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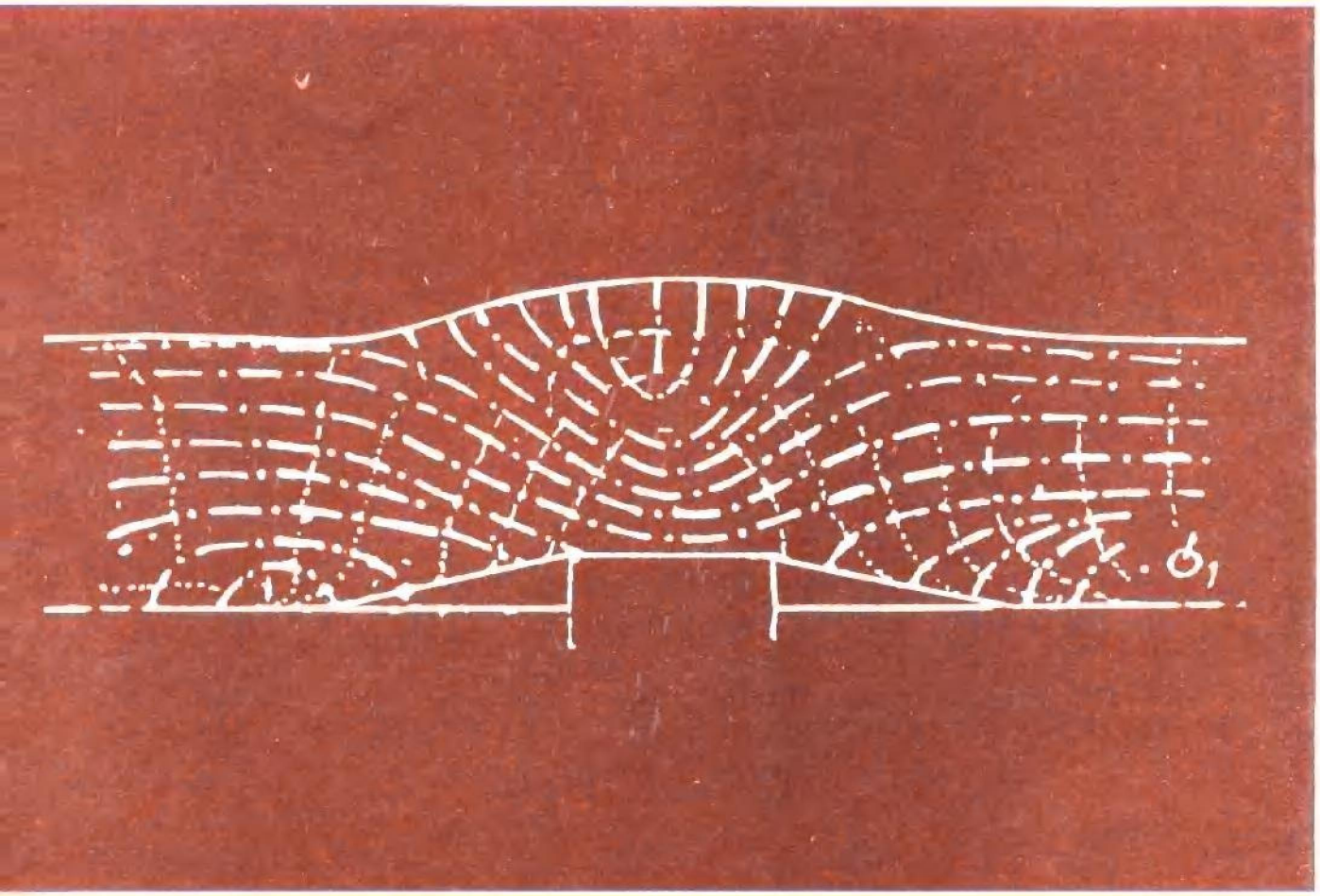
地壳构造与地壳应力文集

国家地震局地壳应力研究所　编



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内 容 提 要

本书介绍了是国家地震局地壳应力研究所近几年在地震观测、预报、实验和理论方面的部分新成果。其中英文论文 10 篇，中文论文 9 篇。主要内容有新构造活动的特征、地震活动性、地震危险性预测、地壳应力变化的观测及实验研究等。

本书可供从事地质、地震、减灾、工程地质工作者及有关院校师生参考。

地壳构造与地壳应力文集（九）

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《地壳构造与地壳应力文集》编委会

目　录

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Research on Tectonic Characteristics of Historical Strong Earthquakes in North China Plain

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1. Introdution

North China Plain locates in the East of China. The density of population in this area is high and traffic condition is developing. The area is also important for preventing disaster.

