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Near surface seismic method for detecting active fault Gobi-Altay Fault in Mongolia

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Abstract

Gobi Altay fault is one of the largest intra-continental faults in Asia where was conducted using the seismic exploration survey which is an effective geophysical method for detecting faults. Based on the shallow seismic data from an active seismic survey in surrounded eastern part of Toromkhon valley, Bogd mountain fault zone, Gobi-Alati range, southwestern Mongolia. The main goal of the work was to identify the features of fault zones using seismic instruments to develop a methodology for identifying late Holocene fault zones that are currently eroded. The seismic survey result shows that the combination of shallow seismic migration and 2D velocity inversion model. The seismic data were processed along a straight CMP line and an interpretation was made under the migrated time section and 2D velocity inversion model based on finite element method.

Keywords: Inversion, Velocity model, Migration

1. Introduction

Seismic methods have long been used in geophysical studies to investigate the properties of geological structure and the near surface characterizations. Among seismic methods, reflection seismic method, that has revolutionized our understanding structure of earth's interior, is certainly the main tool of seismic imaging and the primary technique used in energy exploration: it was initially developed in the 1920s for the petroleum industry. Over the years, this method has undergone continuous improvements in data acquisition, signal enhancement, and geological interpretation, resulting in significant advances (Bruno, 2023). The general principle involves sending artificially generated acoustic waves down the ground layers and into the depth, where the different structures and objects within the Earth's crust reflect this energy back according to their acoustic impedance. These reflected energy waves are recorded by geophones, and the data are processed to produce a visual representation of the sub-surface.

In recent years, started to conduct in Mongolia to determine the geometric characteristics of the faults using the reflected wave method of seismic exploration in the study of active faults caused by earthquakes. Determining the geometry and kinematic patterns of faults is of great importance in solving important problems in seismological science, such as understanding the focal mechanisms of earthquake and hazard assessment. Among all geophysical methods available today, but reflection seismology certainly provides the highest resolution, making it a valuable tool for a fault detection survey. However, seismic reflection data processing is a computationally intensive process. Our study will attempt to answer these questions using seismic method compared with the reflection and refraction methods how to find out and interpret seismic profiles which image the near surface structure of the fault zone. (Figure.1). Some of faults are buried directly below the fanglomerates and stream alluvium. The shallow seismic method has been proven to be the best technique in the exploration of active faults for its high resolution and deep penetration of fault structures (Song et al., 2023). The study area lies in eastern part of Bogd mountain fault, Burgastain am. Burgastain am is an area with a complex tectonic framework composed of low-angle thrust faults with observable shortening when compared to other regions of Bogd fold. The thrust belt and faulted structures are very prominent in the area under study.

2. Geological settings

The studied region is situated in the SW Mongolia, approximately 1000km SW of Ulaanbaatar at the junction of south-western Mongolian Altay with represented by Bogd mountain. Geologically, Mongolia is built by a number of tectonic zones that from the part of the extensive Central Asian Orogenic Orogenic Belt (Hrdlickova et al., 2008).

The December 4th 1957 Mongolia earthquake, generally referred to as the "Gobi Altai" or "Bogd" earthquake, had M=8 and created long and complex surface ruptures length about 270 km long fault line was formed between the North of Baga Bogd and the North of Bayan Tsagaan. As known geological study, several left-laterally and vertically displaced Quaternary alluvial fans and morphogenic markers show cumulative offsets, allowing for an assessment of the effect of repeated earthquakes and active tectonics on landscape evolution (**?**). This belt appears as one of the youngest mountain ranges in the Central Asia, which is consistent with the idea of a northward propagation of the deformation from the Himalayan front to the Siberian Craton (Vassallo et al. 2007). Our research area Baga Bogd is surrounded consist of metasedimentary rocks, volcaniclastics and felsic intrusions deformed in the late Paleozoic, followed by early Mesozoic foreland basin deposits that are uncomformably overlain by later rift-related Mesozoic clastic sedimentary rocks and volcanic rocks (Solonenko et al., 1960; Choi et al., 2012).

