The Application of Shallow Refraction Seismology in Determining the Thickness of Quaternary Cover Layers

1. Application Example

1.1 Overview of the Work Area

The A City's Town is one of the areas most severely affected by the 5.12 earthquake. In order to carry out anti-seismic and disaster reduction measures, as well as future post-disaster reconstruction work, it is necessary to have a relatively systematic understanding of the local geological conditions. Relevant geological data indicate that the area exhibits the development of frontal fold and fault structures. The main structural traces are arranged in a "multi-character" form, with nearly north-south thrust faults and inverted synclines developed in the back mountains. There are also nearly east-west faults distributed in the area, and the structure of the region is characterized by its complexity, multiphase nature, and inheritance. The new tectonic movement is very strong, manifested in the intermittent sedimentation of the Quaternary system. Various methods were adopted for this survey, and shallow refraction wave exploration was one of them, mainly to pave the way for subsequent scientific research work.

1.2 Geological and Geophysical Premise

According to relevant local geological data, the area is mainly characterized by limestone, and the soil and rock layers are relatively uniform. There exists a certain velocity difference between the overburden and various weathered layers, meeting the geophysical prerequisites for using seismic exploration1.

1.3 Field Work Method

The shallow seismic refraction exploration method employed an encounter-chase observation system for this fieldwork. A 24-pound hammer and firecrackers were used as the seismic sources. Data was received using the WZG-48 engineering seismograph, which is known for its high sensitivity, wide dynamic range, high resolution, and stable performance. In this exploration, both 5m intervals were used for the survey. Detailed fieldwork parameters can be seen in the table. Reference to the source or document where the information was obtained.

Shot Distance	Number of Channels	Array Length	Sampling Interval	Record Length	Near Shot	Far Shot
5m	24	115m	0.125ms	512ms	0m	14m

Geophysical Profile Layout: This work area is adjacent to a mountain, and the profile layout direction is perpendicular to the mountain's trend. To ensure clear field recordings and easily interpretable initial arrivals, repeated hammer strikes are employed for recordings where the initial arrivals are unclear. Vertical stacking of seismic recordings is used to obtain satisfactory records. The far shots on both sides can be adjusted according to the terrain.

Figure 1 presents the original records of 4 shots in the same arrangement in this area. In Figure 1, the four plots labeled a, b, c, and d respectively represent the left zero offset, right zero offset, left 14-meter offset, and right 14-meter offset. From the figure, it can be observed that the signal-to-noise ratio of the recordings is moderate, and the initial arrivals are clearly discernible.