North China Plain is an active area of strong earthquake in resent 300 years, There were 8 times destroyed earthquakes ($M \geqslant 7$) occurred in East China territory (east from E114 °). The 6 times of them appeared in North China Plain (NCP) and its boundaries. Seismologists pay more attention to its seismotectonic background.

There are many differences in scale and intensity of the active tectonics between NCP and West China. The tectonic landforms are clear and fault traces can be seen in West China, where the focal structures are the same like the surface active faults. But seismotectonic types in North China Plain are complex. Besides having various orientational seismotectonics developed the discontinuities of tectonics in deep and in shallow layer cause focal and surface structures to perform complicated picturies. In addition, more than hundreds meters Quarternary deposits increase the difficulty of recognizing the properties of seismotectonics of the area. This paper deals with some characteristics of seismotectonics of the area from the aspets of surface seismofaults and activity of Holocene faults as well as the regional tectonic information obtained in recent years.

2. Surface seismofaults of historical strong earthquakes

Field investigations from domestic and overseas have shown that tectonic fractures developing strong earthquake not affected by landform or ground object are the surface reflection of focus fracture. We call it surface seismofault.

Among recent 6 times strong earthquakes developed in North China Plain, there are three times NNE and NW strike seismofaults respectively in two groups(Fig.1).

2.1. NW strike surface seimofaults

During recent history in North China Plain, there were following strong earthquakes

