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DELINEATION OF THE FOCAL AREAS OF CHINA'S HISTORICAL MAJOR EARTHQUAKES AND DETERMINATION OF POTENTIAL SEISMIC FOCUSES USING DATA OF MODERN SMALL SHOCKS

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Delineation of the focal area of historical major earthquake is important because only when the location and dimensions of the focal area and the strike of the earthquake—triggering structure are definitely known will we be able to carry out calculation on the influence field of major earthquake. At the same time, in order to predict whether a new potential major earthquake is likely to occur again in the historical focal area, we must in the first place know the location and the degree of recovery of that focal area and how much seismic energy has been accumulated in it. Qin Baoyan, Chen Jiachao et al. (1989) proposed two methods to determine the location, dimensions and degree of recovery of a historical major earthquake; the first method is based on the concentration domain of modern small shocks and the second method uses the blank domain instead. Both methods are generally applicable merely to those earthquakes that show significant after effect, in which case numerous faults of varied sizes were formed in focal area when the earthquake took place, and these faults in brittle medium took a long time to recover. During such a long period of recovery, the focal area was all along demonstrated by the occurrence of a series of small and moderate earthquakes. Therefore, by using the distribution pattern of small shocks we can delineate the focal area and determine the magnitude of a historical major earthquake. This is the theoretical basis of the first method. Through a considerably long period of recovery, small shocks in the focal area would attenuate and this focal area would eventually become a blank domain standing out against a background dominated by small shocks. This is the theoretical basis of the second method. Qin Baoyan, Chen Jiachao et al. (1989), however, have dealt with only a small part of China's historical major earthquakes in the light of these two methods. This paper describes 71 out of the 84 shallow—source historical major earthquakes with M=7 or more which took place in China's Continental crust during A. D. 138—1976, and discusses as to whether there will be potential seismic focuses for new major earthquakes or not.

Many methods have been developed for determining potential seismic focus. However, we probe into this problem only from two aspects, i. e. from the degress of recovery of a historical major earthquake and from the activity characteristics of the earthquake—triggering fault in the focal area, and our scope is limited to the focal areas of historical major earthquakes.

Generally speaking, when the focal area of a historical major earthquake enters a quiescent period of small shock activity, it means that this focal area has recovered already and begun to accrumulate stress. In this case, if the earthquake-

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triggering fault zone where this historical major earthquake was located is bound to be activated segment by segment, triggering a series of earthquake events before it accomplishes a complete movement, and if such movement has not yet com pleted, then this focal area is most likely to be activated again and thus can be deemed as a new potential earthquake source. As to whether a major earthquake will actually occur in this potential source or not, when will it take place and what is the magnitude if it does occur, these are all complicated problems which already exceed the scope of this paper.

I. Delineation of the Focal Areas of Historical Major Earthquakes Using Data of Modern Small Shocks

Historical major earthquakes can be grouped into two types in terms of after effects: those with serious consequence, i. e. earthquakes which cause severe damage to focal areas and whose aftershocks are significant and numerous; and those which cuase no severe damage to focal areas and whose aftershocks are insignificant. These two types of earthquake are different also in modern small shock activity as well as in property of their focal areas. Focal are of the first type can be regarded as an area made up of weak medium where modern small shocks are numerous under the action of tectonic forces, and as it has been intensely fractured, its scope and dimensions can be delineated approximately the distribution of modern small shocks. Whereas this is not true for the second type, whose focal area can not be delineated easily by modern small shocks. This paper deals only with those historical major earthquakes whose focal areas have been intensely fractured. Of course small shocks have been concentrated not only in some focal areas of historical major earthquakes, but also in or around some potential areas where major earthquakes are likely to occur in future or even in some middle seisms areas, but these three situations can be readily distinguished from one another.

