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Gravity variation associated with Wenchuan earthquake in western Sichuan

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Abstract: Based on the data of mobile gravity observation from 1998 to 2008 in western Sichuan, spatial dynamic variation results of regional gravity field are obtained. The relationship between the gravity variation features and Wenchuan *M*s8.0 earthquake is systematically analyzed. The results show: 1) Gravity variation is closely related to active fault tectonics, and gravity measurement can better reflect material migration following crustal tectonic activity near active fault. 2) The gravity field appeared a wider range regional gravity variation during Wenchuan earthquake occurrence. The dynamic patterns of gravity field demonstrates the evolution process of gravity field: quasi - homogeneous state——non - homogeneous state—earthquake occurrence.

Key words: western Sichuan; gravity observation; crustal movement; gravity variation; Wenchuan earthquake

1 Introduction

Wenchuan *M*s8.0 earthquake on 12 May, 2008 in western Sichuan is the greatest catastrophic event after Tangshan earthquake in 1976 on Chinese continent, which is also in monitoring area. The western Sichuan is located in western China, which has the most intensive crustal movement, high seismic frequency and the greatest seismic strength. In order to monitor spatial dynamic variation features of gravity field and its relationship with tectonic activity, and catch the earthquake precursory information, in 1978, gravity networks were established in western China by the Seismological Bureau of Sichuan Province. From 1986, by using LCR-gravimeter, one-period mobile gravity measurement was carried out in this area every year. Wenchuan *M*s 8.0 earthquake occurred at the neighbor of the gravity networks. Gravity variation features, the relationship between gravity anomaly variation and Wenchuan *M*s8.0 earthquake are analyzed in this paper.

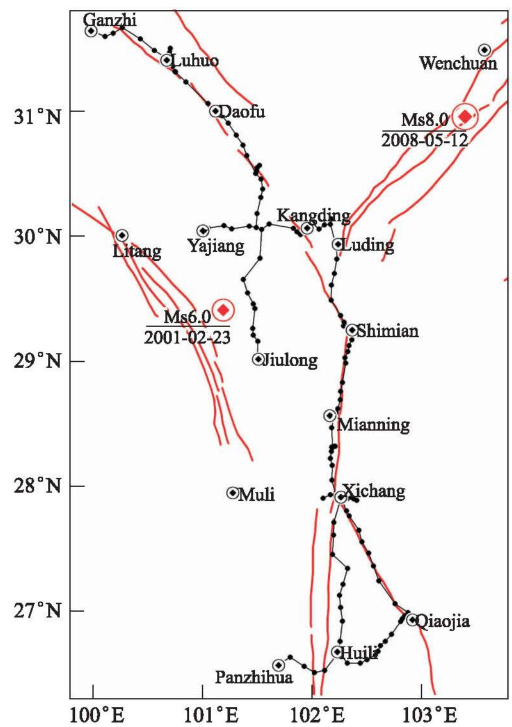

Figure 1 The gravity surveying route and tectonic outline of western Sichuan

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2 Survey situation and processing

Gravity networks in western Sichuan are located in the middle of South-North seismic zone and the edge of eastern part of Tibetan Plateau. Geographical position is N26.5° – 31.5°, E100° – 103°. Xianshuihe-Anninghe-Zemuhe fault in Western Sichuan is a bigger strike-slip fault zone, as a part of Sichuan-Yunnan blocks which is on east of the boundary, and it has intensive seismic activity[1]. This area is earthquake-prone zone. From 1986, since using LCR-G high precision gravimeter in the area, three earthquakes happened here: Xiaojin *M*s6.5 earthquake in September, 1989, Yajiang *M*s6.0 earthquake on 23 Feb., 2001, and Wenchuan *M*s8.0 earthquake on 12 May 2008. Figure 1 shows the gravity surveying route and tectonic outline of western Sichuan.

Data is processed as follows: 1) We use the software LGADJ to take universal star datum to perform Quasi-stable adjustment. Quasi-stable Point adopts stable and little in external interference point from 1998. 2) We use multistage measurement data to carry on the whole analysis. After having the preliminary understanding for observation accuracy of each gravimeter, prior variance is reasonably determined, then we can acquire the most reasonable results. 3) Average precision of each station is $10.5\times10^{-8}ms^{-2}$ – $15.8\times10^{-8}ms^{-2}$, the observation precisions are all better than $20\times10^{-8}ms^{-2}$. 4) We use the least squares collocation to carry on gravity measurement data. After girding to optimum determined gravity value on the ground, it shows gravity effect of structure factor prominently[2-5].

3 Spatial dynamic variation features of regional gravity field

It is discovered that, the repeated gravity measurements of gravity networks in western Sichuan were carried out during April to May, which is rainless, to decrease the influence of seasonal variation for measurement data.