3. Active seismic method and data acquisition

A. Seismic method

For our near surface seismic exploration, we used a multiple time coverage reflection wave method that improve the signal-to-noise ratio of seismic data and helped determine the existence and form of the fault visual image of the subsurface structure. The most common method used in data processing is the Common Mid-Point method. It is a method that simplifies data processing by combining the paths of wave propagation (radiation) occurring between receivers and generators by overlapping positions and calculating them at several gathered points along the measurement line. These gathers are named CMP (common mid-point) or CDP (common depth point) gathers and the number of traces within each CDP gather equals the fold of that gather. In order to achieve enough fold-coverage for imaging, each reflecting point must be recorded more than once (Sheriff & Geldart, 1995).

Here, a time migration section was created using the reflected wave method, and a two-dimensional velocity model was created using the refracted wave method. While the time migration section can provide information on

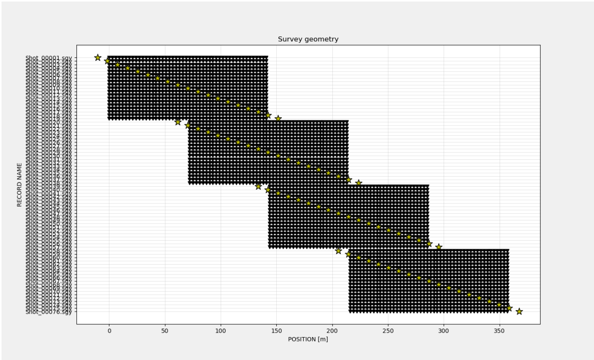

Figure 1. Image of survey geometry with shot and receiver locations.

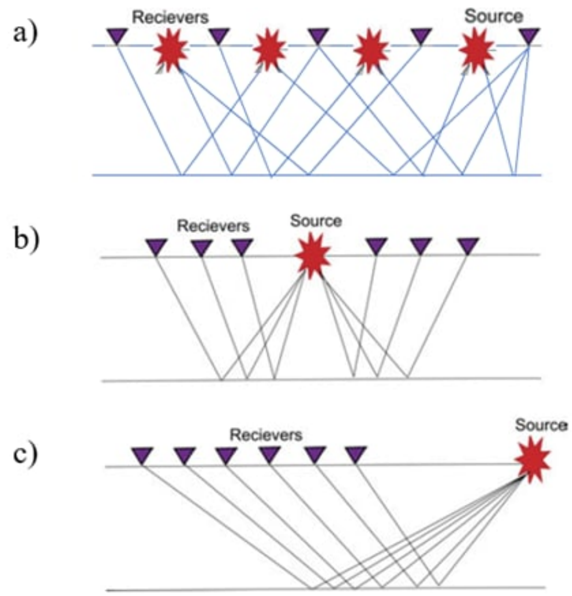

Figure 2. Three types of seismic spreads: a) fixed-spread b) split-spread c) end-on spread.

the displacement of faults and the structure of the environmental layers, whereas the velocity model can be used to determine the boundaries of rocks and sediment according to their density based on velocity inversion analysis along the line, as well as the changes in the velocity of seismic waves propagating in the depth of the layers and the environment.

B. Data acquisition

This seismic data acquisition uses the SUMMIT digital seismograph produced by DMT, Germany. The SUMMIT digital seismograph has a high sampling rate (1/48–8 ms), wide recording frequency band (4.5 $\leq$ Hz), large dynamic range ($\leq$ 120 dB), and processing of the controllable source data, which can solve the problem of interference in shallow high-resolution seismic prospecting.

In this survey, We have done 4 seismic profiles, with a total length of 357 meter. But for this paper, we have shown one of them profile. This profile was localized on the eastern part of the Toromkhon valley, called the Burgastai. The direction of the profile was south to north and measured across the fault planes, therefore approximately perpendicular to the surveyed fault direction. Acquisition geometry was symmetric with weight drop source trailing 48 geophones spread with frequency of 40 Hz and a 200 kg hammer as an active source and moved half of the whole line Figure.1.

The spread geometries of seismic measurements are the main factors to affect the exploration results as well as the accuracy of fault location. There are a some of seismic spread types that can be used for seismic measurement. Seismic spread can be divided into three main pieces: 1) fixed spreading 2) split spreading 3) end-on spread. One of them was employed to acquire the data used is fixed spread. Fixed-spread is a common type survey where the source is located in the middle of each receivers (Figure.**??**a). This kind of spread is suitable for near surface high resolution imaging and when the length of the line is relatively short.

