Inversion Research on the shortening and Sliding of Drape Zones between Chinese Continent Blocks by GPS Data

*Du zhixing Yang fanlin Wang xinzhou Lu xiushan Zhang huizhan
(Key Laboratory of Geomatics and Digital Technology, Shandong University of Sci. & Tech., Qingdao, China)

Abstract

A uniform velocity field of crust can be obtained by cumulative multi-year GPS data. Then the shortening and sliding of drape zones between Chinese Continent Blocks can be researched through the velocity field and dynamics meaning is also analyzed. A model of movement and strain is created to extract displacing and rotating information of blocks in this paper. On the basis of it, the shortening vectors and sliding states of drape zones between blocks can be obtained by the model of level center of gravity moving velocity vectors between neighboring blocks. Some result show as follows. India plate jostles greatly toward north, so a complicated movement situation is formed for 14 sub-blocks. And self-deformations of inner tectosomes can be greatly reflected according to the characteristics of drape zones between tectosomes. The extrusion deformation exists between Himalaya and Qiangtang blocks. Its contraction ratio is about 20.1 $mm.a^{-1}$. However, it only is 2.2 $mm.a^{-1}$ between Tarim and Zhungar. The deformation characteristics and contraction ratio of other drape zones are obviously different with the former. The movement characteristics of contraction, shear, dislocation, etc. are showed in these zones. The average contraction ratio is about 5.0 $mm.a^{-1}$. The whole trend in the west continent has a big movement toward north, and in the east continent has a small movement toward south or southeast. The strain of west continent is far bigger than that of east, and the strain of southwest is bigger than that of the southeast. It is whole showed that India plate jostles toward north-east and the south-north zone has cutting and absorbing phenomena. The total characteristics and present-day trends of deformation of inland drape zones are basically described by the sinistrorse dislocation in south-north zone and Arjin fracture, the sinistrorse shear between south china and north china, etc.

Key words：Chinese Continent , GPS，Movement and Deformation Model, Inversion, Drape Zone Deformation

1. Introduction

China continent and its neighboring zones are the result of joint impaction of Indian Ocean plate, Pacific Ocean plate and Philippine plate Block. The piecewise differences of action and coupled may between the three blocks and Eurasian plate control the asymmetry of present continent tectonic movement. The asymmetry denotes the differences of movement direction, velocity for each block, and deformation way, intensity for interior of each block. Many researchers investigated and researched the living faults in interior of China continent in last 10 years or more. They accumulated abundant information. It is a foundation for researching the relative movement and deformable state between blocks. Some important conclusions were obtained [1-3].

Because blocks are not pure rigidity, and the edges and interiors of blocks have different deformation characteristics (including elasticity, plasticity and viscosity), deformation and relative movement can not be assumed as that of rigidity. It will have shortage and limitation if we only use geologic and seismic data to describe the present tectonic characteristics of interior continent. Present spatial geodesy technology, especially for GPS technology of surveying earth; make it become reality for researching deformation and movement of interior blocks in high precision, big zone and reality.

Since China began the GPS observation in the late 1980s, GPS observations of some regional area such as Sichuan, Yunnan, Hexizoulang, Qingzhang, Xinjiang and north China, as well as the nationwide "climb plan" and national grade A net have been carried out in succession. They provided a data foundation for deeper research. Liu, Zhu, Xu et al. researched many problems in kinematics or dynamics, including strain field in interior continent, euler parameters of block movement, the origin of driving force in edges, the ways of block movement and deformation etc. They disclosed the movement states and characteristics of the earth's crust [4-10]. However, there is little information available in literature about uniformly researching movement and deformation of main blocks in China continent, and deformation of faults between blocks. As the GPS data accumulate, it need total comprehensively research the faults [11-16].

Considering the quantity of observation data on some active blocks especially GPS data, it insufficient to determine their movement parameters, so in the study we made a choice or combination to 18 active blocks in China continent and formed 14 blocks (Fig.1). In this paper, the present GPS data are utilized to calculate the deformation parameters of main blocks through optimum inversion. It is stressed in quantitative analyzing the fault zones between blocks [10].