We can draw the following conclusions from further study of contour of gravity variation,

1) Period division of gravity variation. Figure 2 shows gravity variation is significant in some years, while in some years is not. We call it no significant change period that the change is between (-30 – $+30$) $\times10^{-8}ms^{-2}$ and a small range of positive and negative variation area. In no significant change periods, gravity variation is slight, such as 1998 – 1999、1999 – 2000、2002 – 2003、2003 – 2004. Other periods have some gravity variation, such as 2004 – 2005、2005 – 2006、2006 – 2007、2007 – 2008, the maximum of positive and negative gravity variation is more than $100\times10^{-8}ms^{-2}$, we call it significant change period.

2) Distribution of gravity field in significant change period. In spatial distribution, gravity field has significant difference in different periods. In no significant change period, spatial distribution is comparatively scattered with no significant pattern. In significant change period, spatial distribution of gravity field is regularly varied and relatively concentrated, such as 2000 – 2001、2001 – 2002、2005 – 2006、2006 – 2007、2007 – 2008, especially 2006 – 2007. Regional trend variation occurred in gravity field. Gravity variation gradually strengthened from west to east. Gravity variation near Kangding reached to a peak, which was near the epicenter, thus, the abnormal gravity and high gradient zone appeared.

3) The relationship between gravity variation and tectonic activity. Spatial dynamic variation of gravity field shows that gravity variation in western Sichuan is more violent and fluctuation is great. In intensive activity period, difference of movement in one year is almost up to $100\times10^{-8}ms^{-2}$. From gravity variation and fault distribution, we can see the contour of gravity variation in the northern of Shimian agrees with Xianshui fault towards NW, contour of gravity variation in the southern of Shimian agrees with Anning-Zemu fault in significant change period.

During 2000 – 2001, not only the regional gravity anomaly along with Anning-Zemu fault but also local gravity anomaly caused by fault activity of Zihe fault were monitored. During 2004 – 2005, 2005 – 2006 and 2006 – 2007, gravity contour of the northern area agrees with Xianshui fault towards NWW, and contour of the southern area agrees with Anning-Zemu fault. It can better reflect gravity variation effects caused by deep fault structure activity following Wenchuan *M*s8.0

seismogenic system. This shows: in the process of large earthquake preparation, gravity field changing pattern is controlled by deep fault. Gravity data can better reflect deep fault movement caused by regional tectonic stress field and gravity effects caused by fault activity of focal stress field[7].