1. The Nan' ao Earthquake of Feb. 13, 1918 in Guangdong Province with magnitude $7\frac{1}{4}$. Because this earthquake took place in the sea area, no macroscopic investigation was carried out at the outset. After the founding of new China, macroscopic investigation has been conducted several times, but the location of the epicentre is still a subject of much controversy (Gu Gongxu et al., 1983; Yang Yiquan, 1985). However, according to macroscopic analysis on seismic damage, the epicentre is located in the concentration domain of modern small shocks, namely at latitude 23°20′N and longitude 117°23′E to the east of the Nanpeng Islands, which can be regarded as the focal area of this earthquake (Fig. 1).

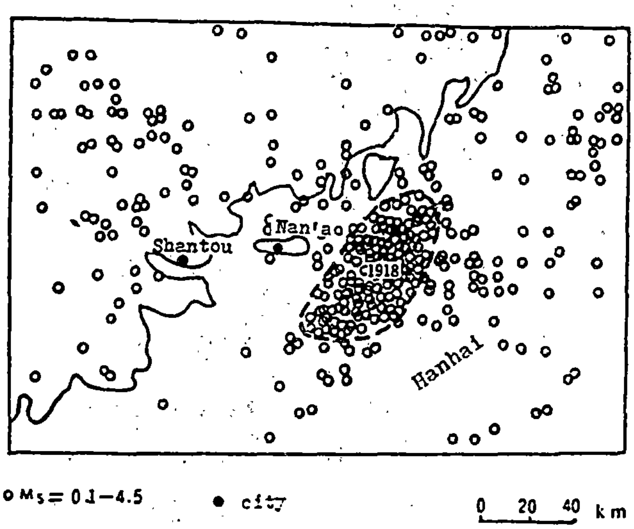

Fig. 1 Distribution of small shocks of 1970—1983 in Nanpeng area

This domain has a NE—SW elongation of about 65 km. According to the empirical formula (Guo Zengjian, Qin Baoyan et al., 1973):

$$M = 3.3 + 2.1 \log L$$

where M stands for the magnitude of the earthquake and L stands for the length of the concentration domain of small shocks, we obtain M equals 7.1 which is very close to that recorded by seismograph. This domain, with frequent small shock activity at the present time, has not recovered yet, and it is a safety region from major earthquake risk.

2. A major earthquake of magnitude 8 took place around Zhaocheng, Hongdong, Shanxi province on Sept. 17, 1303. After 392 years, another earthquake of magnitude 8 occurred around Linfen nearly at the same focal area on May 18, 1695. The epicentres of these two earthquakes are 42 km apart. This suggests that the first earthquake brought about not too severe damage to the focal area. Hence, after a period of recovery and energy accumulation of 392 years, another earthquake of magnitude 8 occurred again in Linfen. The Linfen Earthquake took place 295 years ago, while modern small shocks occur densely and in swarms in the focal area to—day, suggesting that through the damage of two M=8 earthquakes, the focal area is intensely fractured and has not recovered yet. These modern small shocks are distributed in a domain with NNE—SSW elongation of about 200 km, parallel to the regional structural line (Fig. 2). Calculation with the above—mentioned empirical formula yields M=8.1 which is close to that recorded in history. Since the historical focal area has not recovered yet, no potential major earthquakes are to be expected there.