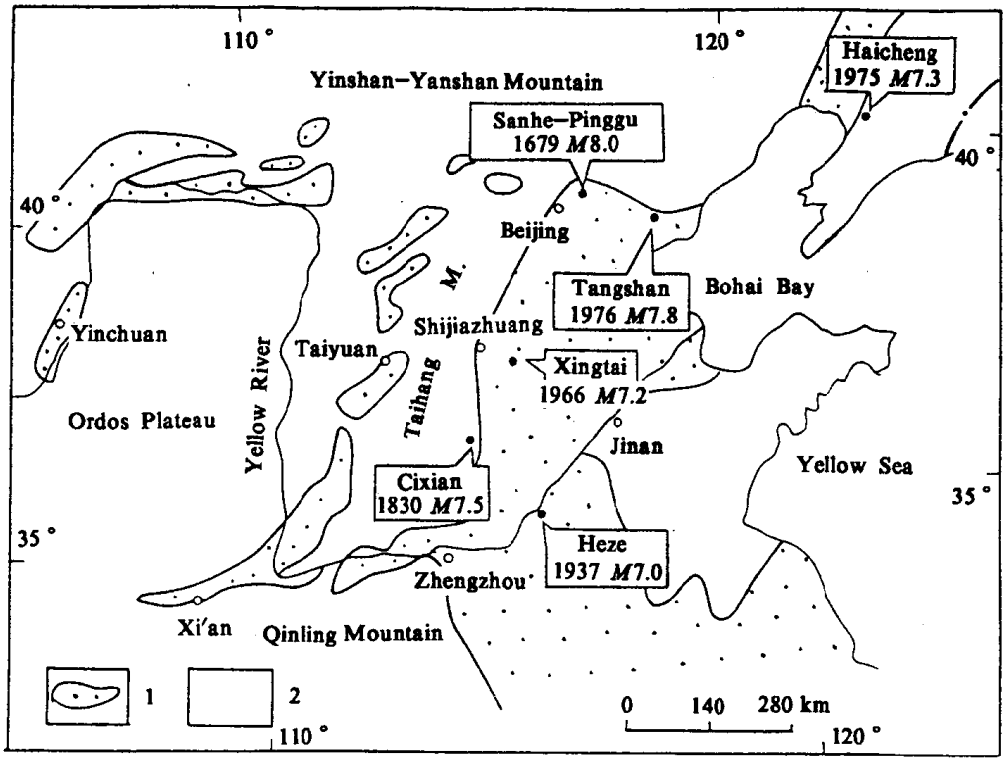

Fig.1 Distribution of recent strong earthquakes in North China Plain

1.Quaternary subsidence; 2.Mountain and hill

which appeared NW strike sureface seismofractures: 1975 Haicheng earthquake magnitude 7.3 in Liaoning Province, 1937 Heze earthquake *M*7.0 in Shandong Province and 1830 Cixian earthquake *M*7.5 in Hebei Province . The detailed degree of investigating surface seismfaults were different, because these earthquakes appeared in different historical period. They also totlely refleted the outline of surface seismofaults. The surface fractural zone of 1975 Haicheng earthquake was about 50 km long composed of four secondary surface fractures. The famous Xiaogushan fissure zone was about 5.5 km long accompanied by 0.55 m sinistral strike–slip[1]. It went through out bedrock area and Quaternary river terraces. It was reported about 1937 Heze earthquake that surface fracture zone jointly consisted of two groups of fractures in NW and NE trends[2]. The NW trend surface fracture zone was about 90 km long accompanied sinistral strike–slip and the NE trend fracture zone was about 20 km long accompanied dextral strike–slip. The fracture zone of 1830 Cixian earthquake was about 40 km long. The west segment of the zone distributes in bedrock area from Fengfeng west. The fault scarps and ground earthquake furrows can be seen along the surface seismofault, which distributes in an en echelon structure of right–handed form. The movement of the fracture zone was mainly dip–slip accompanied left lateral slip[3~6].

The patterns of the seismic intensity areas of the Haicheng earthquake and the Heze earthquake showed intersection of NWand NE directions. But the long axis was basically

along the distribution of the ground seismofracture zone. The ratio of the longest and the second longest axis of the Haicheng earthquake is about 1.34:1. The NE and NW strike long axes of the strongest intensity area of 1937 Heze earthquake were 20 km respectively. The Ⅷ degree area of the intensity was gone to Ⅸ degree area. But NW direction dominated the shape of Ⅶ degree area of the intensity. The ratio of the axial length in NW and NE direction in the Ⅶ degree area was about 1.62:1[7]. The ratio of long and short axis of the strongest intensity area of Cixian earthquake in 1830 was about 3:1 (Fig.2).

2.2. NNE strike surface seismofaults

During recent 300 years, the strong earthquakes which belonged to NNE strike ground fractures were 1976 Tangshan *M*7.8 earthquake, 1966 Xingtai *M*7.2 earthquake and 1679 Sanhe – Pinggu *M*8.0 earthquake in Hebei province. 1976 Tangshan *M*7.8 earthquake was the biggest earthquake in North China Plain this century so far. The intensity of the centre was Ⅺ degree. After the earthquake, the field investigation showed that the surface seismofault was about 10 km long, NE30 ° strike, consisting of secondary fractures which were right lateral strike – slip accompanied tensional property in a form of en echelon fracture of left – step form. The largest displacement of lateral and the vertical of a single fissure were about 1.45~ 2.3m and 0.6~ 0.8m[8~ 10]. The 1966 Xingtai *M*7.2 earthquake was the begining of activity of earthquakes in NCP this century. It is very pity that the surface seismofault wasn't distinguished from a lot of ground fissures occurred in the earthquake due to lacking experience in field investigation after earthquake mentioned at that time. Luckly, the measurement data of net of triangle base line and level can make up for the above. The Niujiaqiao fault appeared right lateral displacement with downthrow of the east side along the slip face. The largest amount of strike–slip and vetical movement were about 1.0~ 0.8 m and 0.2 m based on measure of the displacement[11,12]. The face of fault which was determined by ground deformation is no difference with the deep prospection by geophysics which was done lately[13]. The intensity of epicentre of 1679 Sanhe–Pinggu *M*8.0 earthquake was about Ⅺ degree. The trace of the surface seismofault can be seen even now, 5~ 10 km long, consisted of several NE trending secondary tensile fractures which are mainly dip–slip normal faults in left form of en echelon fracture, NE45 ° strike. The average height of the ground scarps now is about 1~ 2m and the highest vertical displacement was about 3.16m[14~ 16], expressing a dextral movement of tenso–shear.