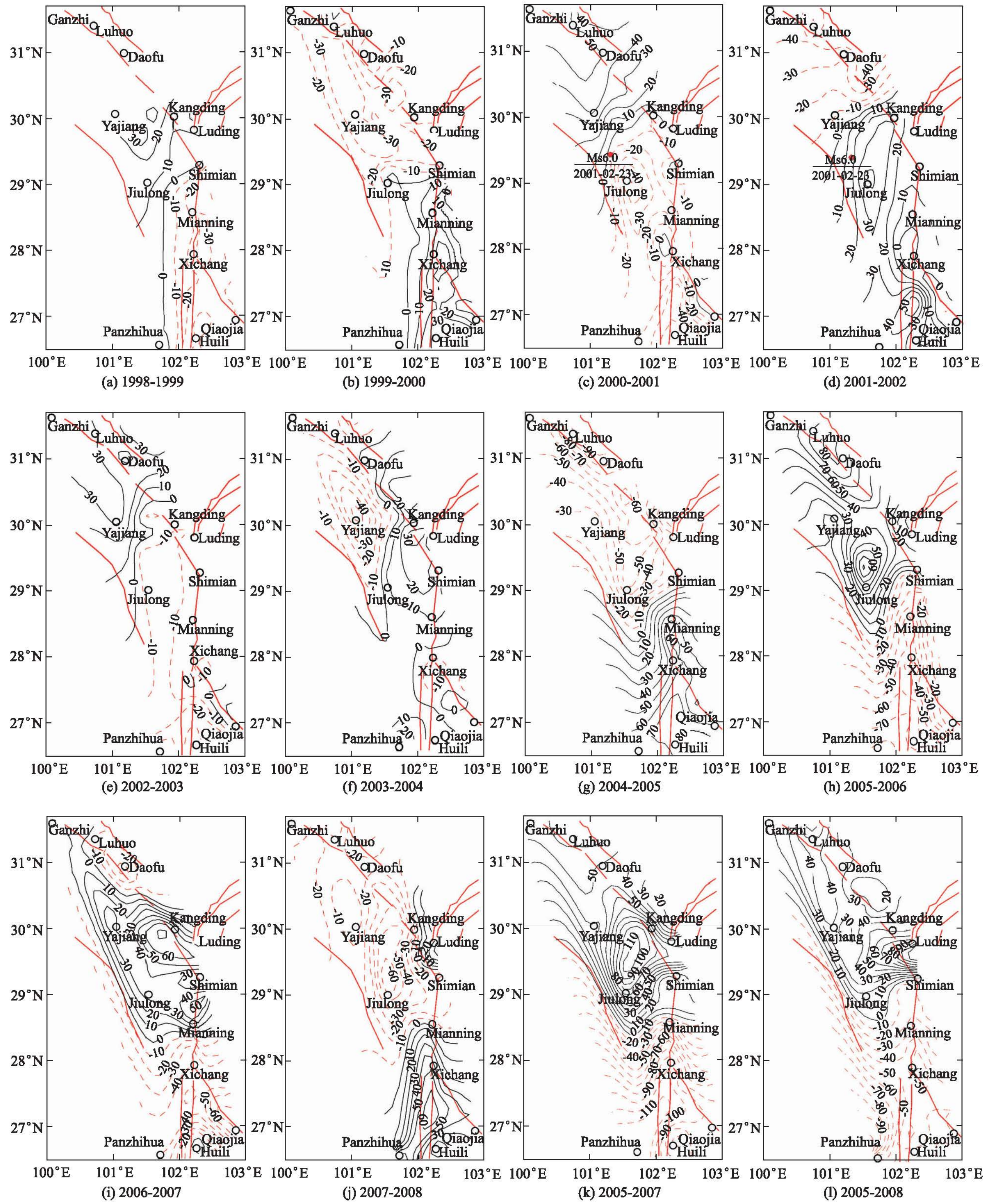

Figure 2 Contours of gravity variation in western Sichuan area (unit: $10^{-8} ms^{-2}$)

4) Regional gravity field is changing dynamically, and its contour shows complexity and diversity. The following obvious characteristics have been obtained from the contours in the temporal variation. 1) During 1998 – 1999 and 1999 – 2000, gravity variation was flat; during 2000 – 2001, regional gravity variation increased gradually from south to north, the local variation anomaly area formed and the high gradient zone was in Yajiang, gravity anomaly up to -40×10^{-8} ms^{-2}; during 2001 – 2002, gravity variation reversed; during 2000 – 2001 and 2001 – 2002, gravity variation better reflected co-seismic of Yajiang *M*s 6.0 in Feb, 2001 and gravity effect in the crust after the earthquake. 2) During 2002 – 2003 and 2003 – 2004, gravity variation was flat in the survey area, during 2004 – 2005 and 2005 – 2006, regional gravity variation changed rapidly, the average of difference magnitude was larger than $150 \times 10^{-8} ms^{-2}$. It may be the reflection of regional gravity anomaly before Wenchuan *M*s8.0 earthquake. During 2006 – 2007, gravity variation was violent too, especially the area near Kangding where was closer to the epicenter, the value reached the peak. Gravity variation continued. It may be the precursor of gravity abnormal variation for Wenchuan *M*s8.0 earthquake on 12 May ,2008; during 2007 – 2008 (measurement data was selected after earthquake in 2008), gravity variation was still violent. It is transition from negative to positive value of the southern survey area located in Xichang-Mianning, and it is also transition from positive to negative value of the northern survey area located in Yajiang-Jiulong. It reflects regional gravity field is adjusting variation. 3) During 2005 – 2007, gravity variation difference movement accumulation was up to $200 \times 10^{-8} ms^{-2}$ in two years, the abnormal gravity happened at crossing point of Xianshui fault and Longmenshan fault, which was near Kangding-Luding, it remarkably reflected regional gravity field rapidly changed before Wenchuan earthquake; during 2005 – 2008, in three years gravity variation gradually increased from WS to NE, abnormal gravity appeared in the south of Longmenshan fault, which was near Luding. It can better reflected regional gravity tendency variation before and after Wenchuan earthquake and local gravity anomaly variation near the epicenter.

4 Gravity variation and Wenchuan earthquake

Earthquake almost occurred on the boundary of active plates or active faults. Before abrupt displacements (earthquakes) occurred at these zones, surface gravity field would have changes related to the pregnant earthquake process, which is long-medium-short term variation[8]. A precursory reflection for mobile gravity almost showed regional gravity anomaly. Premonitory phenomenon of the earthquakes demonstrated relatively the features of concentration and orderliness at that time.