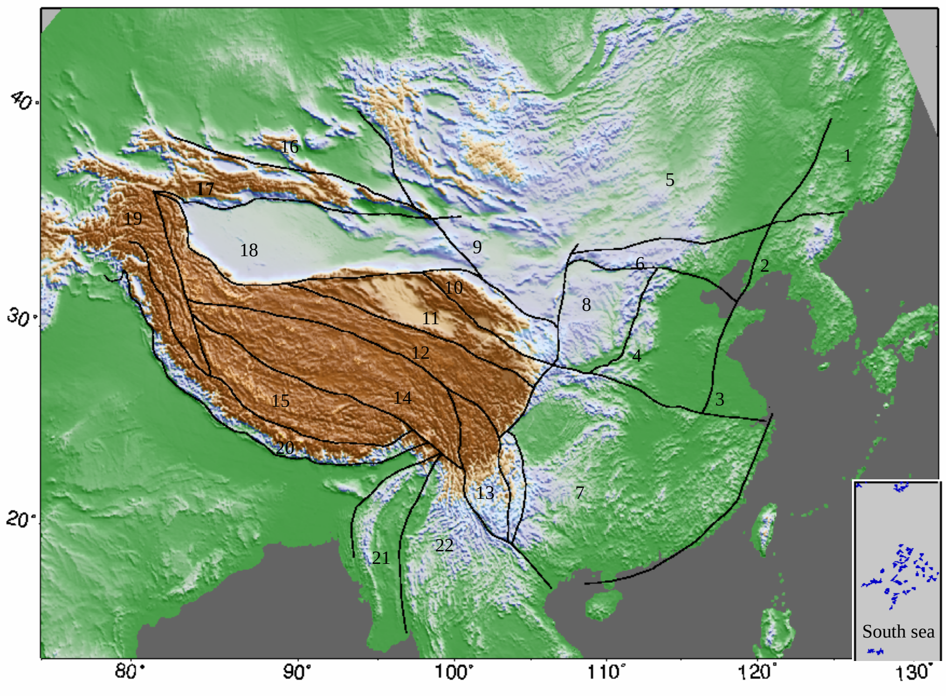

Fig.1 The blocks in China continent and neighboring zones

（1. Chuangbai Mountain Block, 2.North Yellow Sea Block, 3.South Yellow Sea Block, 4.South China Block, 5.Songliao Block, 6.Yinshan-Yanshan Block, 7.North China Block, 8.Ordos Block, 9.Alashan Block, 10.Qilian Block, 11.Qidam Block, 12.Kunlun-Songpan Block, 13.Chuandian Block, 14.Qiangtang Block, 15.Lhasa Block, 16.Zunger Block, 17.Tianshan Block, 18.Tarim Block, 19.Pamier South Block, 20.Himalaya Block, 21.Burma West Block, 22.south-west Dian Block）

2. Inversion model

Most deformations of geological blocks in China continent appear to be both rigid movement and inner deformation. The model of movement and deformation is appropriate to describe this characteristic. According to the characteristic and rule of deformation, the model can be expressed as follows.

$$\left.\begin{aligned} &\mathbf{V} = \mathbf{V}_0 + \dot{\boldsymbol{\varepsilon}}\Delta\mathbf{p} + \dot{\boldsymbol{\omega}}\Delta\mathbf{p} + \mathbf{e} \\ &\mathbf{e} \sim N(0, \sigma^2 \Sigma_{\mathrm{V}}) \end{aligned}\right\} \qquad (1)$$

Here, $\mathbf{V}$ and $\Delta\mathbf{p}$ stands for the vector of the velocity and longitude and latitude difference of the survey nod in the ellipsoid surface respectively. $\mathbf{V}_0$ is the centrobaric velocity of the study area. $\dot{\boldsymbol{\varepsilon}}$ and $\dot{\boldsymbol{\omega}}$ stand for the tensor of the strain rate and eddy rate respectively. And their relationship can be expressed as follows.

$$\mathbf{V} = \begin{bmatrix} V_E & V_N \end{bmatrix}^T, \mathbf{V}_0 = \begin{bmatrix} V_{E0} & V_{N0} \end{bmatrix}^T, \Delta\mathbf{p} = \begin{bmatrix} \Delta E & \Delta N \end{bmatrix}^T$$

$$\dot{\boldsymbol{\varepsilon}} = \begin{bmatrix} \dot{\varepsilon}_{EE} & \dot{\varepsilon}_{EN} \\ \dot{\varepsilon}_{NE} & \dot{\varepsilon}_{NN} \end{bmatrix}, \ \dot{\boldsymbol{\omega}} = \begin{bmatrix} 0 & -\dot{\omega} \\ \dot{\omega} & 0 \end{bmatrix} \qquad (2)$$

In order to obtain the movement parameters, 3 non-linear points or more are required for the solution result. Non-linearity means that they are not in the same longitude or latitude line.