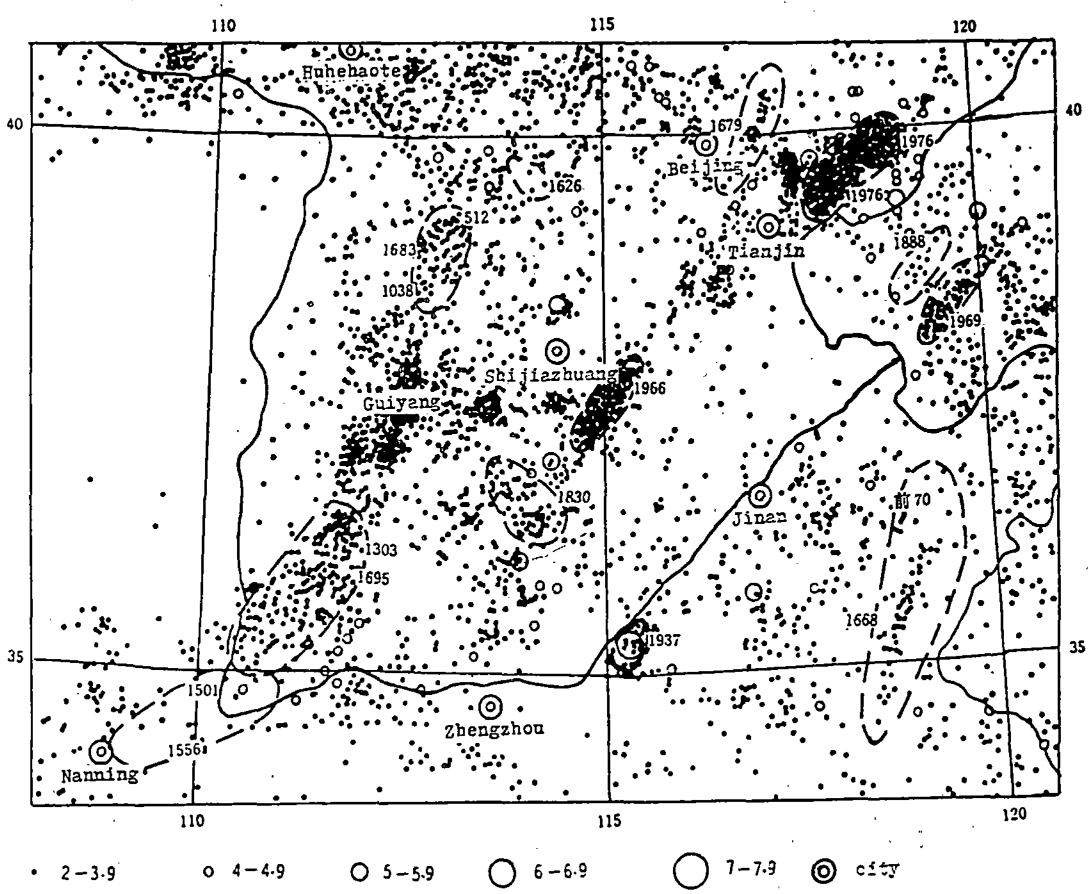

Fig. 2 Distribution of seismic activities of 1970—1985 and the focal areas of historical major earthquakes (M≥2) in North China

3. On June 1, 70 B.C, a M=7 earthquake took place in Changle area, Zhucheng, Shandong Province. One thousand seven hundred and thirty—eight years later, on July 25, 1668 another earthquake of magnitude $8\frac{1}{2}$ occurred in Tancheng, Juxian to the south of Changle. The two earthquakes have the same focal area. The Tancheng Earthquake happened 322 years ago and small shock activity has been persisting even to these days. The concentration domain of

small shock activity has a NNE—SSW elongation of 304 km (Fig. 2), parallel to the long axis of the meisoziesmal area. Calculation using the empirical formula yields M=8. 5, which is in conformity with the historical record. The focal area has not recovered yet, and no potential major earthquakes are to be expected.

4. On Feb. 4, 1975, a major earthquake of magnitude 7. 3 took place in Haicheng, Liaoning Province, with the isoseismal lines forming a nearly E—W elongated geometry. The subsequent small shocks are distributed densely and in swarms, delineating a nearly E—W elongated focal area about 80 km long (Fig. 3). The calculated magnitude from the empirical formula is 7. 3which is equal to the magnitude determined instrumentally. Since the present small shock activity is frequent, the focal area has not recovered yet, therefore no potential new seismic focus exists there.

5. The Haiyuan Major Earthquake of Dec. 16, 1920. Three major earthquakes occurred successively in this historical focal area. The first one (M=7)took place to the north of Guyuan, Ningxia Autonomous Region on Oct. 25, 1622, followed, 298 years later, by the Haiyuan Earthquake (M=8. 5). Only nine days from then, the third earthquake (M=7)happened in the vicinity of Jingyuan, Ningxia on Dec. 25, 1920, which is the strongest aftershock of the Haiyuan Major Earthquake. From 1981 onward, the Jingtai section in the northwest part of the focal area has recovered and has been relatively quiet in small shock activity. However, on the whole this focal area is still in a fractured state and small shocks have been relatively active which can be considered as a result of reaccumulation of energy under tectonic forces. From Fig. 4, the concentration domain of small shocks is seen extending in a NW—SE direction for about 304 km, from which the magnitude of the Haiyuan Earthquake is calculated to be 8. 5. Obviously, the scope of small shock activity is closer to the real dimensions of the focal area than the surface fault zone is. Because small shock activity is very active over the whole focal area, especially in its southeast part, the focal area is at the present time still in an adjustment stage and no potential new earthquakes are to be expected.

