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Improving Subsalt Imaging with a New Seismic Acquisition System

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SUMMARY

Traditional marine seismic acquisition methods (streamer, OBC) struggle to address the combination of high data quality and large survey areas needed to image sub-salt reservoirs and prospects. This article will describe a completely new seismic acquisition system that delivers higher quality data within an acceptable time frame, and the key advantages it delivers for sub-salt and other challenging geological settings. Test results will illustrate some benefits of the system.

Introduction

Sub-salt imaging requires very high quality seismic data. Long offsets are needed to resolve salt dome flanks and undershoot salt bodies to illuminate deep targets. Full azimuth seismic data acquisition vastly improves data resolution, addressing the complexities associated with salt's high velocity contrasts, and enhances illumination capabilities by bringing azimuth diversity. Broadband data significantly improves the use of quantitative interpretation methods.

Streamer-based marine seismic acquisition methods have inherent limitations in delivering full azimuth illumination. Costly multi-vessel or repeat shoot methods only partially make up for theses limitations. Sea-bottom nodes or cables deliver excellent full-azimuth data, but they are very costly and time-consuming. The new system FreeCable^{TM} combines a high productivity with the very high data quality of sea bottom techniques, minimizing trade-offs due to time constraints or budgetary concerns.

Description of the new method

The main originality of the system lies in the set-up of a receiver array and the way it is operated. The receiver consists in a set of cables that are pseudo-stationary relative to the seabed and floating in mid-water, referred to as Midwater Stationary Cable (MSC). Each MSC is physically independent of the others and attached at each end to an Autonomous Recording Vehicle (ARV) that controls the MSC's position, provides electrical power and records the data from the cable. Each MSC is fitted with hydrophones and geophones to measure both wave pressure and velocity. A fully braced acoustic network is integrated in the system to provide accurate positioning data.

Many configurations are possible, and different shooting methods can be used. This article presents a large configuration using the patch method, which prioritizes very high data quality and good productivity. The configuration of the system (Figure 1) comprises 8 km MSCs which include one 4C station every 25 m (320 stations per cable); the system spread consists of 20 parallel MSCs spaced by 400m, leading to a receiving area of 8 km by 8 km; immersion depth is between 10m and 100m.

The 20 MSCs are stationary. The shooting vessel sails orthogonal to the MSCs, shooting every 25m, with an inter-line spacing of 400m. Overshoot of 4 kilometers is used on each side. It is a stop & go process: once the 8x8 km is covered, the array moves to the contiguous zone.

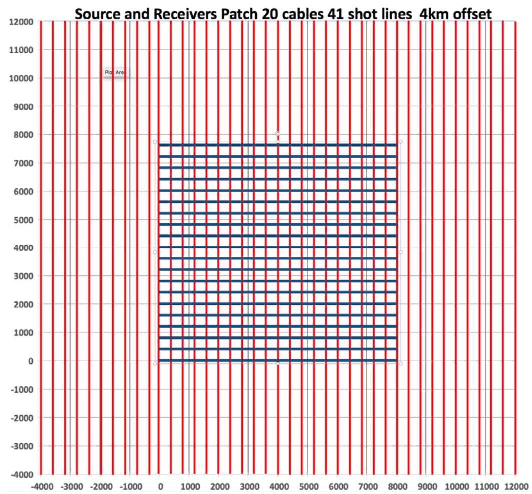

Figure 1 *Patch method configuration: Blue = MCSs Red = shot lines*

Advantages of the system

Low noise 4C data and wide spectrum: The level of noise is significantly reduced compared to towed streamer technology thanks to the fact that the MSC is subject to much lower tension, is stationary during shooting and operates at depths that are below the zone of wave motion. The good quality obtained on geophone signals at low frequencies (thanks to reduced tension and vibrations) allows receiver ghost cancellation to be done at any depth, leading to a flat spectrum over the full seismic frequency band including very low frequency content.

