SEISMIC SOURCE COMPARISON FOR HIGH RESOLUTION DATA PROCESSING

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ABSTRACT. Nowadays, high resolution seismic processing is a key issue for achieving reasonable and reliable information for subsurface geology structure. The importance of the seismic methods lies above all in the fact that the data produced by seismic work, if properly handled, yields an almost unique and unambiguous interpretation. Seismic work is comprehensive and delicate process which depends on many factors and circumstances. On the first place, this is the type of source used to produce seismic waves. A widely used method in the past is to explode dynamite charge in a hole. In the last 10 years, however, there has been a tendency toward replacing explosive sources with some other environmentally less harmful seismic sources. The following work presents a comparison between two type of source signal – Vibroseis and Dinoseis and shows potential advantages and drawbacks in both cases on real seismic data.

Keywords: seismic method, seismic data, sources of seismic signal

СРАВНЕНИЕ НА СЕИЗМИЧНИ ДАННИ ПОЛУЧЕНИ ОТ РАЗЛИЧНИ ИЗТОЧНИЦИ НА СИГНАЛА

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РЕЗЮМЕ. Понастоящем високоразрешаващата обработка на сеизмични данни е основа за получаването на информация за дълбочинният строеж на Земята. При извършване на качествена сеизмична обработка, получените сеизмични разрези носят уникална информация за структурният строеж на земната кора. За осъществеване на така поставените цели обработката на данните изисква да се вземат под внимание редица фактори. Основен фактор се явява изборът на система за създаване на сеизмичния сигнал. За разлика от широко използваният в миналото динамит поставен в сондажи, на съвременен етап голямо разпространение имат неинвазивните източници. Настоящата работа разглежда и сравнява предимствата и недостатъците на два от най-популярните неинвазивни източници на сеизмичен сигнал – Вибросеиз и Диносеиз.

Ключови думи: сеизмичен метод, сеизмични данни, източници на сеизмичен сигнал

Introduction

The main purpose in seismic work is the correct illustration of geology in the study area. Seismic processing is a delicate process so even small variations can have a significant impact, hiding the real signature of the signal or introducing artifacts. Nowadays, technology has gone a long way and the processing of seismic data obtained even in the middle of the last century is not difficult. In the era of state-of-the-art technology, it is possible to achieve high resolution seismic models which in turn leads to an increase in the potential of the subsequent interpretation of the processed data. In recent decades there has been a rapid development in the technical industry and sources for generating seismic waves.

The present work aims to examine and compare the advantages and drawbacks of two of the most popular land sources of seismic signal – Dinoseis and Vibroseis. Recent advance in source technology is further improving the data quality by putting more seismic energy into the earth at wider range of frequencies. The ideal source for seismic exploration is an impulsive source that concentrates its energy at a point in space and releases it instantaneously. In practice, however, sources have finite spatial size and emit signals over a finite period, producing broadened wavelets that add complexity to the processing. The choice which source to be used depends on several factors, including geophysical objectives, cost and environment constraints.

Land seismic survey

Seismic data acquisition requires an energy source, a receiver, and a recording system. In seismic exploration surveys, source–receiver distance is small compared to the target depth. This means that a small part of the down-going energy is reflected on geological layer boundaries. The main fraction of the energy is transmitted and travels deeper where reflections occur at the next layer boundary and so on. This method results in a good vertical and horizontal structural resolution of the subsurface (Hubscher, Gohlb, 2014).

According to Jeffryes (2006) seismic surveying is when a source of seismic energy is caused to produce seismic energy that propagates downward through the Earth. The downwardly-propagating seismic energy is reflected by one or more geological structures within the earth that act as partial reflectors of seismic energy (Fig. 1). The reflected seismic energy is detected by one or more receivers. It is possible to obtain information about the geological structure of the earth from seismic energy that undergoes reflection within the earth and is subsequently acquired at the receivers.