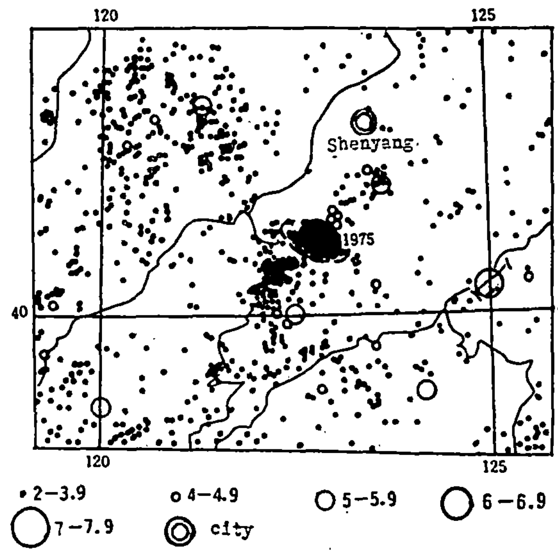

Fig. 3 Distribution of seismic activities of 1970—1985 and the focal areas of historical major earthquakes in Liaoning area (M≥2)

6. The Gulang Earthquake of May 23, 1927. This earthquake is of magnitude 8. No macroscopic investigation was carried out at the outset because of the unfavourable communication conditions at that time. After the founding of New China, several groups of professional persons from Lanzhou Seismological Institute have come to the field but the earthquake—triggering structure remains a subject of much comtroversay. However, as the small shock activity is concentrated relatively at Gulang—Wuwei—Yongchang area, the focal area must have been located there too (Fig. 4). This concentration domain of small shocks has an NW—SE elongation of 200 km. Calculation from empirical formula gives M=8. 1, which is close to that determined instrumentally. The focal area has not recovered yet and no potential new seismic focus is expected to exist.

7. The Wudu Earthquake of July 1, 1879 in Gansu Province was originally determined as of magnitude 7. 5. Mod-

ern small shocks are concentrated within an elliptical area extending northeasterly for 105 km, although a northwest trending is also noted within this area. Calculation from empirical formula yields a magnitude of 7.5 which is in confirmity with the historical record. No potential new seismic focus seems to exist in this historical focal area (Fig. 5).

8. The Pingluo Earthquake of Jan. 3, 1739 in Yinchuan, Ningxia occurred 251 years ago, and was originally determined as of magnitude 8. In the Pingluo—Yinchuan Map of small shocks (M≥3) of 1954—1979, the focal area of this earthquake is a blank domain (Fig. 6); whereas in the Distribution Map of small shocks (M=2—4) of 1970—1985, the same focal area is represented by a small shock active domain (Fig. 4). Making allowances for the fact that the focal area has not yet recovered and that the small shock active domain extends northeasterly for 160 km, we have calculated a magnitude of 7.93 which is close to the historical record. Since the focal area has not recovered yet, there is no potential new seismic focus for major earthquake to occur.