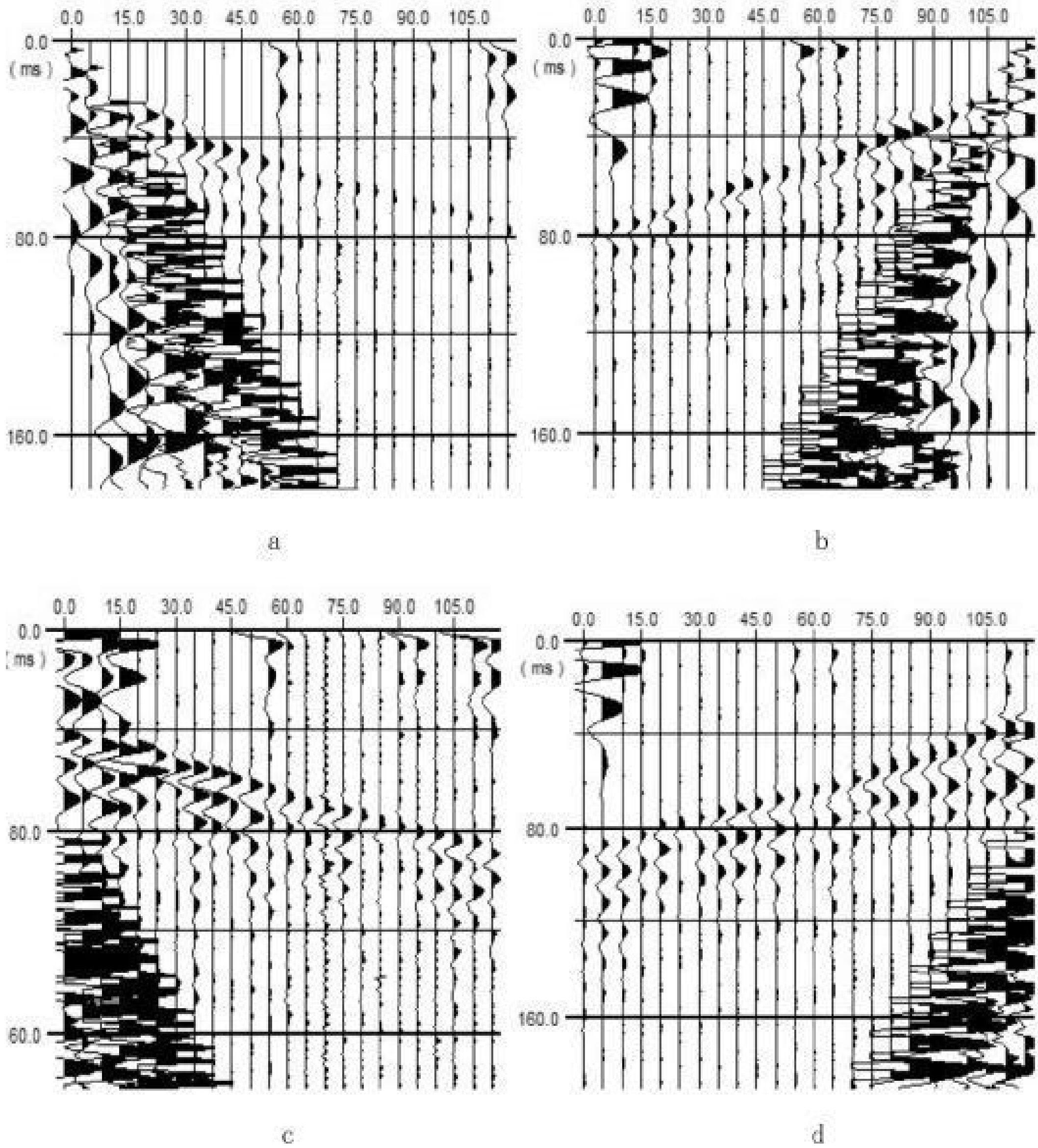

Figure 1: Original Seismic Refraction Records

2. Refraction Wave Data Processing and Interpretation

2.1 Interpretation and Processing

The t_0 difference time-distance curve method is used for data processing [5]. Firstly, V_1 and V_2 are calculated, and the thickness of weathering layer h is calculated according to V_1 and time t_0, and then the geological interpretation is made according to the change characteristics of the velocity of V_2. For a structure with more than two layers, in order to find the wave velocity V_n and the burial depth h of the nth layer, we can use the substitution layer with effective velocity and thickness to replace the medium of the first layer to the nth layer with the medium of the first layer to the nth layer, so as to make it into a two-layer structure, and then we repeat the steps mentioned above. Figure 2 shows the time-distance curves of refracted waves in Section 5 of the work area.

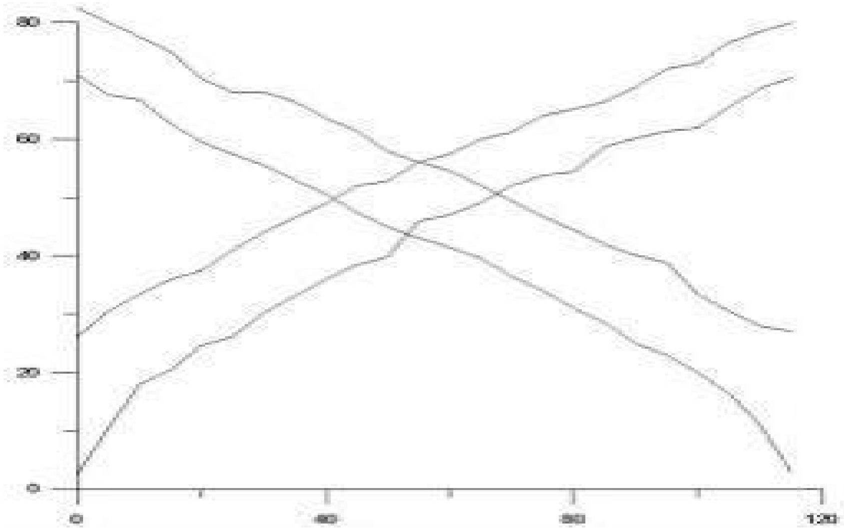

Figure 2: Time-Distance Curve Diagram.

