Application of gravity exploration in urban active fault detection

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Abstract. Active faults are a major source of danger for destructive earthquakes. It is an important task for urban earthquake disaster prevention to find out the spatial location and structural attributes of active faults. At present, the most effective geophysical exploration method for detecting and locating urban concealed active faults is shallow seismic exploration, while other geophysical exploration methods are seldom used. In the detection of active faults in Shanghai, seismic exploration is greatly influenced by human factors in urban areas and the efficiency is low. In this paper, through the comparison and analysis of the alignment of seismic and gravity, it is found that the interpretation results of gravity exploration have a good correspondence with the fault structures interpreted by shallow seismic exploration. At the same time, gravity method reveals that there may be other fault anomalies near the fault anomalies identified in previous literature. It illustrates the effectiveness and feasibility of high-precision gravity detection methods in the detection of urban active fault, and also provides important reference significance for active fault detection in other regions.

1. Introduction

The main culprit of the earthquake is the latest activity of the fault. Especially the fault located under the important city suddenly staggered which resulting a greater loss of the earthquakes occurring directly beneath cities [1]. Active faults are not only the place of earthquake preparation, but also the most serious area of earthquake damage. Once these faults are active, they will inevitably lead to the destruction of buildings and casualties near the fault zone. The current seismic measures can’t prevent the direct damage of the active fault to the ground and underground facilities. The only way is to find out and confirm the active faults which should be avoided [2-3].

Because of the Quaternary loose sedimentary coverage area in Shanghai area, the rock outcrop is less and the fault trace is not obvious. At the same time, most of the detected target faults are concealed faults [4]. Therefore, geophysical exploration has become an essential means in active fault detection. At present, there are many geophysical detection methods used in the spatial positioning and activity evaluation of urban active faults [5-8]. Different geophysical detection methods have their own characteristics and application conditions. According to their characteristics and tasks at different stages, appropriate detection methods are selected reasonably to realize the best combination of different geophysical detection methods, which can achieve good fault detection results.

Although the resolution and precision of seismic exploration are high but its efficiency is low, its cost is high, its construction method is complex, and it is also greatly influenced by external factors [9-12]. As a conventional geophysical method, gravity exploration is highly efficient and free from electromagnetic interference, and has obvious effect in reflecting bedrock fluctuation and fault.
occurrence [13-14]. Therefore, it is widely used in the exploration of cities and surrounding areas. In this paper, Zhangyan-Jinshanwei active fault is selected to carry out the detection method test. The application of high precision gravity exploration method in the detection of concealed faults and related knowledge are introduced.

2. Gravity Prospecting

2.1. Geophysical premise
The study area is located in Zhangyan town and Jinshanwei town, Jinshan District, Shanghai. Zhangyan-Jinshanwei active fault which is the boundary between Chashan salient and Jinshan sag is distributed from near Zhangyan to Jinshanwei. Bounded by faults, the Quaternary isopach in the East is distributed in NE direction, with a thickness of 100-140m; the Quaternary isopach in the west is distributed in NW direction, and the sedimentary thickness is rapidly thickened to the west, with a maximum thickness of 240m. The upper breakpoint of the fault ends at the bottom of the upper Pleistocene. However, no evidence of activity has been found since the late Pleistocene.

On the basis of the drilling and regional geological data, the bedrock in this area is grey andesite with a density of 2.30-2.70g/cm3. The stratum lithology of the lower Pleistocene is mainly grey and variegated clay, silty clay and grey medium coarse sand, silty fine sand interbedding. The stratum lithology of the middle Pleistocene is mainly grey clay, silty clay and medium fine sand and fine sand interbedding. The stratum lithology of the upper Pleistocene is mainly grey silty clay, dark grey clay and silty fine sand interbedding. Holocene stratum lithology is grey silty clay and muddy clay. The density of Quaternary clay is 1.60 ~ 2.04g/cm3, and there is obvious difference from the density of bedrock, which conforms to the premise of gravity exploration.

2.2. Field work method deployment
CG-5 high precision gravimeter produced in Canada is used as the gravity exploration equipment, and the observation parameters are relative gravity values. The gravity survey is an experimental method. In order to analysis the effectiveness of the method, the deployed gravity profiles are partially coincident with the seismic section. From south to north, the survey lines are line G01 of Longsheng Road, line G02 of Longxuan road and line G03 of Chamei road. In order to ensure that the observation results can eliminate the interference of urban environment as much as possible, 50m away from the surface of high-rise buildings and 20m away from the general buildings [14] in the actual data collection process. At the same time, we avoid the peak travel time and repeat retests at the same point to get the average value, while the number of checkpoints is increased and the area with large change of outliers of adjacent points is retested.