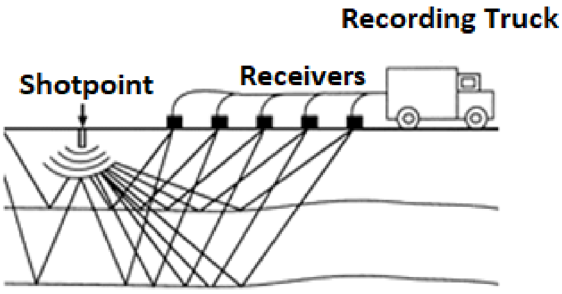

Fig. 1. Seismic land acquisition

In practice, a seismic surveying arrangement comprises of an array of sources of seismic energy. This is essential because it has to generate sufficient energy to illuminate structures deep within the earth and a single seismic source generally cannot do this.

Characteristics of seismic signal received from Dinoseis land seismic source

Since the beginning of seismic exploration the most popular impulse source for land acquisitions is dynamite, because it produces great quantities of energy. Other impulse source, which uses air and gas guns to produce energy is Dinoseis (Fig. 2). This energy source, largely used in the past, produces sufficient results in good seismic conditions, but is questionable in areas of poor response. The energy here is created by exploding a mixture of oxygen and propane gases, mostly, contained in a confined chamber, the bottom of which is a moveable plate resting on the ground surface. This way the designed chamber is attached to the bottom of a heavy vehicle to increase coupling its plate with ground surface.

Fig. 2. Dinoseis truck

When detonating the gas mixture, a sudden pressure impact occurs, which is transmitted through the base-plate to the ground surface (Alsadi, 2017).

Dinoseis generates relatively weak seismic energy, developing strong surface waves, and producing low-frequency seismic pulses. The method is rarely applied these days, but there are seismic sections acquired by Dinoseis and reprocessed nowadays. This makes it necessary to compare this energy source with the modern Vibroseis source. Defining the similarities and the differences between the shapes of the signal can help geoscience engineers to tie the lines received with both seismic sources when reading previously collected data or reprocessed one.

Characteristics of seismic signal received from Vibroseis land seismic source

Seismic sources are mainly divided into two groups - impulse and non-impulse sources of energy. However, the current dominant non-impulse energy source for land seismic exploration is a seismic vibrator. The use of such a vibrator is generally identified by the trademark Vibroseis. In Vibroseis survey, specially designed vehicles lift their weight onto a large plate, in contact with the ground, which is then vibrated over a period of time, with sweep of frequencies (Fig. 3). Seismic vibrators are the predominant source used in land acquisition (Grigorova, 2016).

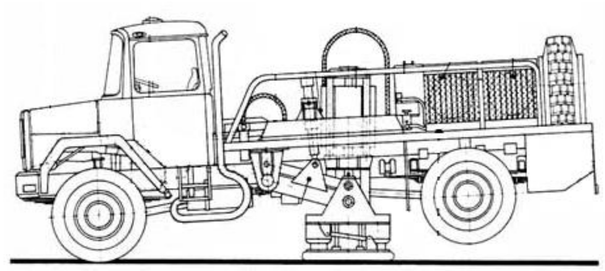

Fig. 3. Vibroseis truck

The vibrator is a surface source that emits seismic waves by forcing vibrations of the vibrator baseplate which is kept in tight contact with the earth through a pulldown weight. The driving force applied to the plate is supplied either by a hydraulic system, which is the most common system in use, or an electrodynamic system. Nowadays driving force can be managed also by magnetic levitation which is a new development in the field of seismic vibrator technology. The plate can vibrate in different directions: P-wave vibrators (where the motion of the plate is in the vertical direction) as well as S wave vibrators (vibrating in the horizontal direction).

There are many advantages using vibrators for seismic acquisition:

- The frequencies can be controlled easily;
- Real time monitoring and adjustment of the vibrations to the ground;
- This technique can be used both in urban areas and in environmentally sensitive areas, such as sand dunes or arctic snowpack;

Of course, this technique has also several drawbacks:

- It still has areas of limited access like swamps, mountains and coastal areas;
- The input signal is not impulsive, so additional processing and filtration is required to extract interpretable data;
- A recorded trace is correlated with a reference trace to extract the reflected signal.

One of the most important characteristic of the Vibroseis method is the limitation of the bandwidth of the source. Thus, the Vibroseis technique allows us to generate only those frequencies we actually need, whereas with an impulsive source like dynamite, some of the frequencies generated by the blast are ignored during the seismic acquisition (Levi, 2015).