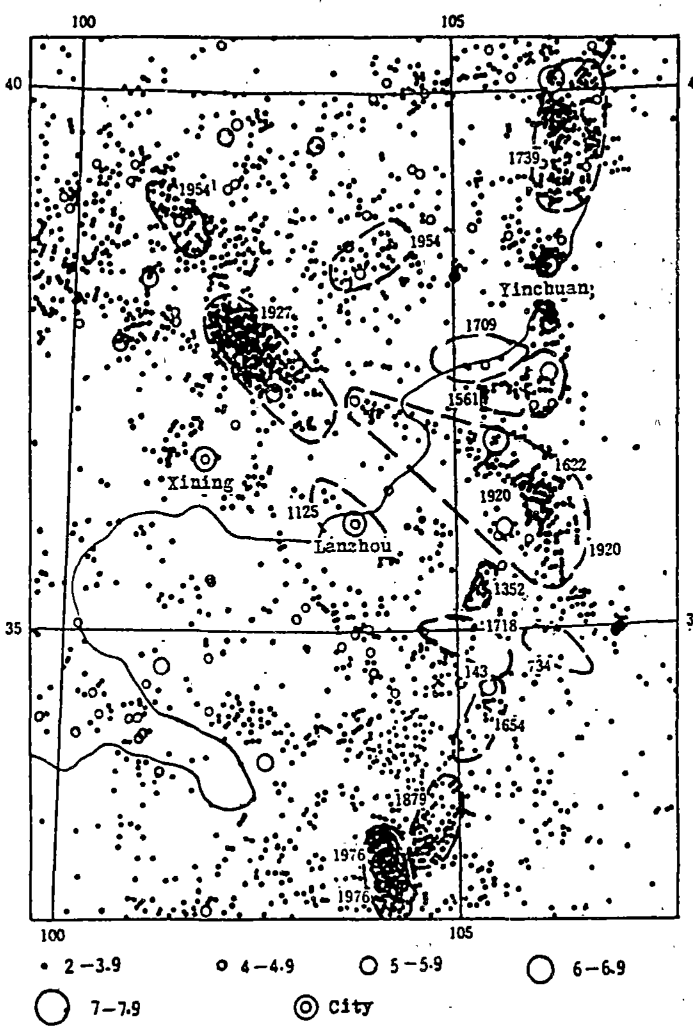

Fig. 4 Distribution of seismic activities of 1970—1985 and the focal areas of historical major earthquakes in Shanxi—Gansu—Ningxia area (M≥2)

9. The Fuyun Earthquake of Aug. 11, 1931 in Xinjiang was originally determined as of magnitude 8. An aftershock of magnitude 7 occurred to the north of the focal area seven days later. Detailed macroscopic investigations carried out in the last decade have arrived at the conclusion that the earthquake—triggering structure has a NNW trend. Modern small shocks are distributed rather densely in the focal area against a low background (Fig. 7), forming a concentration domain extending NNW for 192 km. Calculation using the empirical formula gives M=8.1 which is close to the historical record. Because the focal area has not recovered yet, no potential seismic focus is likely to exist in this area.

2)

10. The Manasi Earthquake of Dec. 23, 1906 in Xinjiang was originally determined as of magnitude 8. The faulting in focal area is oriented in a NW direction which is parallel to the regional structural line. The focal area is relatively qui-