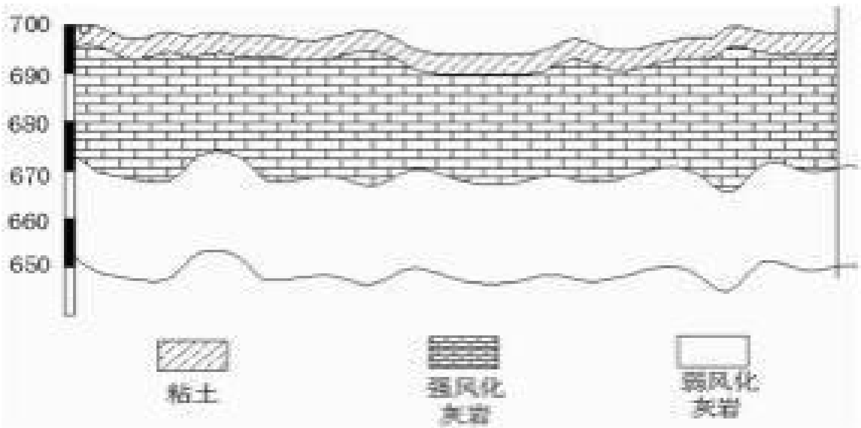

Figure 3: Schematic Diagram of Geological Structure Distribution.

2.2 Interpretation of Results

Based on Figure 3 and in conjunction with the local geological conditions, the local geology is continuous and can be divided into three layers from a velocity structure perspective: fully weathered, strongly weathered, and weakly weathered layers[6].

The first layer consists of Quaternary slope deposits or a fully weathered layer. The slope deposits are primarily loose, silty clay with a small amount of limestone mixed in. The thickness of this layer varies from 4.5 to 5.5 meters, with a seismic wave speed ranging from 625 to 720 m/s.

The second layer is the strongly weathered layer, primarily composed of strongly weathered limestone. The thickness of this layer varies significantly, ranging from 5.5 to 24.5 meters, and the wave speed ranges between 1740 and 1875 m/s.

The third layer is the weakly weathered layer, primarily composed of weakly weathered limestone. The wave speed for this layer ranges between 2050 and 2500 m/s.

3 Conclusions and Insights

Shallow seismic refraction is an effective method for addressing engineering geological issues such as determining the thickness of the cover layer, identifying the undulations of bedrock, probing shallow water depths, locating concealed faults, assessing the location of karst caves and fissures, and evaluating the quality and classification of the overburden[7]. Using shallow seismic refraction to study and detect the thickness of the cover layer is accurate, rapid, and feasible. Shallow seismic refraction is relatively less constrained by geological conditions, and with minimal exploration work, one can understand the local geological situation, yielding satisfactory results. This work effectively resolved the geological stratification, delineation of weak zones, seismic wave speeds, and other geological and geophysical issues in this area, achieving the expected results and paving the way for subsequent geological work.

The seismic refraction method has been well applied in addressing various geological problems, but it also has some shortcomings. For instance, when encountering two layers with no significant velocity difference, it's challenging to distinguish between them, and they are treated as a single layer. If the wave speed of the underlying layer is lower than that of the overlying layer, the seismic exploration results are invalid. Since seismic observations are not direct, there are errors in interpreting the results.

During exploration, certain precautions should also be taken, or they may influence the results. For example, it is crucial to minimize interference as much as possible. When the instrument is collecting signals, one should avoid causing artificial disturbances (like walking or talking near the geophone). Choosing some effective anti-interference techniques is essential, such as the multiple superposition technique.