Does Your FWI Dive Deep Enough? A New Acquisition Platform for Ultra-Long Offset Data Recording

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Summary

Benefits of ultra-long offset acquisitions and low frequencies usage are evident for both the academic and seismic industry community but due to technical issues it has often been considered as low efficient, cost & time demanding and not easily applicable. To overcome these technical and cost issues, Geology Without Limits (GWL) has developed a new technology able to emit low frequencies (GWL LF Source™) and record ultra-long offsets (GWL Seismobuoy™) in a cost-effective way. These tools have been successfully tested during field trials and are fully operational. They form the basis of a new seismic data acquisition method FloatSeis™ (perfectly suitable for FWI velocity model building data acquisition technique).

Introduction

Velocity is a key to clear seismic image and reliable time to depth conversion. In 90% of cases companies use 2D/3D CDP marine seismic acquisition to obtain both structural image and a velocity model. Unfortunately, based on overall experience, CDP velocities fall within ±15-20% of the true velocities. In complex geological environments (salts, basalts, irregular bedding, high-velocity formations and so called “gas chimneys”) CDP velocity field tends to be even less reliable. As a result, unsuccessful drilling continues to be the major source of concern.

Full Waveform Inversion (FWI) (Tarantola, 1984) is a game changer approach for velocity model building. It uses two-way wave equation and carries out forward modeling to compute the difference between the recorded seismic data and the present velocity model. As a result, high-fidelity velocity model that misses all the drawbacks typical for CDP velocity analysis and traveltime tomography is derived. FWI approach has potential to become a key tool to interpret seismic data acquired in complex geological settings and grow into a new standard for velocity model building.

The important stipulation is that the majority of impressive results achieved by FWI were accomplished on synthetic data. The reason is that CDP method drives standards for seismic equipment. Streamer length is limited by 12 km and seismic source usually has a 10-70Hz bandwidth with a dominant frequency of about 30-40 Hz. Data sets acquired with such parameters are not able to unleash the whole potential of FWI approach. It has been demonstrated that with much longer offsets and good low-frequency component, FWI can produce significant seismic image uplift and can potentially help simplify the labor-intensive salt-model building (Chao Peng et al., 2018). Acquisition of long-offset seismic data with help of equipment available on the market demands significant extra expenditures. Meanwhile low frequency component will be still missing. To keep costs down and ensure both recording of ultra-long offsets and low frequency component GWL has developed a new acquisition platform being based on two tools: a drifting recording unit and a low frequency source.

Drifting recording unit

GWL Seismobuoy™ is a free drifting standalone seismic recording device designed to record ultra-long offset seismic data at offsets up to 120 km. GWL Seismobuoy™ sensor frequency range of 1-1000 Hz is perfect for recording low frequencies, that can be beneficial both for FWI data sets and deep targets illumination.

The recording unit was initially designed to provide superior operational integrity. The device control and data transferring are maintained by wireless connection. In this manner we were able to design the unit without any connectors and need for dismantling. In-built satellite communication channel enables online tracking the status of the data recording process, the battery charge level and the readings of internal auxiliary sensors (temperature, humidity and accelerometer). Constant automatic humidity control permits to quickly respond even to a small leakage of the unit and replace it immediately with a leak-tight one. The armoured cable with hydrophobic filling prevents the unit from short circuit in case the cable shield is damaged. All these factors drastically increase the overall integrity of each unit that is crucial for an autonomous overboard equipment.

GWL Seismobuoy™ as well as OBS and other seismic equipment is utilized in a seawater environment. Corrosion aggressiveness of seawater is complex, with many factors such as salinity, temperature, dissolved gas content, water flow and turbulence (Schumacher, 1979). During the OBN programs, the seismic equipment suffers from accelerated rates of corrosion. Survey durations of over 2 months may require additional spare nodes (Stone et al, 2016). GWL Seismobuoy™ body is made of heavy-duty polyvinyl chloride that makes GWL Seismobuoy™ corrosion free, light weight and inexpensive in fabrication but reliable and long-lasting seismic recording device in a severe operating conditions.

Acquisition technique

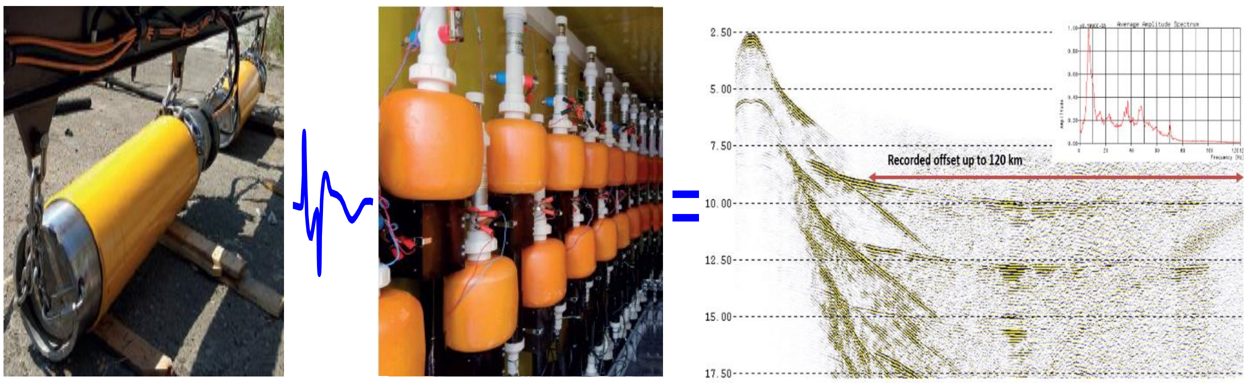
The main idea of the new FloatSeis™ acquisition technique is to make long-offset surveys much more affordable, especially nowadays in a low oil price environment. There are several main factors that allow to considerably reduce the total price of the long-offset seismic survey.