The axis directions of the three NNE intensity line of the destroyed earthquakes were almost consistent with that of the surface seismofaults. The ratio of the length of the long and short axes is about 2:1 in Tangshan and Sanhe–Pinggu earthquakes. The deviation of directions between the epicentre intensity line and surface seismofault in Tangshan earthquake was considered as a result of complex processes of focal fracture[17](Fig.2)

2.3. Summary

To sum up, there are following characteristics on the surface seismofaults in NCP:

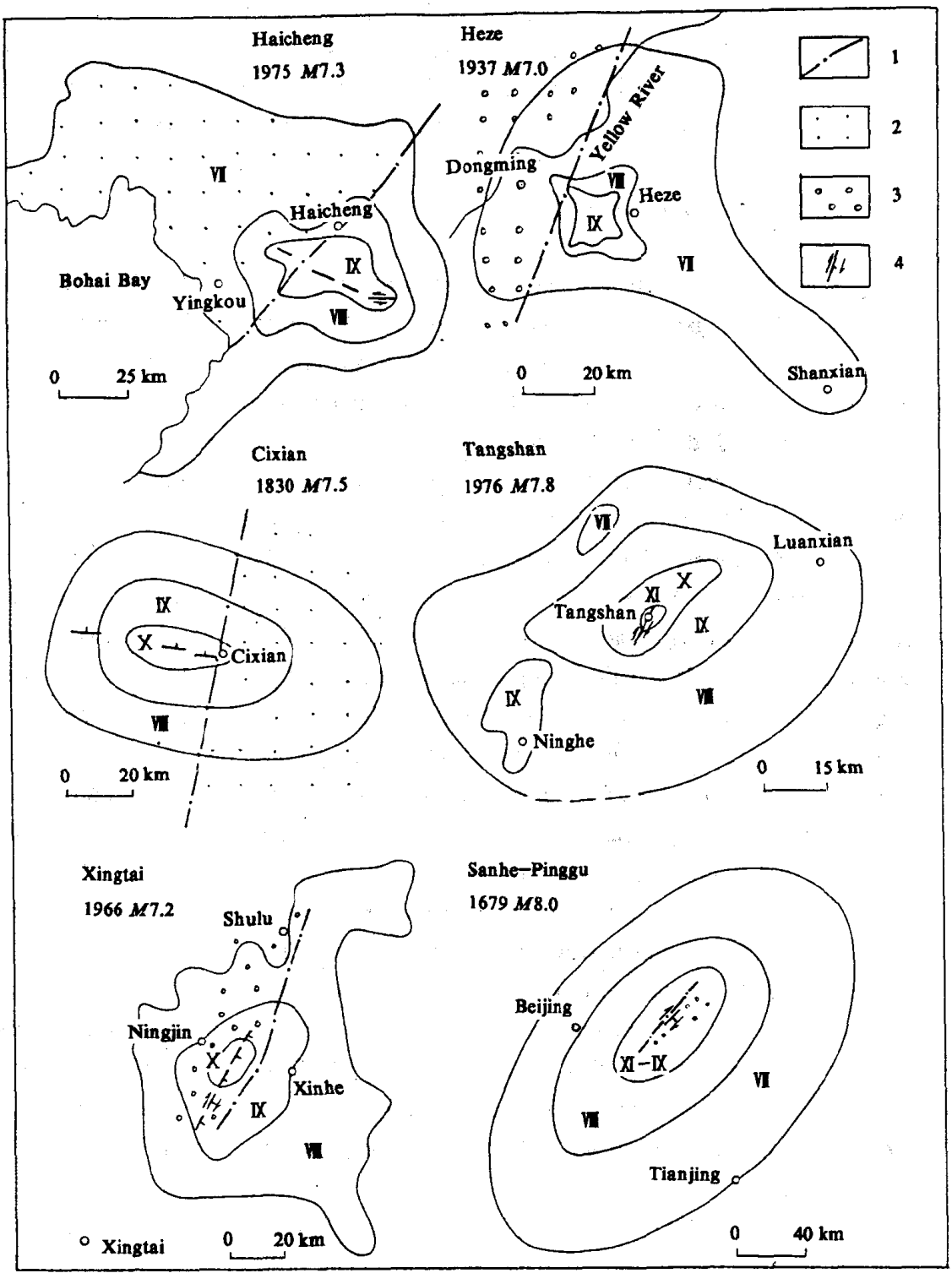

Fig.2 Surface seismofaults and seismic intensity of recent strong earthquake in NCP

1.buried faults; 2.Quaternary subsidence area; 3.Tertiary fault depression;

4.surface seismofaults

(1) Wether NW or NE strike strong earthquake fractures, their long axes of centre seismic intensity were along the surface seismofault of strong earthquake.

(2) Although existing some divergence on dip– slip among these ground fissures, the three times NNE surface seismofaults showed dextral strike–slip and the three times NW surface seismofaults showed sinistral strike–slip.

(3) Among the NNE fratures of destroyed earthquakes, the length of surface seismofaults was not more than 10 km. The largest dextral and vertical displacement were 1.45～2.3m and 3.16m. The scale of the surface seismofault is small compared with their magnitutes. The NW strike surface seismofault had the same condition. Although above said the length of the three NW surface fractures of destroyed earthquakes were close to the length of the epicentre seismic intensity, their distribution were not successive, and showed off and on. The actual length of surface seismofaults of Haicheng and Cixian earthquakes were only one second or one third of their center intensity length. These phenomena showed the surface seismofaults in NCP were weak in appearance. One reason is probably the disturbing occurred by the difference of shallow and deep geological structures. The other reason may be the action that the loose deposits in these Quaternary areas absorbed a part of the deformation of the focal displacement, weakening the surface appearance of the deformation.

