Introduction

The Vertical CSEM method developed by Allton (Holten, 2009) has been used by Norwegian oil company Concedo for exploration purposes during the last decade. In 2017, a 480 km^2 multiclient survey (PM17250) was acquired by Allton on the Eastern part of the prolific Haltenbanken province of the Norwegian Sea. This area has been one of Concedo's important focus of exploration since the company pre-qualified in 2007, with numerous prospects identified on the basis of seismic data mainly. As part of the de-risking strategy for both owned production licenses and acreage opportunities, Concedo licensed the PM17250 data as early participant. Within the acquisition area, covering two differentiated sectors to the East and South of the Heidrun Field respectively, a prominent horst defined at the BCU level had remained undrilled by the time of acquiring the CSEM survey (Figure 1). The horst, currently within PL889 (operated by Neptune) was named the Grind Prospect, with main reservoir target in Middle Jurassic sandstones of the Fangst and Båt groups. Although this moderate size structure, 10 km to the East of the Heidrun Field had been known for decades, the high charge-risk had prevented companies from drilling it earlier. The reason was that two similar structures along a NS-trending ridge just 5 km west of Grind, proved to be dry, raising the question of migration failure to the East of Heidrun.

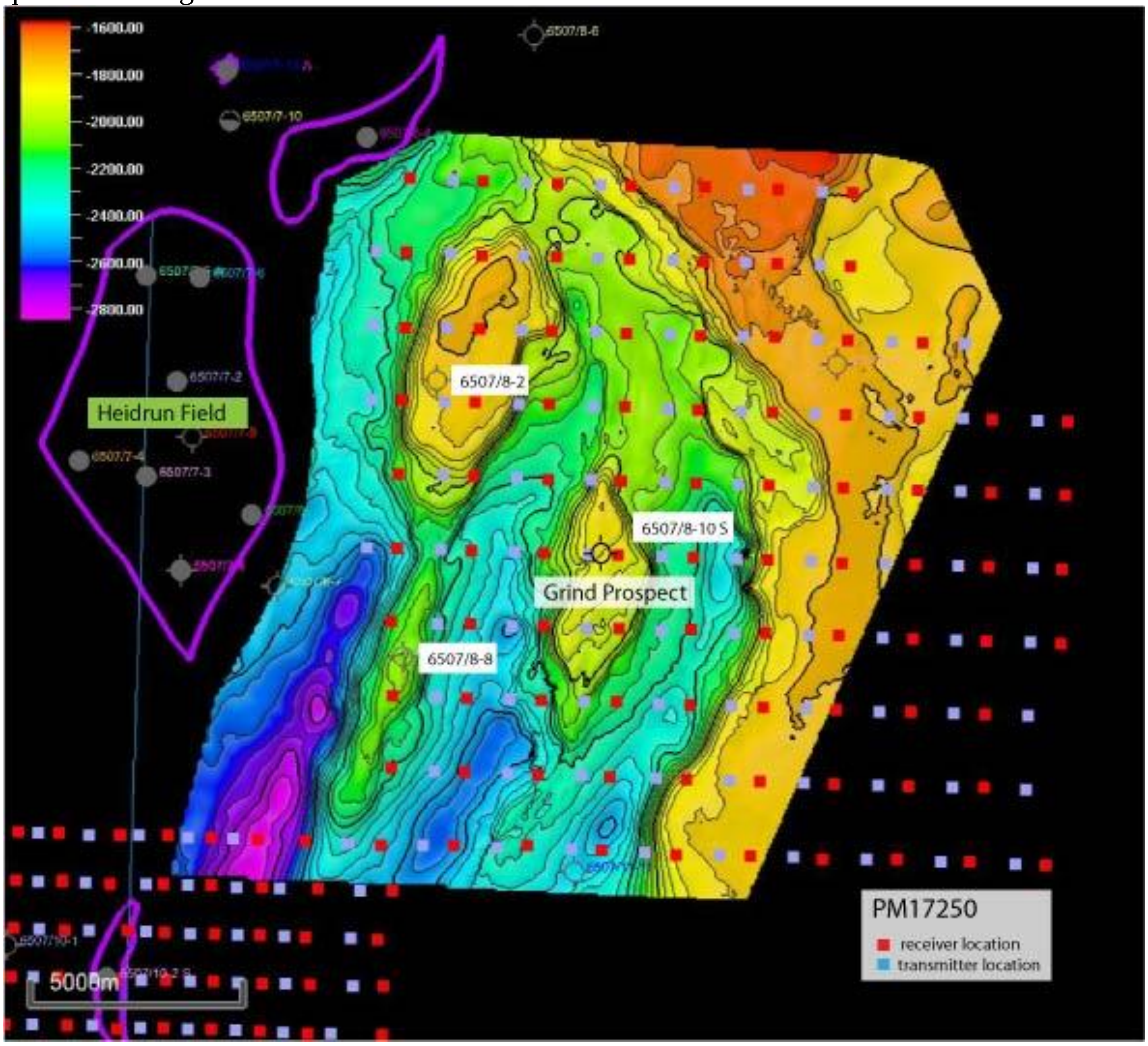

Figure 1 *Survey layout of the PM17250 CSEM acquisition overlying a BCU time surface. The Grind Prospect and well location is in the center of the figure. The location of the two dry wells to the West of Grind are shown along a prominent NS-trending ridge.*

