Seismic Data Acquisition Technology in Loess Mountainous Area of Ordos and Southern Jiangsu

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Abstract

The surface of the loess mountain area in southern Ordos is covered by a thick loess layer, and the seismic exploration process has poor excitation and reception effects of seismic waves, and the reflection energy of seismic waves in the target horizon is weak, and the quality of collected data is poor. According to the principle that high water saturation and good lithology of loess layer will be beneficial to seismic wave excitation, through the investigation of water saturation and lithology of loess layer in the study area, the best seismic wave excitation horizon and depth are determined, and the best single well excitation dose is determined according to practical experience. In the aspect of seismic wave receiving and recording, the basic flow of survey line layout is worked out, and the seismic wave acquisition scheme suitable for the study area is finally worked out by combining the seismic wave receiving scheme with small path distance, large offset distance and high coverage times.

Keywords

Loess area, Seismic exploration, Seismic wave, Data acquisition

Introduction

Seismic exploration is a geophysical exploration method which generates elastic waves by artificial seismic source excitation on the surface of the earth and analyzes geological structure and stratigraphic characteristics by recording the reflection and propagation of seismic waves [1]. The topography of the loess mountainous area in southern Ordos is complex, and the groundwater table and the top surface of the high-speed conductive layer are buried deeply in the stratum, generally more than 120m m. The ultra-thick loess layer absorbs seismic waves strongly, and the interference wave signals are common, and the recorded seismic waves are of poor quality. This area has always been a difficult and important area for seismic exploration [2].

Improving the frequency, energy and bandwidth of seismic waves, suppressing interference waves and improving the signal-to-noise ratio and resolution of seismic data have become the urgent needs of seismic acquisition and recording. The water-bearing and lithologic characteristics of loess layer in the study area are investigated, and the optimal depth position of seismic wave excitation horizon is determined. The combined detection method is used to optimize the detection process, formulate a reliable acquisition scheme, and then improve the best seismic wave acquisition technology in the study area.

The loess layer in the study area is thick, and the surface elevation changes sharply. The depth of the borehole is about 22m due to the large, buried depth of the shallow water surface, which will also lead to the difference of stratum excitation effect and affect the quality of the finally recorded seismic waves. The relationship between rock density and seismic wave velocity is linearly increasing under certain conditions. The higher the seismic wave velocity generated by the rock that excites the seismic wave, the higher the frequency and energy of the seismic wave excited [3]. When the water content in the loess layer is high, it is beneficial to the propagation of seismic waves, and the speed, frequency and energy of the excited seismic waves are basically better than those in the general loess layer.

Before collecting seismic wave data, we can investigate the lithology and sweat characteristics of yellow soil layer in the study area to determine the distribution and location of lithology with good water content in the stratum. When selecting the excitation depth, we can set the excitation point below the stratum interface with good lithology or water content, which can improve the speed, frequency and energy of exciting seismic waves and improve the quality of recorded seismic wave data [4,5].

Through practice, it is found that the seismic wave excited by a small dose of 2 ~ 4kg has high frequency and wide frequency band, while the seismic wave excited by a large dose (greater than 4 kg) has strong energy, but the frequency band is narrow, so it is determined that the dosage used for single well excitation is about 3kg in practice. At the same time, the single well excitation also has the characteristics of fast energy attenuation and low reflection energy after excitation. To effectively improve the amplitude and signal-to-noise ratio of seismic wave signals, the excitation mode of combined explosion can be adopted.

Seismic wave reception

Seismic acquisition line layout

When the seismic survey line is arranged, it is influenced by landform, surface vegetation, buildings, roads and bridges and farming, which leads to the failure to realize the continuity of detection points and affects the quality of recorded seismic data.

The purpose of optimal adjustment of survey line position is to make shot points more uniform and realize the continuity of detection points. When choosing the shot point, try to be in the area with better lithology, avoid the complex geological conditions on the surface, and stay away from the village farmhouse as far as possible to avoid safety risks. The location of survey line can be selected through satellite maps, field survey, indoor design and secondary adjustment in the field, to improve the quality of data collection, reduce safety risks and improve construction efficiency [6,7].

Specific survey line layout can be referred to as follows.

(1) satellite map, traffic map collection, grasp the obstacles and road traffic situation in the target area.

(2) field reconnaissance, preliminary design layout line sketch.

(3) The secondary layout design of survey line, and the overall design shall meet the requirements of technical specifications.

(4) The layout scheme of field survey line shall be adjusted and implemented according to the actual situation.

Trail spacing selection

In the selection of trail spacing, it is necessary to meet the technical requirements of non-aliasing frequency and lateral resolution of the target layer is determined according to formula (1) of non-aliasing frequency law and empirical formula (2) of CMP side length of lateral resolution.

$$b = V_{int} / (4 \times F_{max} \times S_{in\theta}) \quad (1)$$

Where: b is the CMP side length, Vint is the upper layer velocity, Fmax is the highest aliasing-free frequency, and θ is the formation dip angle.

$$b = V_{int} / (4 \times F_{dom}) \quad (2)$$

Where: Fdom is the main frequency of the reflecting layer.

Multi-line number

Interference waves will appear in most survey lines in the loess area, and the reception of multi-survey lines will effectively suppress the interference noise information and improve the coverage times of seismic waves [8]. Two-dimensional multi-line seismic acquisition can effectively suppress interference waves and obtain a high signal-to-noise ratio of two-dimensional profile. With the combination of joint shooting and inspection, the general optimal line spacing is 30 ~ 50m.

Small line spacing

Through the early construction experience in the study area, the seismic profile with 30m shows that the continuity of shallow, middle and deep weak reflection layers is poor, and the resolution of seismic data is low. The 50m line has good continuity and high resolution from the shallow weak reflection layer. The continuity, signal-to-noise ratio and resolution quality of weak reflection layer with 80m line spacing begin to decrease. According to the comprehensive situation of the study area, the line spacing of 50 ~ 60m is considered to suppress interference and improve the signal-to-noise ratio [9,10].

Geophone combination

Combined detection has become the main acquisition technology under complex landform conditions in recent years, which has better effect of suppressing interference waves. At present, in the field application, 20 geophones are used to combine detection with a combined point distance of 1m. According to the technical requirements of combined detection, the height difference in the channel should be less than 1m when the detector is buried.

Drafting of acquisition scheme

Observation system: 3560-30.5-25-30.5-5-3560
Number of tracks: 4×336
Line spacing: 60m
Track distance: 20m
Shot spacing: 70m/90m
Coverage times: 150/120
Well depth: determined according to lithology and water-bearing investigation.
Number of wells: 10
Dosage: 30kg

Conclusion

(1) According to the structural characteristics of loess layer in southern Jiangsu, the water content and lithology of loess layer are analyzed. The lithology distribution law of loess layer in the study area is clarified, and the optimal horizon is selected for seismic wave excitation, to obtain high-frequency seismic wave and strong seismic wave energy. According to practical experience, it is concluded that the single-well initiation charge is about 3kg.

(2) The loess layer in the study area is thick, and the seismic wave interference is obvious. According to the empirical formula and model analysis, the maximum migration distance is 3560m, the number of survey lines is 4, and the coverage times are 150 (in the thick loess layer area) and 120 (in the thin loess layer area). The geophone is used to combine detection with a combined point distance of 1m, and the height difference in the channel is less than 1 m. Finally, the best seismic data acquisition scheme for the study area is drawn up.

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Conflicts of Interest

The authors declare no conflict of interest.

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