(4) The Haicheng earthquake and the Heze earthquake were the similar cross shape of centre intensities. But the fracture of the Haicheng earthquake was a single fracture along NW direction. The fracture of Heze earthquake was considered as bi–fractures in NE and NW directions. Author thinks that the appearance of right lateral displacement of the Heze earthquake is the one of the conjugate fracture of focus or the result of ground fracture under the action of stress field during earthquake and that should be pending further study.

3. Activety of Holocene faults and palacoearthquakes

3.1. NW striking Holocene active faults and palaeoearthquakes.

Recent research has shown that there are NWW strike active faults in the three erathquake areas mentioned above.

The length of the NW active fault in Cixian area is approximately 50 km long in two segments. The west segment is the Nanshancun–Chakou active fault. The traces can be followed in bedrock area of Fengfeng west. The main marking of the active fault is the clear fault landforms. For example, the offset ridge, the fault cliffs and fault scarps dislocated the slopes, and a series of fault negative landform etc. The vertical displacement of these fault landform is obvious. The accumulation of dislocation of fault landform can reach to tens metres, even to one hundred metres. The angles of the slope along fault cliffs appeared sev-

eral times transforms, lower steep and upper lower angle, showing several times activity of the fault. The wedge which composed of loess and pieces of rubbles of bedrock in line one meter wide and heigh respectively was found at Nanshanchun village. The later slope wash whose age was about (3876± 146) years B.P. determined by ^{14}C dating covered the wedge. From it the conclution can be get that the early paleoearthquake occurred in about 3700 years ago. The surface origin condition of the east segment of Cixian NWW active fault was destroyed seriously by human activity. But from the data of the drilling we can get some information. The separation of upper strata of Middle Pleistocene Series and lower strata of Late Pleistocene Series along the fault was approximately 50m. The displacement of Holocene deposits along the fault was about 5~ 6m. The Cixian NWW fault was an active fault during Late Quaternary and Holocene[5,6].

