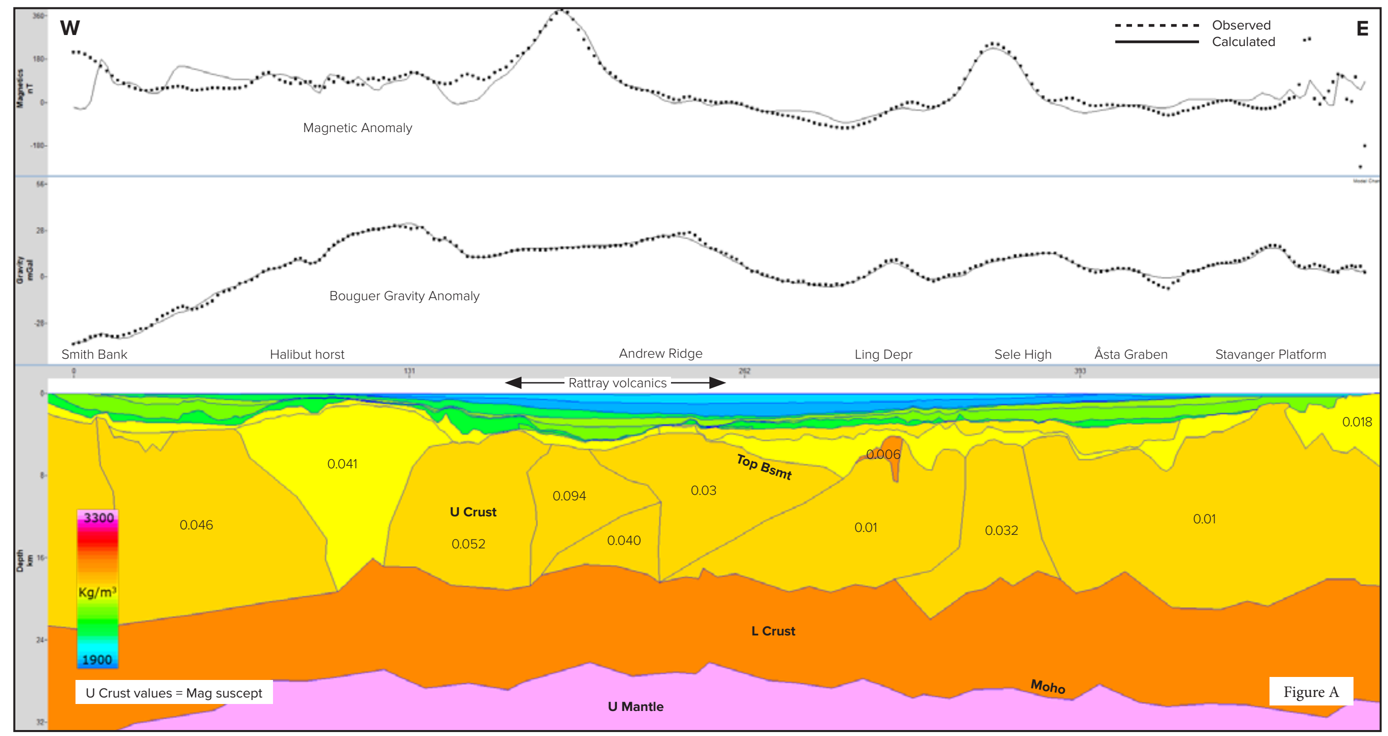
Furthermore, the modelling and the seismic show that the thickness of the Lower Crust is fairly constant, while the thickness of the Upper Crust varies considerably. One interpretation of this observation is that the Lower Crust is more ductile than the Upper Crust which seems to be more brittle. This has implications for faulting, heat flow and in the end maturation of source rocks.

Another interesting observation of the crust is that the Halibut Horst has a pronounced gravity anomaly but little magnetic anomaly. The magnetic anomaly is much larger over the Rattray volcanic province. The Sele High has both a magnetic and gravity anomaly.

Do these observations make changes to the tectonic understanding we have today?

In 2020 MCG will acquire more lines in the North Sea (see map), the RDI20, to better understand the relationship between these differences observed in the seismic and modelled in the gravity and magnetic data.

MCG started late July the RDI19 campaign which will focus on the Norwegian Sea. With more than half the streamer at 30+ meters we have observed very quiet data with a noise level of only 2-4 micro bars. Hence, we again expect to see the deep part of the crust and we are looking forward to seeing what the seismic and the gravimetry and magnetic data will reveal of secrets from this huge area. The RDI19 campaign will be 7,000 km and the processing should be completed early next year.



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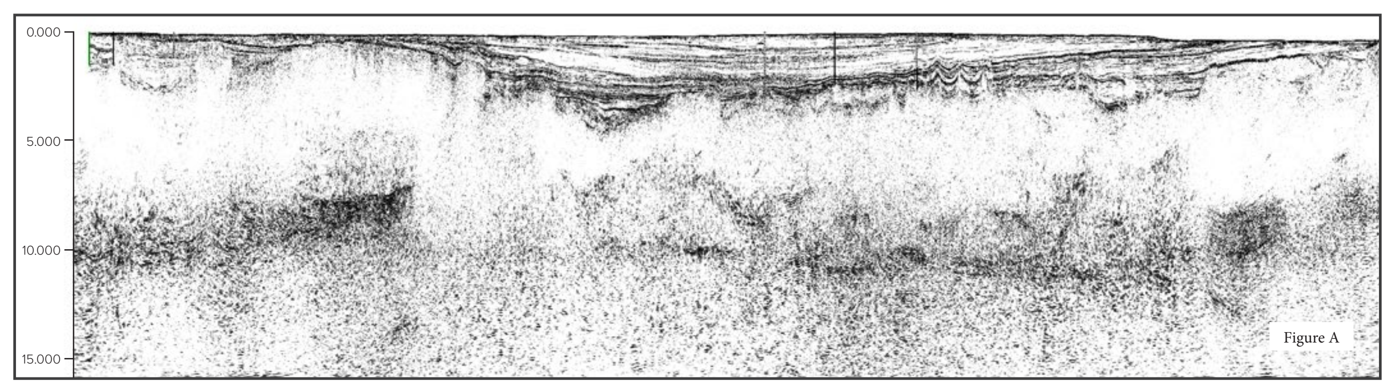
Gravity and magnetic modelling results. On top is the observed and modelled magnetic anomaly. In the middle the Bouguer gravity. At the bottom the preliminary showing density in colours and susceptibility in numbers. Main geological boundaries are the Moho, the Lower and Upper Crust and the Basement.



Provided by Lundin.

Same line as in the foldout on pages 44-46 but scaled and displayed to enhance the crustal structures.