Earlier in 2012, Concedo considered to apply to the APA licensing round with Grind (then called Epsilon) as the main target on block 6507/8. Concedo engaged Allton to acquire an exclusive 2D survey consisting of one single line along the strike of the Grind horst. Prior to acquisition it became clear by a feasibility study that the area was suitable for CSEM detection of a prospect with the characteristics of Grind. Despite the relatively small areal extent of the prospect, its moderate burial depth, combined with a 400 m water column and a notoriously low-resistive background made Grind an easy target for the vertical CSEM method. The inversion results came with negative news for the Grind prospect. The expected low-resistive background trend dominated the entire section from seabed down to the half-space threshold at 3000 m depth. While the subtle overburden resistivity trends were nicely depicted, the Grind horst was devoid of any resistivity anomaly and was indistinguishable from the background trend. Such a negative outcome in a suitable CSEM context made Concedo abort the application process.
In 2017, production license PL889 containing the Grind Prospect was awarded to Concedo, after having applied on the basis of another prospect. Once again, both 2D and 3D inversion confirmed the absence of relevant resistivity anomalies at the location of the Grind prospect. The results are strongly consistent with the local stratigraphy of the 2 km plus thick overburden layer. The characteristic low resistive layer representing the Lower Tertiary and Cretaceous interval extends further deep to include part of the Jurassic prospective layers before becoming gradually more resistive with depth (Figure 2). Further South within the southern sector of PM17250, the known discoveries of Novus (6507/10-2S) and the northern tip of Midgard produced significant anomalies.