The thickness of Quaternary system in Heze region reaches about 400m, covering the Neogene system. There Holocene Series is about 40 ~ 50m. The data from different depth showed the variance of muck under the surface 8m, 20m and 50m depth. The age of the muck is younger than Late Pleisticene Period. The analysis pointed there were a near east–west trending uplift along Malinggang where northern margin was a subsidence area[6]. It expressed that there was Holocene structure activity in Heze area. The evidence of above supports the idea that NW direction was the focal fracture of 1937 Heze earthquake.

After 1975 Haicheng earthquake, the NWW trending paleoearthquake furrow near the Shuiquan village was found. Through opening of trench, last paleoearthquake from present (3645± 135)a dating by ^{14}C has been found. Another palaeoearthquake which occurred 8100 ~ 11000 years ago has been found at famous Xiaogushan surface seismofault zone[18]. In addition, the Late Quaternary active structures in Haicheng area have been found by interpretation of aerophotoes. The most attractive information is that there was a NWW trend 16km long dislocated landform line on the south 5km of Xiaogushan. This active structure line dislocated the slope, forming scarps and furrows. The detail of these tectonic landforms should be continued to research. Now the information from palaeoearthquake has proved that 1975 Haicheng earthquake isn't the first strong earthquake in this area.

3.2. NNE striking Holocene active faults and palaeoearthquakes

Now we don't know clearly about the condition of Holocene activity of NNE trend seismotectonic in NCP. Some information showed that there were palaeoearthquakes in Tangshan area 7000 years ago[9]. In the trenches of the field investigation of the 1679 Sanhe–Pinggu M8.0 earthquake, some palaeoearthquake events also have been found[15]. In addition, the phenomenon that the displacement of the lower stratum was larger than that of the upper also expresses the evidence of existing palaeoearthquake event except the creeping of fault.

3.3. Summary

Summaring above, there are some characteristics as following about active structures of the six times strong shock areas in NCP.

(1) Besides Xingtai area where we need to learn more information about Holocene active structures and palaeoearthquake, the other strong earthquake areas above said exist Holocene active faults or palaeoearthquakes.

(2) The distribution of these Holocene active faults or palaeoearthquake events were coincident with extension of the surface seismofaults in these areas.

(3) Until now we haven't know the characteristics of NNE Holocene faults in these areas. Depending on information of the NW active structures, the extension of Holocene active faults was the same like off and on extension of the surface seismofaults occurred during strong shocks.

(4) The last recurrent interval of the destroyed earthquakes in Cixian and Haicheng areas was approximately 3600 years.

4. Characteristics of regional seismotectonic

The five times strong earthquakes among recent six times strong earthquakea in North China Plain occurred at the boundary of NCP, the margin of the west、north、east–north and east of it (Fig.3). The centre of 1830 Cixian earthquake and 1975 Haicheng earthquake located at bedrock or hill areas. The Heze earthquake in 1937 located at the Tertiary period uplift where were covered by Quaternary deposits. The Tangshan earthquake in 1976 occurred at the margin between the north of North China Plain and Yanshan Mountain where was a Tertiary uplift covered by Quarternary system. The Xingtai earthquake in 1966 located at the graben of NNE trend Tertiary period in the Hengxing uplift of North China Plain.

From above, we can see that the amount of the seismostructures corresponding to nongraben structure is two times more than that of the seismostructures due to a graben. So the relation between strong earthquake structures and the boundary of NCP is close. And the relation between strong earthquake structures and Tertiary grabens is not obvious. Recent years the information of deep geophysic prospection in Xingtai area has shown the focal seismofault didn't possess direct relation with the Tertiary subsidence in the upper crust, although the deep fault in the middle lower crust may have some relation with the upper crust Tertiary subsidence in kinematics[13].

