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Vertical deformation and tectonic activity in Tianjin area

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Abstract: Vertical deformation in Tianjin area during 1992 – 2008 was calculated from leveling data. The effect of large surface subsidence caused by extensive groundwater pumping was removed by fitting the data along each survey line with a polynomial function. The results are fitted with crustal blocks individually in this area. Vertical deformation rates are mapped, vertical rates of the main fault zones were calculated, and the activities of the blocks and fault zones were investigated. The observed vertical deformation shows that some of the blocks tilted and some blocks rose or subsided as a whole. The vertical rates at fault zones in the area vary within the range of 0.13-0.48 mm/a, with an average value of 0.29 mm/a.

Key wards: level data; ground subsidence; crustal vertical deformation; block motion; vertical velocity of fault zone

1 Introduction

Leveling has been widely used in monitoring tectonic and man-made crustal deformations. Their observation provides direct visual explanation for the characteristics of the vertical deformation of the objects under study. Geodetic leveling has been playing an important role in studies on modern crustal tectonic activities, earthquake prediction, land subsidence and deformation due to large-scaled construction[1-5]. By using leveling data, some previous studies made significant findings on land subsidence in Tianjin Area in the 1970s – 1980s[6-8]. Such subsidence, caused by massive groundwater exploitation to meet fast industrial and agricultural needs, has far exceeded subsidence associated with tectonic deformation. Thus, there are currently very few studies on tectonic activities based on leveling data in this area. In this study, we use leveling data from 1992 to 2008 to study the vertical deformation and current activities of major fault zones in Tianjin area.

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2 Data processing

Groundwater exploitation may cause land subsidence at a rate of as much as about 100 mm/a near the mouth of the pumping well[9], far exceeding the rate of tectonic deformation. Groundwater-exploitation related subsidence shows a V-shaped curve along with the leveling lines centered at the well or group of wells. The first task in our study was to fit the subsidence data with polynomial functions along the leveling line, and to eliminate or greatly reduce the exploiting effect. We then proceeded with interpolation and according to tectonic blocks, and tried to fit the result with the following equation[10]:

$$\Delta h = h_0 + a_1 + a_2 x + a_3 y + a_4 x^2 + a_5 y^2 + a_6 xy \qquad (1)$$

Where Δh is the rate of level change at an observation point; h_0 is the vertical motion parameter of a block; a_1, a_2, a_3, a_4, a_5 and a_6 are undetermined coefficients; x and y are distance parameters of the observation point from block center. By using the results calculated from (1), we were able to suppress information on local

changes and enhance the overall deformation information of the blocks, thus facilitating the study of tectonic activity of the blocks and their boundary faults.

3 Crustal deformations

We divided the leveling data in Tianjin area during 1992 – 2008 into two stages, 1992 – 1999 and 1999 – 2008. Fig. 1 and 2 show, respectively, maps of vertical deformation rates calculated directly from leveling data after close-loop adjustment and with Beijing as the reference point. The root-mean-square error per kilometer is less than 1 mm/a. The inter-bench-mark distance is generally 2 – 3. 5 m.

The ground surface in Tianjin area has shown universal subsidence in recent decades. During 1992 – 1999 (Fig. 1), the subsidence rate was large in the middle part of Tianjin, and smaller in northern and southern parts. In the northern part, the rate was less than 10 mm/a in Baodi and 10 – 20 mm/a in Dakoutun-Panzhuang-Tianjin. In the southern part, the rate was less than 30 mm/a between Chenguantun and Tangguantun. In the middle part, the rate was as large as 50 mm/a between Yangliuqing and Xianshuigu, and locally as large as 90 mm/a in Yangliuqing and 80 mm/a in Xianshuigu. From Xianshuigu southward to Dasuzhuang there appeared a subsidence zone at a rate of as much as 60 mm/a. In Wuqing and Ninghe, which are respectively northwest and northeast of Tianjin, the rate was as much as 50 and 60 mm/a, respectively. In coastal area east of Tianjin, the rate was larger in northern part in Han'gu, as much as 50 mm/a, and smaller in southern part in Tanggu-Qikou, about 20 – 30 mm/a.

Compared with the crust deformation during 1992 – 1999, the pattern changed somewhat during 1999 – 2008 (Fig. 2). The subsidence rate in Baodi in the northern

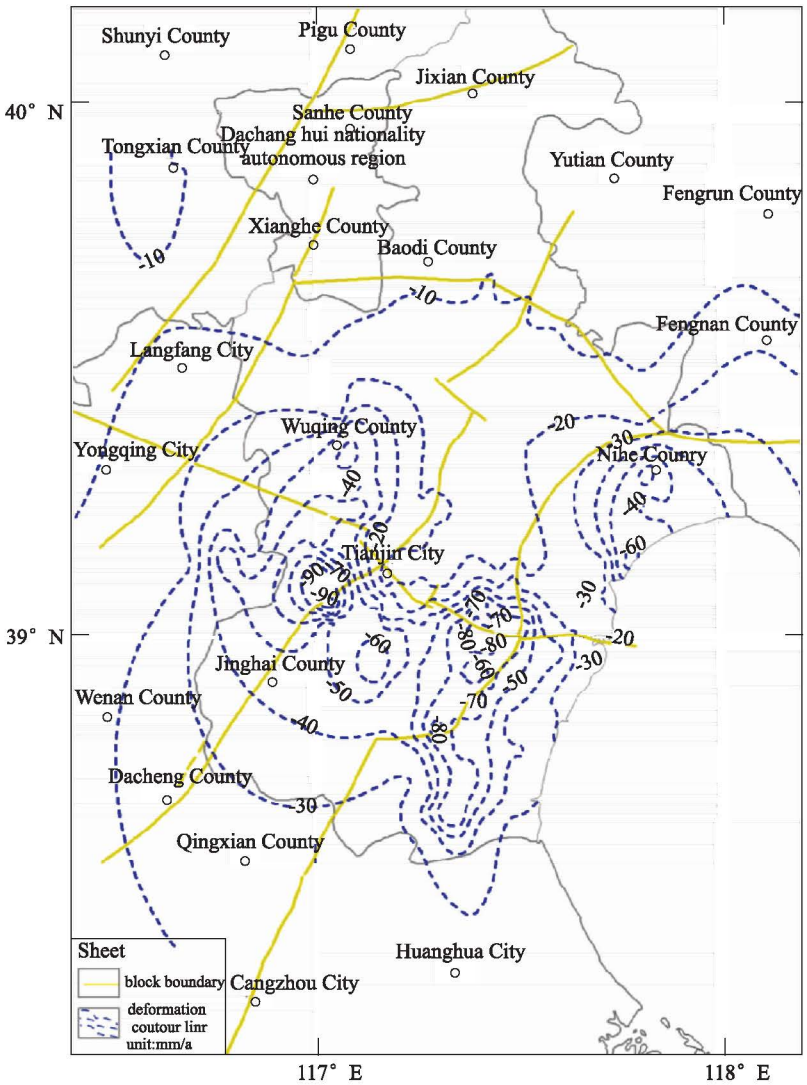

Figure 1 The vertical deformation rate of Tianjin area during 1992 – 1999