Real data comparison between Vibroseis and Dinoseis

According to Grigorova (2016) in reflection seismology seismic data are usually contaminated with noise, which refers to any unwanted features in the data. One of the most important criteria for data quality is visibility of primary reflections, often quantified as signal-to-noise ratio. In seismic processing we usually manipulate our measured data, so that we can obtain an accurate image of the subsurface. One of the key components of seismic processing is determining which part of the recorded energy is noise and removing it from the data.

Results after pre-processing of Dinoseis and Vibroseis seismic data are presented in this paper. On shot records filtration techniques are demonstrated and different kind of signal behaviour is observed.

In Figure 4 is shown Dinoseis shot record before filtration procedures and its corresponding spectrum. In the case of the surface impact sources such as Dinoseis, the pulse is predominantly low frequency, due mainly to the coupling effect between the impact pad and the surface.

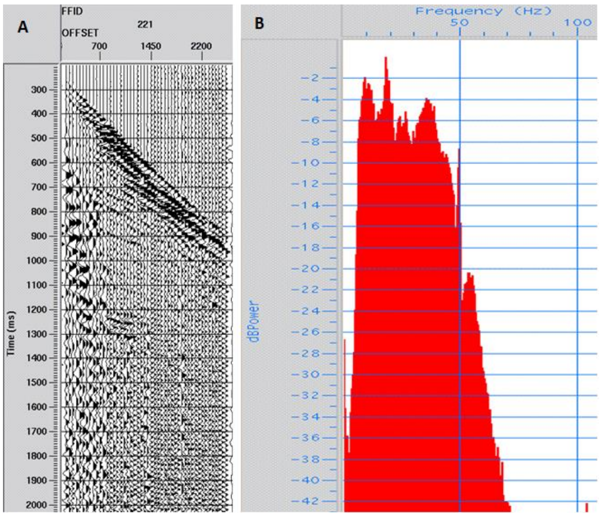

Fig. 4. Seismic shot (A) and its corresponding frequency spectre (B), received by Dinoseis seismic source

On the record low frequency noise can be noticed, which makes it difficult to analyse the real reflection data. Removal of the noise is a key component in preparing the data for velocity analysis and next imaging techniques. Effective noise removal, which preserves the original amplitude and phase characteristics of the data, provides the opportunity for advanced attribute work and inversion for better understanding of the reservoir (Dingus, 2011).

Looking at the spectra of these data, i.e., by transforming the time axis to a frequency axis using the Fourier transformation, different arrivals will give different peaks in the Fourier spectra. What we achieve is that we can analyse and interpret different frequencies in terms of different events. Moreover, we can start thinking about using the Fourier-transformed data for filtering purposes, i.e. removing certain frequency bands with the aim to remove undesired signal, like, e.g. cultural noise (Drijkoningen, 2019). It produces a characteristic 50 or 60 HZ sinusoidal noise on traces that can be measured. Its amplitude is relatively constant with recorded time, whereas the seismic data amplitudes decay with time. Notch filters are used to attenuate this type of noise and were often applied in the recording of the data. The notch filter is applied here and it attenuates all recorded data at a given frequency.

The same Dinoseis seismic shot is presented filtered in Figure 5. According to Dingus (2011) properly addressing the noise and then its removal provides the opportunity to track amplitude anomalies and stratigraphic objectives with confidence.

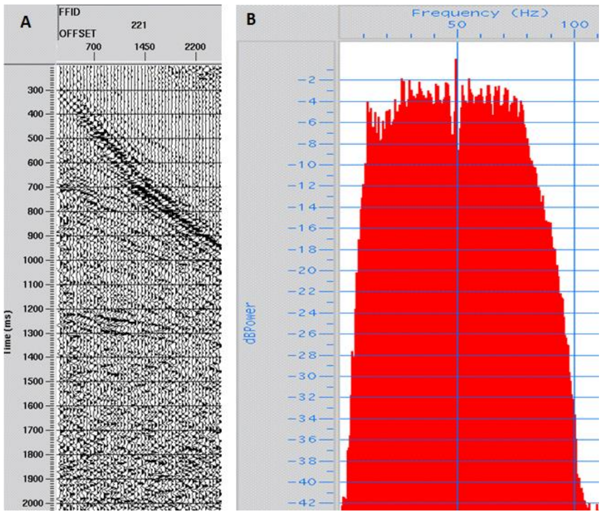

Fig. 5. Seismic shot (A) and its corresponding frequency spectre (B), received by Dinoseis seismic source after noise attenuation

Significantly better real reflection data in comparison with the same shot before filtration in the time range of 700-1400ms can be noticed after filtration procedures (Fig.6).