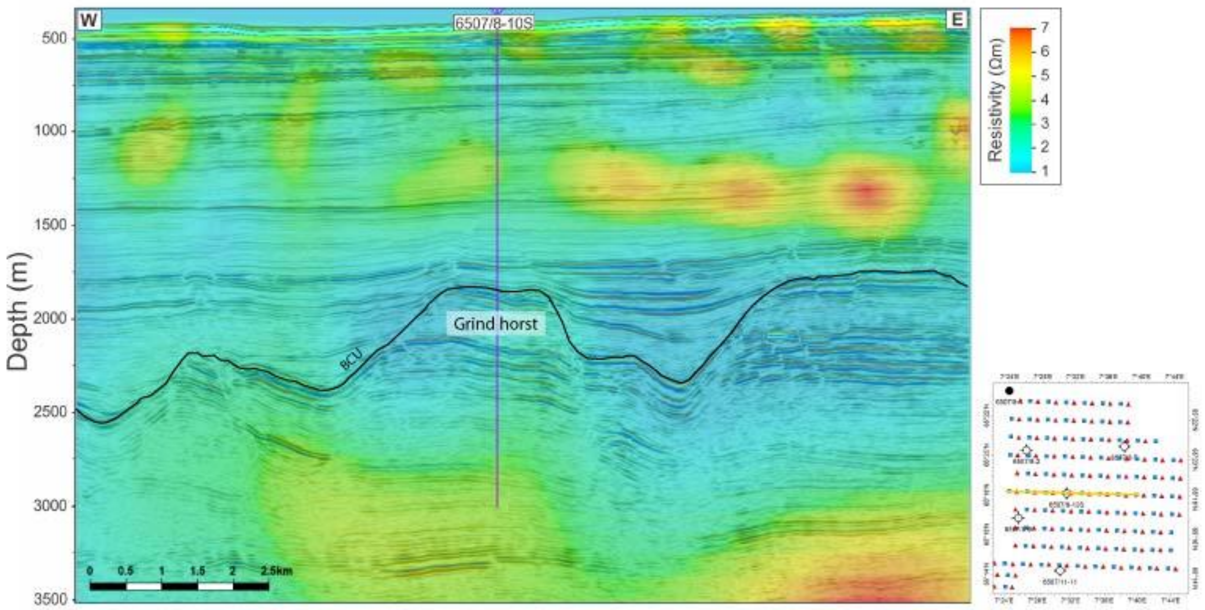

Figure 2 *Seismic depth section across the Grind horst with superimposed 3D inversion profile of the PM17250. The negative results of well 6507/8-10 S are in accordance with the presence of a continuous, 1 km thick low resistivity layer centered at the BCU surface (thick, black line).*

After the PL889 operator proposed to drill the Grind prospect, Concedo and DNO withdrew from the license and new partners entered prior to drilling. The negative CSEM results in such a favorable context for the Grind discovery case were considered by Concedo as valuable to help to take this decision. By late April 2020, the well results after the drilling of Grind were made public. The NPD press release read: *The well encountered the Tilje*

Formation about 150 m thick, of which 100 m net sandstone with good to very good reservoir quality. The Åre Formation was 195 m thick with 100 m net sandstone of good to very good reservoir quality. There were no oil shows and the well was classified as dry.

Method and/or Theory

Allton`s benchmark EM technology is known as the "vertical CSEM method" and it is characterized by the use of vertical electric dipole antennas (Helwig, 2019) both on the transmitter and the receivers. The receivers are dropped to the seafloor in predefined positions and adjusted automatically for verticality. The lower electrode of the transmitter is positioned on the seafloor, and the upper source electrode kept in a vertical position with a DP 2 vessel. The signal is transmitted in time domain, by sending a strong electric current of 5000 A for typically 5 seconds, and then switched off for 5 seconds. This is repeated for typically 30 – 45 minutes to stack the signal. The signal discharging from the subsurface after shutting off the transmitter, gives the response of the subsurface resistivity. This way of acquiring CSEM data enables a much closer offset between the transmitter and receivers, compared to the traditional horizontal CSEM method, and have therefore the ability to detect smaller targets.
Most of the PM17250 survey, including the sector containing the Grind prospect, was acquired with a 1700 m receiver spacing 3D grid. Only a specific target area south of Heidrun was acquired with a denser spacing of 1100 m. The PM17250 survey came after an important technological upgrade of the Allton EM method, with a new generation of sea-bottom receivers and improved 2D inversion solution. A new 2.5D forward modelling confirmed the feasibility for vertical CSEM of the survey area for moderately deep prospects (2000 m) of the size of Grind.
The survey sector East of Heidrun (covering Grind) consisted of 10 E-W striking lines, each between 12 and 15 km in length. The Grind prospect was thus dissected by at least three different lines, at right angle with the elongation of the horst. Despite being a narrow structure, multiple 2D inverted lines and full 3D inversion should readily resolve a Grind discovery case.
3D time-domain unconstrained inversion was carried out by CGG and 2D time domain inversions by Petromarker. 3D anisotropic inversion was run covering offsets of 1900 to 2900 m and times of 0.056 to 3.99 s after source switch -off. The majority of the 3D inversions began with an a priori model based on seismic horizons and resistivity from well logs, subsequently refined by 3D-constrained 1D inversion.

Conclusions

The use of Vertical CSEM data as a prospect de-risking tool has proven useful in a negative scenario case such as the Grind Prospect. Although being aware of the known uncertainty behind CSEM methods, this case is built upon a strongly positive feasibility scenario of this particular region. This fact, together with the the reasonable calibration of the survey to the known discoveries made the possibility of a false negative unlikely.

References

Helwig, S.L., Wood, W. and Gloux, B. [2019]. Vertical–vertical controlled-source electromagnetic instrumentation and acquisition. *Geophysical Prospecting* **67** (6)

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