The shortened velocity of the drape zone in the inter blocks are calculated through the horizon velocity vector of the barycenter of the contiguous geological blocks.

$$\mathbf{V}_{ij} = \mathbf{V}_j - \mathbf{V}_i, \ \mathbf{V}_{ij} = \mathbf{V}_1 + \mathbf{V}_2 \qquad (3)$$

Here, $\mathbf{V}_{ij}$ is the shortened velocity of each drape zone; $\mathbf{V}_i$ and $\mathbf{V}_j$ is the horizon velocity vector of the barycenter of the contiguous geological blocks, $\mathbf{V}_1, \mathbf{V}_2$ respects the longitude and latitude velocity vector of $\mathbf{V}_{ij}$ .And $\mathbf{V}_{ij}$ is the evidence for analysis the slip of each drape zone.

3. The deformation of drape zones

3.1 Displacement and rotation of the Geological Block

14 movement parameters of the geological blocks can be inversed according to the rigid body movement model (Tab. 1).

Tab.1 the movement parameters of main blocks in China continent, referring to Eurasian plate

Sub-blocks	Movement Parameters		
	V_e /mm.a^{-1}	V_n /mm.a^{-1}	$\dot{\omega}$ /(10^{-9}°.a^{-1})
Songliao	2.08±0.006	-3.44±0.006	–0.607±0.003
Yinshan-Yanshan	2.7±0.001	-0.7±0.001	10.841±0.004
Ordos	5.1±0.006	-2.7±0.006	0.371±0.001
North China	5.0±0.008	-3.2±0.007	0.844±0.001
South China	7.3±0.012	-3.9±0.009	-0.77±0.006
Chuandian	6.7±0.04	-8.6±0.03	-5.225±0.004
Qiangtang	19.8±0.017	7.4±0.013	-13.234±0.003
Himalaya	11.2±0.031	26.2±0.021	-4.913±0.008
Qaidam -Qilian Mountain	6.4±0.038	4.6±0.028	1.65±0.002
Tarim	2.4±0.027	7.1±0.020	–10.310±0.004
Tianshan	3.3±0.074	9.1±0.062	-0.725±0.001
Zunger	1.6±0.089	2.9±0.078	2.721±0.002
Alashan	3.4±0.013	2.3±0.010	-6.142±0.001
Kunlun-songpan 1	1.1±0.13	11.3±0.11	-22.375±0.023
Kunlun-songpan 2	14.9±0.15	3.3±0.09	-32.779±0.020

3.2 The shortened velocity of the Drape zone and slip movement

Using the horizon velocities of barycenters of the contiguous geological blocks and model （4） to compute the shortened velocity of the drape zone in the inter geological body, the result is shown as the Fig.2. (Geological blocks' distribution is the same as Fig.1, the unit of the shortened velocity is mm.a^{-1})