Wenchuan *M*s8.0 earthquake on 12 May, 2008 at Longmenshan fault of western Sichuan is the biggest event on Chinese continent for fifty years. From the analysis of spatial dynamic variation features of gravity field in western Sichuan, we can find: 1) during 1998 – 1999 and 1999 – 2000, gravity variation was almost the same, during 2000 – 2001 and 2001 – 2002, it can better reflect gravity variation before and after Yajiang earthquake; 2) during 2002 – 2003 and 2003 – 2004, regional gravity changed slightly, which showed quasi-homogeneous state. After 2004, gravity field mainly showed regional sequence change from west to east and local gravity anomaly appeared near the intersection of Xianshui fault and Longmenshan fault. The trend of the gradient zone of gravity significant variation agreed with Xianshui fault and Anning-Zemu fault, which demonstrated non-homogeneous state. During 2004 – 2005, gravity variation gradually decreased from west to east at Litangwude fault and Xianshui fault; During 2005 – 2006 and 2006 – 2007, it gradually increased, and high gradient zone came out , whose trend agreed with Xianshui fault and Zemu fault, local gravity anomaly moved to Longmenshan fault from west to east (from Jiulong to Kangding); gravity field variation decreasing from west to east developed into increasing in a large-scale space, and local gravity anomaly moved from Jiulong to Kangding, which reflected regional tectonic activity was acute and local stress moved to Longmenshan fault. 3) During 2007 – 2008, gravity variation was still acute, which was up to $120 \times 10^{-8} ms^{-2}$, but changed trend was contrary to previous two periods. Local gravity anomaly was obvious in the area near Luding, which was the intersection of Xianshui fault and Longmenshan fault. Wenchuan earthquake occurred in Longmenshan fault. In the time sequence, earthquake occurred in the process of reverse recovery, which was in agreement with the previous studies[2,3,7].

The western Sichuan is located in the middle of south subplate and the Qinghai-Tibet subplate, which is mainly and eastwardly extruded by Tibetan Plateau[9]. Strong activity of the gigantic tectonic belt in western Sichuan is based on extruding eastwardly caused by Tibetan Plateau, its force source is the one extruded by NE-trending Indian plate. With sustainable source power, eastern-directed stress field is formed, and fracture and block fault are aroused. With stress transmission in fault structure, the material movement and tectonic deformation of active fault are aroused, and gravity variation is formed on the surface. Wenchuan *M*s8.0 earthquake happened at Longmenshan fault. Before the earthquake, gravity variation was obvious, which appeared at Longmenshan fault intersected by Xianshui fault and Anning-Zemu fault. It showed, the movement of India plate in the ES direction strengthened, which pushed Tibetan Plateau to Kunlunshan fault. Crustal movement strengthened in Xianshui and Longmenshan. Deep structure movement appeared in Xianshuihe and Anning-Zemu fault. The dynamic source of Wenchuan earthquake is high strain of deformation accumulation in a long time.

5 Conclusion and Suggestion

Mobile gravity measurement can reflect non – tidal variation of regional gravity field. Tectonic information of discrepancy of the crustal density variation and the material migration of deep crust can be reflected by gravity variation. It has not only activity of deep and big faults under the effect of regional stress field but also the activity of local faults under the action of focal stress field. Spatial dynamic variation features of gravity field can be considered as the basis of relationship between the contemporary crustal structural and earthquake preparation.

1) Gravity variation and the faulted structural activity are closely related. In significant change period, spatial distribution changes of gravity fields show regular variation and high gradient zone of Xianshuihe-Anninghe-Zemuhe fault; before Wenchuan earthquake, there is relatively remarkable gravity variation near Xianshuihe-Anninghe-Zemuhe fault.

2) An impending prediction was made based on the regional gravity variation in western Sichuan. During 2005 – 2006 and 2006 – 2007, gravity field variation can reflect not only regular variation from west to east increasing gradually and regional gravity anomaly moving to Longmenshan Fault Zone, but also regional gravity anomaly sustainable development in the same direction; During 1998 – 2008, the dynamic patterns of gravity field mirrored the evolution process of gravity field: quasi-homogeneous state-non-homogeneous state-earthquake occurrence.

3) Gravity measurement is a branch of earthquake prediction research. Its research depends on abundant observational data largely. The layout of mobile gravity monitoring network is mainly along Xianshuihe-Anninghe-Zemuhe fault zone, most of which are branch connection surveying. Graphic control ability of the network is too poor to satisfy monitoring and forecasting earthquakes which are bigger than *M*s6.0[11,12]. It can be a perfect and enlarge time-space domain of regional gravity monitoring system (gravity monitoring network at present in western Sichuan), which is independent of Longmenshan monitoring network, the range of space control is smaller and has a blank at some area. Seismic monitoring and prediction is seriously affected, strengthening gravity monitoring network is composed of adjacent mobile gravity network in western Sichuan.

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