Another seismic shot but recorded using Vibroseis as a source signal is presented on Figure 6. Although it is received with generally modern technology row data still consist of relatively much ambient noise. Surface waves and ground rolls waves have strong energy and reflection data can hardly be observed in the upper time of the section.

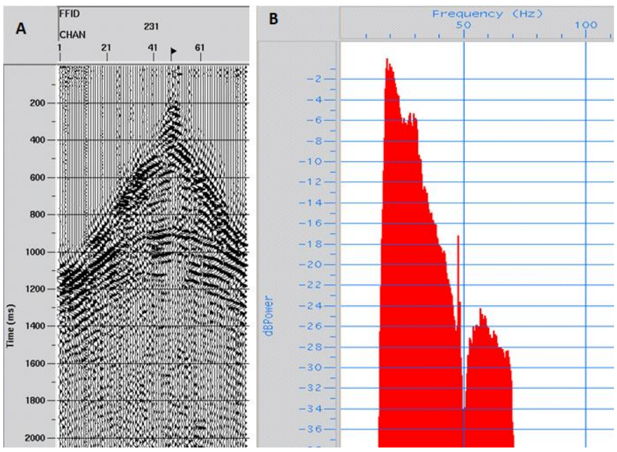

Fig. 6. Seismic shot (A) and its corresponding frequency spectre (B), received by Vibroseis seismic source before noise attenuation

In frequency domain notch filter is applied during the field works, but the spectrum is presented of predominantly low frequencies. According to Wardell (1970) frequency spectrum from surface sources, which influences the reflection quality, may not have sufficient high frequency energy where very high resolution is required.

After application of several filtration procedures and whitening of the spectrum, the frequency domain becomes broadband and respectively the shot data become more readable. Applying spectral whitening improves the resolution and appearance of seismic data and it is crucial to correct the frequency attenuation.

In Figure 7 it is obvious that better signal-to-noise ratio is achieved, which leads to more confident determination of real reflection data.

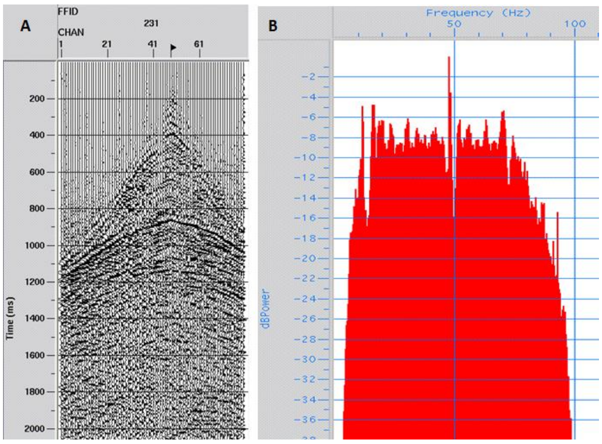

Fig. 7. Seismic shot (A) and its corresponding frequency spectre (B), received by Vibroseis seismic source after noise attenuation

Conclusions

In conclusion, both sources are capable of giving satisfactory seismic data in conditions suited to their use. The real goal for pre-processing of seismic data is to minimise all artefacts that are not part of the seismic signal, such as noise, multiple and acquisition irregularities. There are many areas which are now being re-evaluated. Many of these areas are being recorded using Dinoseis as seismic source, so they require special consideration in processing. In these areas, proper noise attenuation that maintains the amplitude and phase characteristics of the primary signal is a key issue. Proper seismic pre-processing gives the opportunity to extract the maximum benefit of seismic data. In such a way pre-processed data meets the exploration and development targets by providing quality information for pre-stack imaging techniques, and appropriate data for such reservoir characterisation techniques as rock properties, attribute analysis and inversion.

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