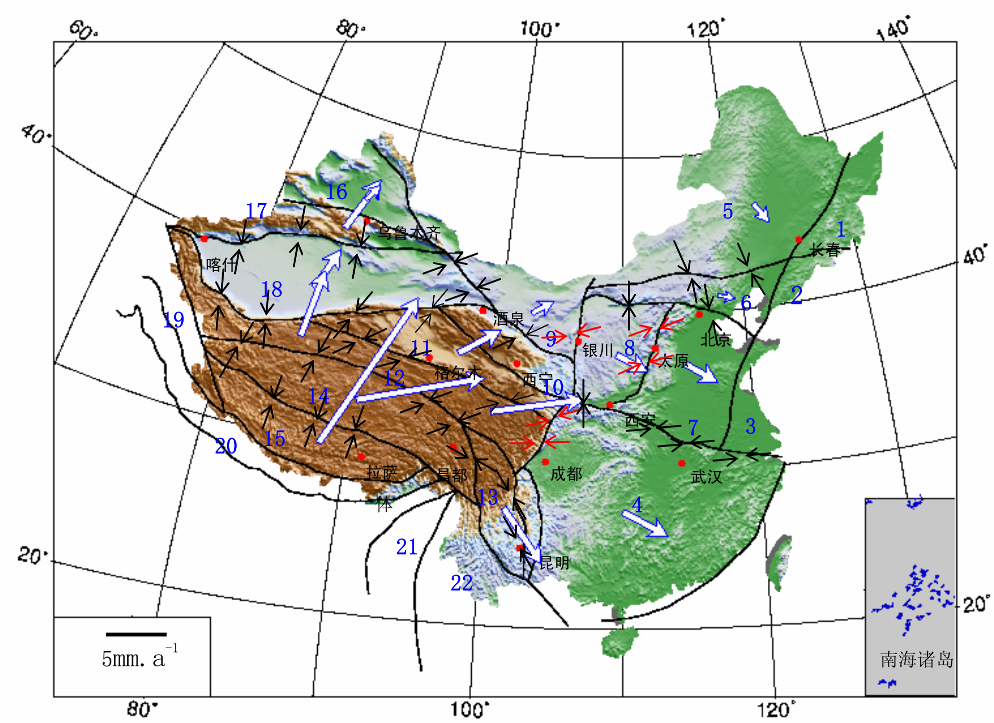

Fig.2 the shortened velocity of Main Blocks in Chinese Continent

4. Discuss and Conclusions

4.1 Deformation characteristics of the drape zones between blocks

The movement and deformation of blocks and drape zones in China continent can be obtained through present GPS data. An optimum inversion algorithm is adopted in this paper. The values are somewhat smaller than a result of joint inversion of GPS data and seismic moment tensor. They only reflect the contribution of displacement according to GPS data.

As expressed in the Fig.2, there are distortion in the drape belts between the bodies of Himalayas block and Qiangtang block, their shorten rate is 19.5 mm.a^{-1}, Qiangtang block and

Kunlun-songpan block, their shorten rate are 16.0 mm.a^{-1} and 5.1 mm.a^{-1} b in west and east respectively, and shown as laevogyrate slip. The shorten rate is 4.2 mm.a^{-1} between Kunlun-Songpan block and Tarim block, and is 6.9mm.a^{-1} between Kunlun-Songpan block and Qaidam block. Tarim block and Zunger block, Zunger block and Tianshan block, shown as extrusion deformation, the shorten rates are 2.3 mm.a^{-1} and 5.8 mm.a^{-1} respectively. Tarim block and Alashan block shown as laevogyrate slip, the shorten rate is 4.2 mm.a^{-1}。 Each belt in the north and south is different in the deformation characteristics, most of them are dextrorotation shear movement. The shorten rates of the Chuandian block , Kunlun-songpan block, Qaidam block, Alashan block ,are 4.1 mm.a^{-1}、8.2 mm.a^{-1}、5.4 mm.a^{-1}、5.8 mm.a^{-1} respectively. The eastern is less than the western in the NS belt, the average is 4.3 mm.a^{-1}.Boundary between the north china plate and south china plate shown as laevogyrate shear deformation, the shorten rate is the minimum, 2.3 mm.a^{-1}. Boundary between the Ordos and north china sub-plate shown dextrogyrate deformation, the shorten rate is the maximum, about 4.9 mm.a^{-1}. These results show the total characters and present trend of the deformation of the drape zones in China continent. They are basically coincided with the geological conclusion [1, 2].

4.2 The dynamics meaning of rule of blocks deforming

India plate jostled toward north. It resulted in the uniform movement of Himalayas block, Qiangtang block and Kunlun-songpan block toward north-north-east. The rates are gradually contractible along north, and that more intensive jostling deformation is formed in drape zones. Chuandian block had a more intensive movement toward south-east, and it denoted the influence of India plate.

The conclusions can be obtained according to the results. Jostling resulted in movements of north China toward east-west, movements of Tarim and Zunger and Tianshan block toward west, movements of Qaidam -Qilian Mountain block and Alashan block toward east. The activity and function of Philippine plate made the degree weaken and had a movement against south-east of north China. Alkin fault’s laevogyrate slipping in northwestward and laevogyrate shearing deformation between the northchina sub-plate and south china sub-plate are the characteristic reflection of complicated movement and deformation.