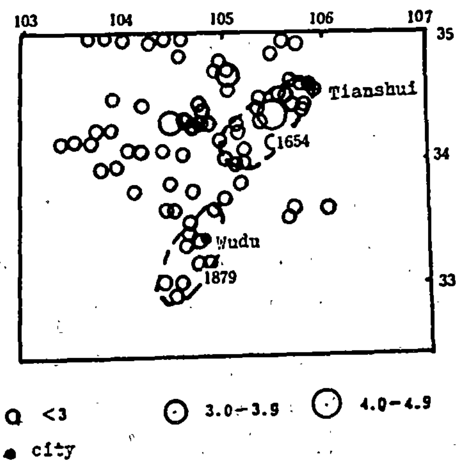

Fig. 5 Distribution of small shocks of 1976—1979 in Tianshui—Wudu area

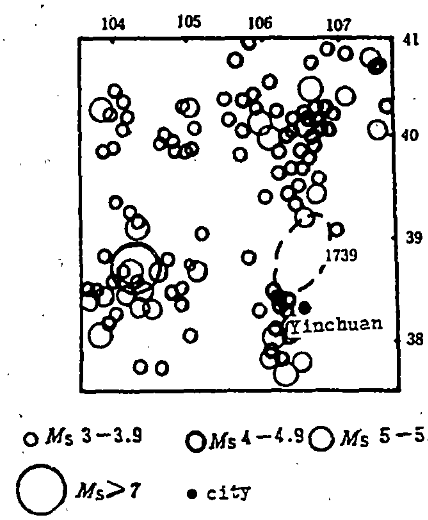

Fig. 6 Distribution of small shocks of 1954—1979 (M>3) in Pingluo—Yinchuan area

et against a high background of modern small shock activity, although there still have been a few small shocks in it. This suggests that it has recovered to a certain degree. The relatively quiet domain representing the focal area has a NW—SE elongation of 184 km (Fig. 8). Calculation from the empirical formula gives a magnitude of 8, which is close to the historical record. Since the focal area has not entirely recovered yet, and since it must take a long period of time to accumulate yet, and since it must take a long period of time to accumulate energy even after recovery, no potential new seismic focus exists for the time being.

11. The Wuqia Earthquake of Feb. 24, 1949 in Xinjiang is of magnitude $7\frac{1}{4}$ according to historical record. The isoseismal lines show a NE—SW elongated geometry parallel to the regional structural line. Modern small shock activity in epicentral area has a high level. The focal area as depicted by small shocks has also a NE—SW elongation of 88 km (Fig. 8). Calculation from the empirical formula obtains M=7.38, which is close to historical record. The focal area is now in an adjustment stage, hence new major seismic focus has not yet been formed.

12. The Tonghai Earthquake of Jan. 5, 1970 in Yunnan Province has a magnitude of 7.7 with the rupture trending NW. Small shocks of 1970—1985 are distributed in an area extending northwesterly for 140 km (Fig. 9). Calculation from the empirical formula yields M=7.8 which is o.1 greater than that determined instrumentally. The focal area has not yet recovered, and there is no potential new seismic focus of major earthquake.

13. The Yanglin Earthquake of Sept. 6, 1833 in Songming, Yunnan was originally determined as of magnitude 8. Small shocks are still active although 157 years have elapsed since the earthquake took place. The small shock domain has a N—S elongation of 180 km (Fig. 9). Calculation from the empirical formula gives M=8.0 which is the same as that in historical record. No potential new seismic focus exists as the focal area has not yet entirely recovered.

14. The Dongchuan Earthquake of Aug. 2, 1733 in Yunnan took place to the west side of Dongchuan and was originally determined as of magnitude $7\frac{1}{2}$. Small shocks are still active although 257 years have elapsed since then, indicating that the focal area has not yet recovered. The small shock domain extends NNW for 100 km (Fig. 9). The calculated magnitude based on empirical formula is 7.5, which is the same as recorded in history. Because the focal area has not

yet recovered, no potential new seismic focus exists, and this area is seismologically safe.

15. The Yongsheng Earthquake of June 17, 1515 in Yunnan was originally determined as of magnitude $7\frac{1}{2}$. No macroscopic investigation has been carried out since the earthquake took place 475 years ago. The modern small shocks concentrated in an ellipse extending NNW for 100 km (Fig. 9) suggest that the focal area has not recovered yet. Calculation from the empirical formula gives M=7.5, which is close to the historical record. Since the focal area has not recovered, no potential new seismic focus exists in this area.

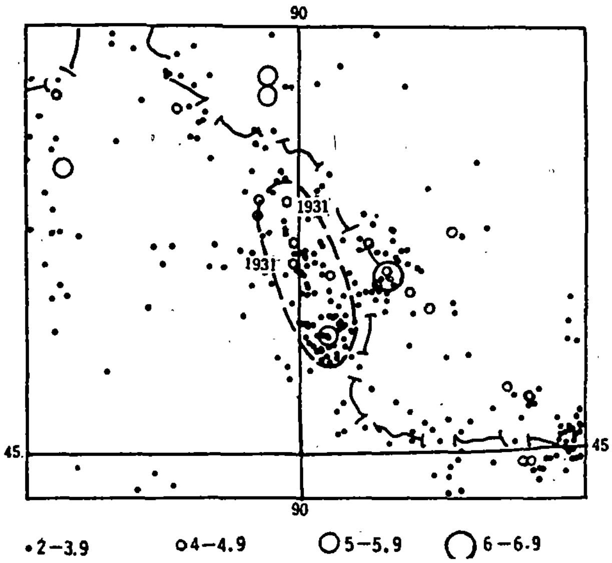

Fig. 7 Distribution of seismic activities of 1970—1985 and the focal areas of historical major earthquakes in Altay area Xinjiang (M≥