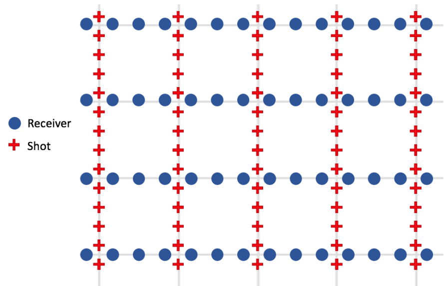

Figure 2 *Shot point (+) and receiver (o) sampling*

Data richness: 3D, high fold, full offset, full azimuth: The method produces full 3D high fold seismic data with full azimuth and full offset (including zero offset). This is obtained by exploiting the fact that the sources and the receivers are not linked and the shooting vessel navigates freely in the survey area. The method uses an ideal geometry with regularly spaced receivers inline and regularly spaced shot points crossline (Figure 2). It leads to a natural square bin of 12.5m x 12.5m in this configuration, with a seismic fold of 400 in the natural bin. Each patch produces 64km² of coverage. This high coverage per bin greatly improves the post-stack signal-to-noise ratio (+26 dB). The geometry produces a completely isotropic response since full offset full azimuth is obtained in every bin (Figure 3). The full 3D acquisition brings among others two qualitative advantages: in complex subsalt geological structures it will improve the illumination of zones appearing as shadow zones for other methods; it also provides richer data for AVOA (Amplitude versus offset and azimuth) reservoir characterization studies.

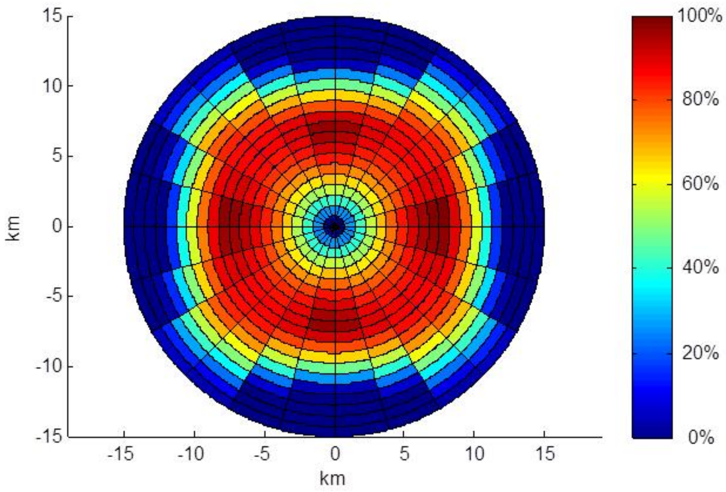

Figure 3 *Rose diagram in full fold area.*

Productivity and HSE: The receiving area of 64km² means each shot results in a large volume of data. With the cable at significant depths, there is little weather downtime, and productive times in excess of 90% have been achieved. Estimated productivity is a 3-fold improvement on OBC. HSE benefits relate to the very low fuel consumption of the ARV's, and the option to use a weaker source for the same final signal-to-noise ratio, which is favorable for marine mammals and fishery activities. There is no impact on the sea bed, avoiding damage to delicate ecosystems or to sea floor production facilities surrounding platforms.

Operational experience

Surveys were acquired in an area comprising water depths from 0m (shore) to 400m, with islands and a drilling rig making the planning more complex. Different patches were acquired in shallow water and in deep water, with very high productivity. The MSCs moved from one acquisition area to the other using the ARVs' propulsion system, and used their ability to navigate around obstacles. An initial processing run produced a stacked 3D volume and a Kirchhoff migrated 3D volume. The processed data demonstrates high quality results with a broad frequency content, despite complex currents and relatively shallow cable depths.

Conclusions

Sub-salt exploration and production is a demanding target for seismic imaging. A new system has been developed to address these challenges. Generally speaking, the system combines the advantages of both streamer and OBC/OBS techniques, providing an efficient high end 3D method.
It may also be described as performing land acquisition at sea with a perfectly sampled geometry, without the complex statics from the surface weathered zone and without the terrestrial obstacles such as mountains or forests, thus offering full offset full azimuth in a regular square bin with high fold.