All indexes and total precision of this gravity exploration are superior to the requirements of the specification, and achieve the expected effect. The gravity observation accuracy is 0.022×10-5m/s², and the total accuracy of Bouguer anomaly is 0.023×10-5m/s².

3. Gravity Data Analysis

3.1. Bouguer anomaly
Through data processing, Bouguer gravity anomaly value is obtained, which reflects the gravity change caused by the density difference between geological body and surrounding rock. A gravity base point is selected in the working area. In order to compare with the results to the seismic, the direction is the same as that of the seismic that is from east to west. The relative Bouguer gravity anomaly of each survey profile is shown in Fig.1-fig.3. It can be seen from the Bouguer gravity anomaly map that the variation of Bouguer gravity anomaly in the three sections is -2.228~6.096 ×10⁻⁵ m²/s² ,0.395~3.489×10⁻⁵ m²/s²,1.802~4.728×10⁻⁵ m²/s² respectively. It can be seen from the results that the abnormal value decreases from east to west and increases from south to north.
3.2. Fault Recognition

According to the shape of Bouguer gravity anomaly, the location of the extreme point of the horizontal first derivative and the zero point of the vertical first derivative, combined with euler deconvolution (the structural index is taken as zero), the faults in the study area are divided. The results of each section are shown in Fig.4 ~ Fig.6, and the red plus thick solid line in the figure is the location of inferred fault.

There are four faults inferred from the Longsheng Road of line G01, which are respectively distributed at about 250m east of Xuefu Road, near the intersection of Weiling Road, 200m east of Weiling Road and near the intersection of Mengshan Road.

Figure 1. Section of Bouguer gravity anomaly of line G01

Figure 2. Section of Bouguer gravity anomaly of line G02

Figure 3. Section of Bouguer gravity anomaly of line G03

Figure 4. Fault recognition and seismic geological interpretation section of line G01
Figure 5. Fault recognition and seismic geological interpretation section of line G02

Figure 6. Fault recognition and seismic geological interpretation section of line G03

Five faults are inferred from the Longxuan Road of line G02, which are respectively distributed near the intersection of Xuefu Road, about 140m east of Xuefu Road, about 240m west of Dongping.
North Road, about 250m east of Dongping North Road and about 200m east of Weiling Road. The scale of the three faults in the east is small.

Three faults are inferred from the Chamei Road of line G03, which are respectively distributed near borehole K1, Changchun Road intersection and about 220m west of Changchun Road.

4. Comprehensive Analysis

For the purpose of comparing the detection results of seismic and gravity methods and verifying the previous detection results, the two methods are deployed respectively at the same survey line position in Longsheng Road, Longxuan Road and Chamei Road to carry out comparative detection.

4.1. Longsheng Road

As illustrated in figure 4, the results of this gravity survey show that there are fault anomalies in the same area as those in the previous reference [2] and the detection results of both have good correspondence, but the details of the anomalies reflected by the gravity survey results are more rich and complex. The high precision gravity method reveals that there may be other faults near the faults identified in previous reference.

The results of gravity detection and small point distance seismic detection indicate that the fault anomaly displayed in the same area in the previous reference may be composed of several small branches.

4.2. Longxuan Road

As illustrated in figure 8, for the fault anomalies in the same area, the detection results of gravity and small point distance seismic have a good correspondence. The high precision gravity method reveals that there may be other faults in the Chashan salient outside the seismic exploration area.

4.3. Chamei Road

As illustrated in figure 6, for the fault anomalies in the same area, the detection results of gravity and small point distance seismic have a good correspondence. The high precision gravity method reveals that there may be other faults outside the seismic detection area.

Through the comparison of detection tests, it is considered that the two methods of seismic and gravity show the existence of fault anomalies in the same area, and the detection results of the two methods have good correspondence. In addition, the high precision gravity method reveals that there may be other fault anomalies near the fault anomalies identified in previous reference.

5. Conclusions

(1) The results show that the distribution characteristics of Bouguer gravity anomaly can highlight and extract structural information such as fault location, which can better reflect the fault structural characteristics of microzonation field and near-field area. It indicates that the effectiveness and feasibility of high precision gravity exploration in the detection of hidden faults in urban microzonation field;

(2) High precision gravity prospection is a kind of geophysical exploration method with simple operation, high efficiency and low cost. In the early detection of concealed faults, it plays an important role in determining the surface position of faults and reducing the scope of exploration area. At the same time, its observation and analysis results can also provide reference for other geophysical exploration methods and project implementation.

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