In the dividing of fault block, these strong earthquakes were near the boundary faults of blocks. For example, the Cixian earthquake located at the east margin of Taihang Fault Block, close to Taihang Mountain piedmont fault zone which divides Taihang block and Yibo block. The Haicheng earthquake occurred at the west margin of Jiaoliao Block, close

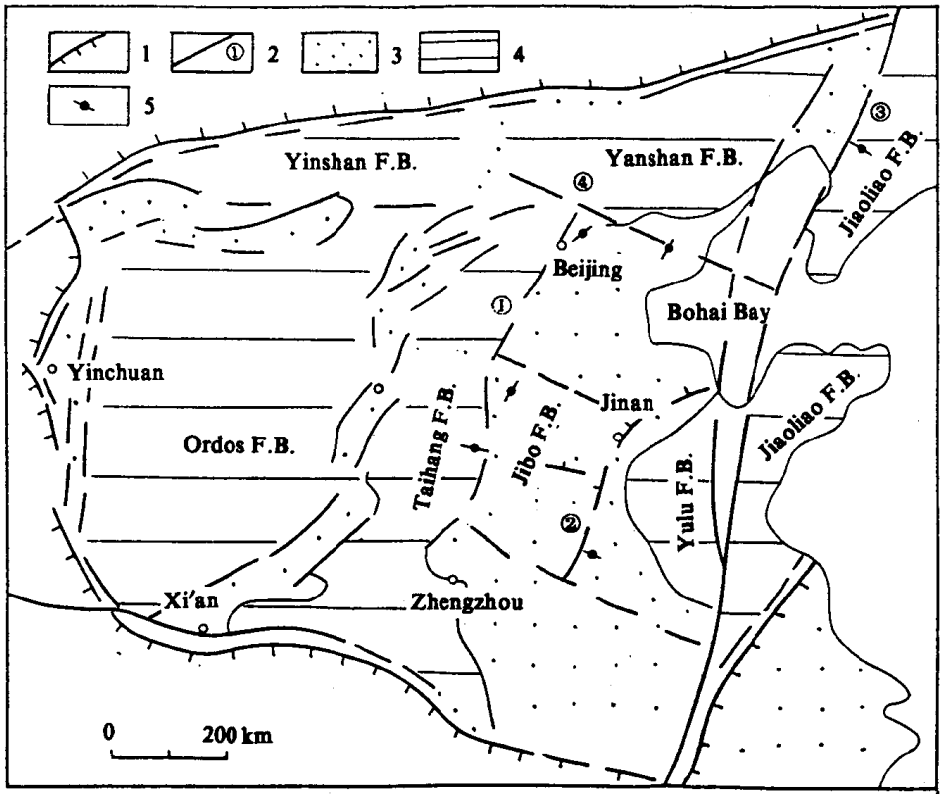

Fig. 3 Sketch map showing Fault Blocks of North China Plain

1 Boundary of North China Plain; 2 Boundary of fault blocks; Fault name; ① Taihang Mountain piedmont fault zone; ② Liaolan fault zone; ③ Jinzhou fault zone; ④ Zhangbo fault zone; 3 Quaternary subsidence area; 4 Mountain and hill; 5 strong earthquake in NCP and the fracture direction of surface seismofault.

to Jingzhou fault zone which divides Jiaoliao Block and Yibo Block. The Heze earthquake occurred at the west margin of Luxi Block,close to Liaolan fault zone which seperates Yibo Block and Jiaoliao Block. The Taihang Mountain Piedmont fault zone、Jinzhou fault zone and Liaolan fault zone are all more than 300km long large fault zones. But the NW trend surface seismofault didn't show the influence of the NNE large fault zones. The NW trend surface seismofault went through the NNE large fault zones to continue their extension in NW–SE orientation. Especialy the Handan fault didn't give any influnce to the distribution of earthquake intensity although it was a strong active Holocene fault close to Cixian[19,20]. The Cixian NW trend Holocene active fault is the west end of the Daming fault zone which is along the northern margin of Neihuang uplift. The Sanhe–Pinggu earthquake and the Tangshan earthquake located at the areas along the south of Yanshan Mountain, close to north Yibo Block. The area was a uplift during Early and Middle Eogene Period. Late, NNE orientation fault depression included in the area from the south to north during the Late Eogene Period and the whole area was in depression condition during Quaternary. The Xingtai earthquake in 1966 occurred at a secondary one among the NNE strike