4. Result and Interpretation

The result of the data processing is plotted on each spread with a velocity model and a time migration section. Showing the result on the same line as a time migration and velocity model give us some advantages. (1) Seismic wave velocities are low because the fault zone caused by earthquakes is sparse and less density. Based on this characteristic, it is possible to determine the fault section using

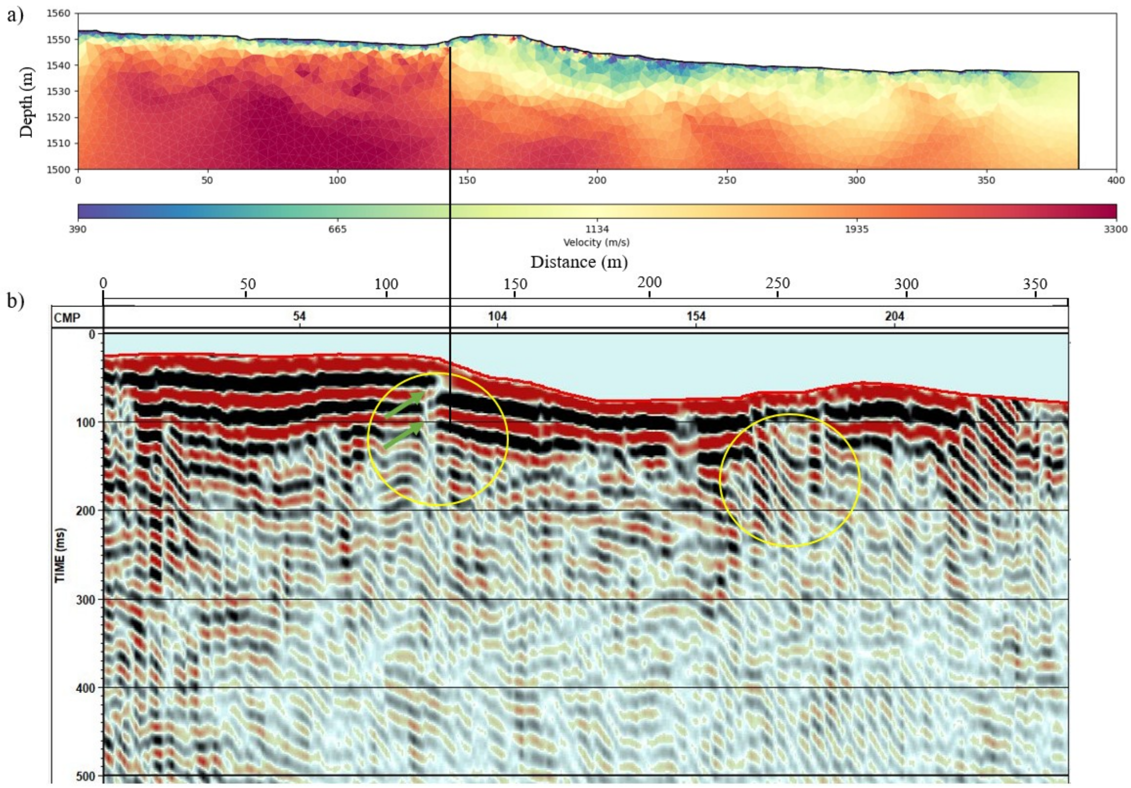

Figure 3. Summary of refraction and reflection processing result: a) velocity 2D inversion model b) seismic time migration imaging.

the refracted wave method. (2) Due to earthquake, the environmental geology medium becomes stratified heterogeneous. Therefore, the phase of the waves passing through it changes. Based on this characteristic, parameters such as fault displacement and dips are estimated by the reflection wave data processing. (3) However, our seismic migration result show in time section, it is not possible to see the depth of the observed fault. Thus, the thickness of the boundaries can be estimated from the velocity model obtained by the refraction wave method and compared to the time section, the depth of the fault can be evaluated. As we know, along the Bogd fault has been generally considered to be sinistral (Tapponnier & Molnar, 1979), and the reverse faults were commonly described in the area of Baga Bogd at the eastern termination of the Bogd fault zone its include Toromkhon valley, Burgastai etc (Berbiglia et al., 2013).