In a word, the movement of India plate toward north is the root of movements and deformations of blocks and drape zones in west China. The movements of blocks and drape zones in east China not only have a trend toward east and east-south, but also impacted by the movements of Pacific Ocean plate, especially for Philippine ocean plate, toward west-north and correlative back-arc spreading. It has a total deforming trend in China continent of compressing in westward and spreading in eastward. But different tectonics, blocks and drape zones have different ways of movement and deformation.

References

1. Ding G.Y. et al. Lithospheric dynamics of China. Beijing: Seismological Press, 1991: 131~140; 142~ 153; 163~165 (in Chinese)
2. Liu D.W. Some general problems in geodetic deformation analysis and interpretation. Crustal deformation and earthquake. 1991, 11(2): 27~34.（in Chinese）
3. Wang S.Y., Xu Z.H. Inversion for the plate driving forces acting at the boundaries of China and its surroundings. Acta Geophysica Sinica, 1996, 39(6):764~771 （in Chinese）
4. Zhu W.Y, Cheng Z.Y, Xong Y.Q, et al. The primary results of crustal movement in Qinghai-Tibet Plateau by GPS techniques. Science in China, 1997,27(5):385~389
5. Zhu W.Y, Cheng Z.Y, Xong Y.Q., et al. Preliminary results of crustal movement in Chinese mainland by GPS data. The science of China (in Chinese), 2000, 30(4): 394-400
6. Liu J.N., Xu C.J., Song C.H. Study of the crustal movement in the middle east region of the Qinghai-Xizang plateau with GPS measurements. Acta Geophys. Sinica, 1998, 41(4):518~523 (in Chinese)
7. Liu J.N., Xu C.J., Song C.H., et al. Study on recent crust movement and stress field based on several periods of GPS surveying data on Qinghai-Tibet Plateau. Chinese Science Bulletin, 2000,45(24):2658~2663 (in Chinese)
8. Zhang Q., Zhu W.Y. Preliminary study of movement model for tectonic blocks on the Chinese mainland. Chinese Science Bulletin (in Chinese), 2000, 45(9): 967~974
9. Dang Y.M. The Theory and methodology for geodetic deformation analysis and interpretation based on inversion theory. Technical University of Surveying and Mapping. PH. D. Dissertation. 1998.（in Chinese）
10. Wang Q., Zhang P.Z., Niu Z.J., et al. The Crustal movement and tectonic deformation, the Science of China（D）, 2001，31（7）：529-536（in Chinese）
11. Wang Q., Zhang P.Z., Freymueller J.T., et al. Present-Day Crustal Deformation in China Constrained by Global Positioning System Measurements, Science, 19 October 2001, Volume 294, pp.574-577
12. Shen T B, Holt W E, Haines A J. The contemporary kinematics of the Western United States determined from earthquakes moment tensors, VLBI and GPS observations. J. Geophys. Res.,1998,103:18087-18118
13. HU Jyr-ching, and YU Shui-beih, et al. Active deformation of Taiwan from GPS measurements and numerical simulations. J. Geophys. Res., 2001,106(B2), 2265-2280.
14. Holt W E, Pichon X L, Haines A J, et al. Velocity field in Asia inferred from Quatemary Fault slip rates and GPS observations. J. Geophys. Res., 2000,105:19185-19209
15. Philippines from GPS and seismicity data. J. Geophys. Res. 2000, 105(B1), 663-680
16. Heflin M B, Bertiger W I, Blewitt G, et al. Global geodesy using GPS without fiducial sites. Geophys Res Lett, 1992,19:131-134

Foundation item: project supported by Special Project Fund of Taishan Scholars of Shandong Province（TSXZ0502）and the national science fundation of China (40474005)

Biography: Du Zhi-xing(1965---), male, Associate professor, Ph. D., research direction: geodesy inversion and geodynamics

Address:

College of Geo-information Science & Engineering,
Shandong University of Science and Technology
Qianwangang Road 579,
QingDao Economic & Technological Development Zone,
QingDao, Shandong Province, China
Email: zhixingdu65@163.com, zhixingdu@sina.com