Introduction

During the installation of the Clair Ridge jacket in 2015, BP encountered significant variation in piling depth, predicted by the geotechnical campaign, but undetected by seismic, despite having shot 2D UHR data using an air gun source on a 50m grid. In preparation for the installation of a platform at Clair South, we wished to avoid repeating this problem. It was determined that in order to reduce risk of this re-occurring we would need to be able to image with confidence boulders, channels (20-30m wide) and other geological features that can slip through a 50m grid of 2D data, and thus set our spatial and vertical resolution goal of 1 metre to a depth of 30m below the seabed.

In terms of the vertical resolution, previous attempts to used high frequency data (>3000Hz via CHIRP) at Clair had failed due to the penetration issues associated with the hard sea bed. However, recent advances in sparker sources (Normark, 2014) and a BP survey in 2016 in a similarly traditionally challenging area gave us confidence on embarking on a 2D technology test at Clair (2018) which yielded images with frequencies in excess of 2000Hz. We then commenced further modelling studies to determine what spatial sampling was required in order to capture such frequencies. The results of which used to inform our 3D acquisition for 2019 over an area of ~1km$^2$.

Method - 2D field trial

Following successful trials of sparker data both elsewhere within BP and by others in the renewables sector, albeit in significantly softer sea bed environments, we were encouraged to try once more with this technology at Clair. The 2D line was designed to tie an existing shallow borehole (BH1 at Clair Phase 1) and a typical area representative of Clair South.

The test line was acquired twice, once with a conventional 2UHR airgun source (5 cu in) as a control and also with the multi-level stacked sparker source. The streamer was made up of 24 channels at 1.5625m (near offsets) and 24 channels of 3.125m (far offsets). The shot interval was ~ 0.78m and a typical shot is shown in figure 1.

This initial data, whilst encouraging, did identify issues with the source configuration, where the delays had been coded in milli-seconds instead of micro-seconds. As such it was only a partial success, but it did validate our proof of concept at Clair. We re-acquired the 2D line in mid-2018 with the correct source firing delays resulting in significantly improved bandwidth as shown by figure 2.

To maximise our chances of extracting most out of this data, the line was processed with several vendors. The outline processing flow was broadly similar, but despite this, the results varied considerably. The key approach was around deghosting, denoise, wave-height compensation and residual statics. A comparison of the different results is shown in figure 3.

During the processing of the 2D we were able to establish a robust and speedy workflow in preparation for the 3D survey.

We also took the opportunity to validate some of our sampling assumptions in the inline direction as a proxy for what would be our crossline sampling. During our pilot processing, we also looked at depth migration, ran FWI and even output an RTM to 2500Hz.

Results - 3D deployment

Due to cable availability, the 3D was acquired with a 48m cable length rather than the longer cable of the 2D trial, As data was not overly velocity sensitive and via analysis of the 2D line, we concluded that this would not compromise our results in our key area., we took the decision to focus on the very near offsets for the 3D. Having a shorter cable allowed us to improve our fold as we could then have a 1m channel increment. The acquisition layout is shown in figure 4, where we tow the cables 8m apart, which with flip-flop shooting allows us to get to a 2m crossline bin size and via interpolation allows us to resolve to 1m at 2000Hz, although much above 1200Hz is noisy 10m below mudline, but this is...
successful as the natural aliasing condition is around 800Hz. The source was again a multi-layer (0.45m, 0.6m and 1.2m) source shot at 0.75m intervals and in total we acquired in excess of 118 sail lines over a period of 6 days.

**Figure 1** – a typical shot, with a very clear ghost arrival, note the change in channel interval from the mid-point in the cable

**Figure 2** comparison of spectra from the 2D test line, original (incorrect source delays) in blue, corrected (green) and final processed (red)

**Figure 3** comparison of various vendors processing of the same data which shows considerable variation. The “bump” is as the survey passed over the Clair pipeline.
As a result of the pre-work carried out on the 2D line, the final deliverables from the 3D acquisition were delivered within 4 weeks of last shot, despite the full fold area being 1km² the dataset is of considerable size (equivalent to 575km² of data on a 25m x 25m bin, 9.6 seconds at 4ms) and delivering the data in this time frame was a success.

**Figure 4** acquisition geometry for the 3D survey.

The final data allowed us to see boulders in the shallow section below our 2m criteria and also resulted in seismic volumes with a 20-30cm vertical resolution. This data has led to the moving of the proposed location of the platform.

**Figure 5** An image from the final 3d volume.
**Figure 6** an amplitude extraction from the top 5m showing the spatial resolution acquired.

**Conclusions**

The final data allowed us to see sand filled wallow puts (20-30m wide – smaller than our standard 2DHR grid size) and small (less than 2m) boulders are detectable in the shallow section. The survey has also resulted in seismic volumes with a 20-30cm vertical resolution and interpretation of the data has led to the moving of the proposed location of the platform.

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**References**

Normark, E., Bendixen, C., Jensen, J., Clausen, O. [2014] Simultaneous Acquisition of Aigrun Seismic and High Resolution Sparker Data – Combining the two types of data,. EAGE Near Surface Geoscience conference.