The velocity model of profile according to the time-term inversion method is shown in Fig.3a. The one strong manifestation of a velocity gradient appears on this section. Its outstanding anomaly (marked in black color line) reaches the seismic velocity from 1100 m/s to 2400 m/s. This anomalous observed at length 140 meter and depth 3 metr. Seismic velocities beginning of 1-2 meter: 390 to 500 m/sec and around 1134 m/sec at depths of 2-4 meter until the fault line in measurement line. Whereas at 3 meter, its outstanding anomaly reaches the more than 3000 m/sec. At the 150 meter, sediments and basic rocks are showing to change velocity performances.

The resulting migrated seismic imaging according to conventional seismic data processing is shown in Figure.4. There are combined results of reflection and refraction methods, the fault boundary is far more precisely demarcated. In the seismic section, anomalies are vertically dipping towards the middle of imaging, which is in accordance with the orien-

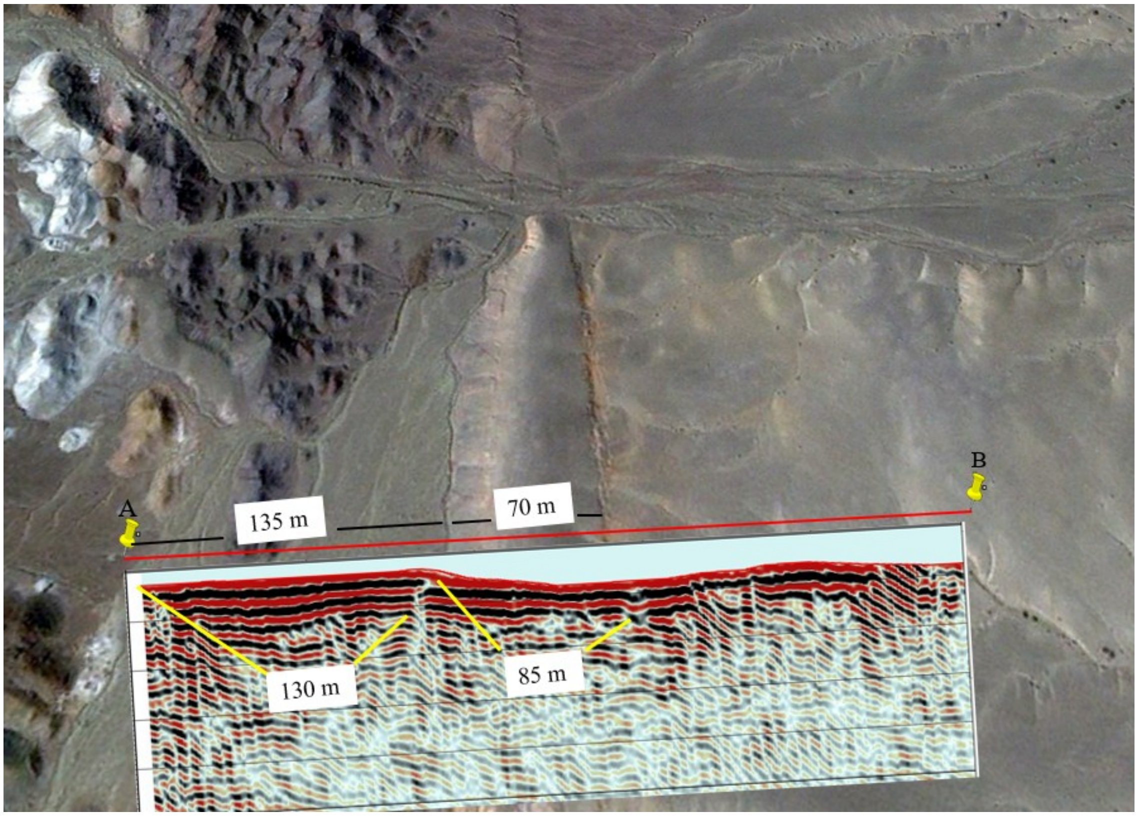

Figure 4. Calculation result against the background of the topography..

tation of medium, bedding and displacement zones are observable under the surface. The second anomaly is appeared at the 240 meter with sense of dip towards down.

5. Conclusion

The seismic exploration method relatively accurately determines the fault zones, however, the slope angle and fault direction are not determined unambiguously. These details can be resolved by joint interpretation with other geophysical instruments.

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