The main costs of any marine seismic survey fall on hiring of vessels involved. FloatSeis™ has a good survey's economy comparing with known alternatives. Utilization of a portable, container based, easy-to-transport, assemble and install equipment (GWL Seismobuoy™ and GWL LF Source™) allows to rig small gross tonnage vessels (about 300-500 t) both as shooting vessel and as a recording units deployment/recovering vessel, reducing the hiring expenditures and MGO consumption.

The deployment and shooting speed can be amounted up to 7-8 knots. This is possible because no seismic streamer is towed behind the vessel. Thus all limitations peculiar for a towed seismic streamer surveys are not applied to the FloatSeis™ acquisitions. The upper part of the recording unit is always settled down above water level making detection and recovery of the unit being fast and convenient. This is especially notable on deep water areas when compared to OBS surveys. Thus FloatSeis™ survey is able to maintain the same speed of data acquisition as the towed streamer seismic giving overall lower costs.

Real-time GPS positioning and online QC gives substantial advantage in comparison to OBS/OBN surveys for a given type application in respect of efficiency, quality and safety through data acquisition.

Recent experience and lessons learned



Lesser Antilles FS line was aimed at testing GWL FloatSeis™ technology capabilities in a complex geological environment. The simultaneously acquired 295 km of long-offset 2D seismic streamer data together with GWL FloatSeis™ super-long offset data helped to reveal add value that GWL FloatSeis™ technology is able to bring to the market. 2D towed seismic streamer data was acquired with help of a 12 km streamer and a standard 7060 cu. inch air gun array. Free drifting recording units deployment spacing was 6 km and shot points spacing equaled to 50 m.

Dominance of diffractions and ray bending associated with steep dips and irregular bedding reduced veracity of CDP velocity analysis causing CDP velocity model being "patchy" and non-geological. Presence of high-velocity igneous layers caused problems with energy penetration because of the large seismic impedance contrast. Thus, the main goals of seismic imaging and interpretation became challenging. Long offset data recorded with help of FloatSeis™ acquisition technique and asserted into the processing routine helped to create geologically consistent velocity model along the 2D CDP seismic line. Pre-stack depth migration with an alternative FloatSeis™ long-offset velocity model considerably enhanced wavefield quality in the challenging areas with complex geological structures. Therefore, the clarity of the seismic image, quality of reflecting horizons tracing and data interpretation were uplifted.

Even though the pilot project had an overall success, we had faced with a few challenges. Among them: presence of a random broadband spikes on the data linked with heaving (difficult to eliminate with a data processing routine); considerable drift of the unit in areas with strong currents; inability of a standard gun array to ensure recording of offsets greater than 50 km in areas with high attenuation properties.

These lessons learned forced us to improve the recording unit's body and develop a stabilizing device. The stabilizing device is a separate device that is attached on the cable of a recording unit. It was designed to fulfil two functions simultaneously: dampening the heaving and serving as a “sea anchor”. Thus random broadband noise is attenuated during the data recording and the drifting was reduced by factor of three, being less than 3-4 degrees if we convert from distance to the angle domain.

To ensure a robust recording of offsets exceeding 50 km GWL focused efforts to design a GWL LF Source™. The key difficulties in low frequency signal emission are air gun’s durability and signal stability. GWL LF Source™ is a combination of the best technical solutions and modern materials and components giving a stable low frequency signal with no compromise to production. GWL LF Source™ is compatible with the majority of existing gun controllers; has an improved inner construction of the source in combination with an innovative firing system, high signal stability and is fish and mammals friendly.

Conclusion and vision for future

CDP towed seismic streamer surveys provide data for migration and stacking but do not ensure an accurate velocity model. FWI algorithm can help us to obtain well-resolved and precise velocity models even in a complex geological environment. But to accomplish superior results, FWI requires fundamentally different input – data containing both ultra-long offsets and low frequency component. It’s not possible to acquire such data in the framework of towed seismic streamer survey in a cost effective way with the equipment available nowadays on the market. That circumstance leads us to a slow adaptation and narrow practical implementation of FWI techniques. The majority of FWI results obtained and papers published are based on synthetics or shallow depth data.

The new equipment specially designed for the ultra-long offsets and low frequency data acquisition can help to leapfrog this situation and set aside such kind of surveys in a separate equally important data acquisition – velocity surveys. The separate velocity survey has to be fast and inexpensive, providing us with an accurate velocity model before the start of a towed seismic streamer survey. Such velocity models can be interpretable by themselves and be used to amend towed streamer survey design, be applied for streamer data processing and migration considerably reducing time span from the first shot to the final product delivery.

GWL foresees a considerable demand for 3D standalone long-offset low frequency velocity surveys. To implement 3D velocity surveys on practice in a cost effective way we have to shift our paradigm from rolling massive amounts of recording units from patch to patch towards self-deployed and positioned autonomous recording devices or/and towards unmanned “handling” and shooting vessels. Unmanned vessels can be the next big step in geophysical prospecting. Moreover, unmanned operations will definitely improve safety that is always the first priority.

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