16. The South Kangding Earthquake of June 1, 1786 and the Kangding Earthquake of April 14, 1955 took place at the same focus in different periods. The first $M=7\frac{1}{2}$ earthquake occurred at the southern tip of the focal area, followed 169 years later by the second $M=7\frac{1}{2}$ earthquake that took place at the northwest tip. No macroscopic investigation has been carried out on either of the two earthquakes. The modern small shocks are distributed along a NW—striking Xianshui River Fault, suggesting the latter to be the triggering structure. The focal area as depicted by modern small shocks has a length of 90 km (Fig.9), sugstituting which into the empirical formula yields M=7.4, which is close to the historical record. The focal area has not yet recovered, and there is no potential seismic focus for a new $M_L>7$ earthquake to occur.

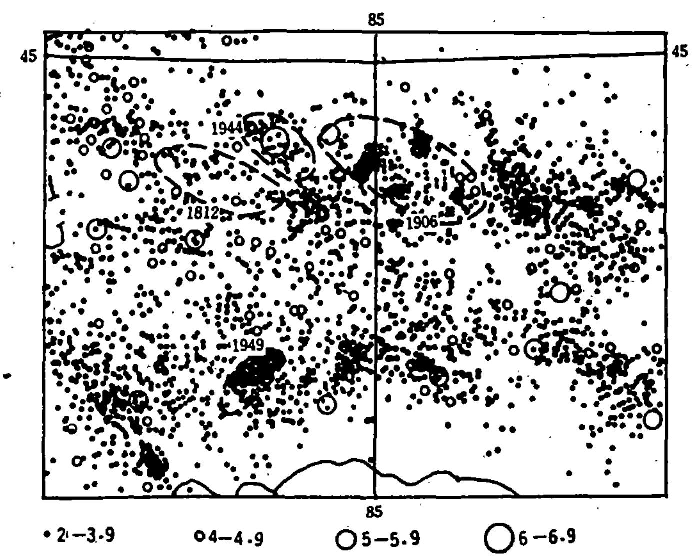

Fig. 8 Distribution of seismic activities of 1970—1985 and the focal areas of historical major earthquakes in Mid—Tianshan area, Xinjiang (M≥2).

Thus, it is known from the above that part of the focal areas of historical major earthquakes can be identified by using the data of modern small shocks, and the locations can also be delineated.

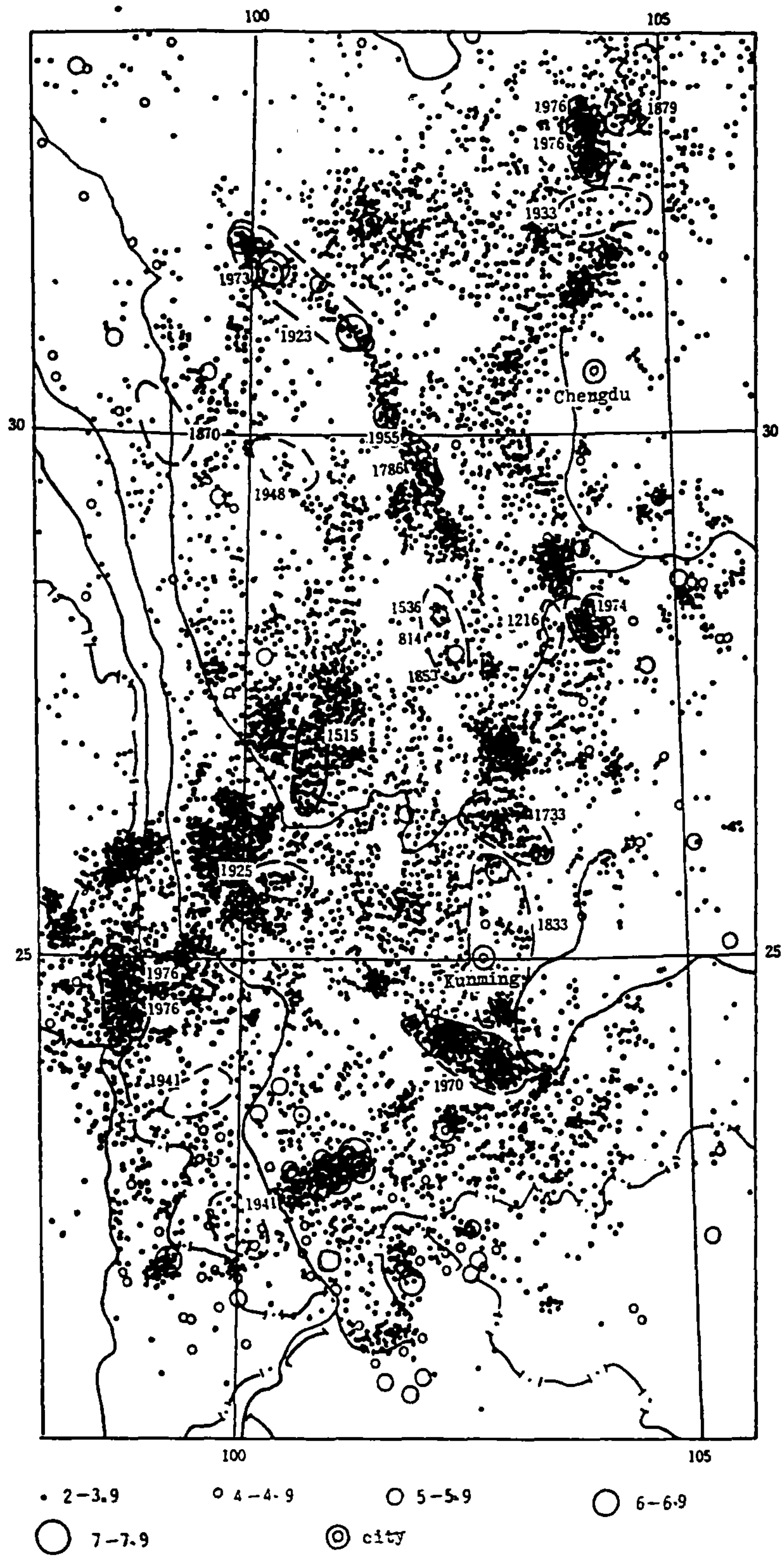

Fig. 9 Distribution of seismic activities of 1970—1985 and the focal areas of historical earthquakes in Sichuan—Yunnan area (M≥2)

II. Delineation of the focal Area of a Historical Major Earthquake and Judgement of a Potential Seismic Focus

When the focal area has gradually recovered from an earthquake, it is distinguished from its background in the light of modern small shock activity, Which took place around but not inside the focal area, so that the focal area has become a blank domain of small shock activity. This suggests that the focal area has recovered and begun to accumulate stress to become a potential new seismic focus. Nevertheless, under such situation we still can not say whether a major earthquake will actually take place or not unless we have already gained a clear idea of the characteristics of the faulting (including repeated faulting and segment—by—segment faulting), the rate of fault activity, and the intensifying nature of the seismic activity around the blank domain.

1. On Jan. 19, 1501, a M=7 earthquake occurred in

Zhaoyi at the eastern end of a focal area of a M=8 earthquake which took place at Huaxian in 1556. This Zhaoyi Earthquake is one within an adjustment unit because it was resulted from the adjustment movement at the end of the focal area of the Huaxian Earthquake. Since the Huaxian Earthquake which took place 434 years ago, the stress has largely been released and at present seismic activities in the whole Weihe River Graben have a low level. The focal area is seismologically quiet and modern small shocks are distributed mainly at its ends. The blank (quiet)domain delineated in the light of small shock distribution (Fig. 2) extends northeasterly for 189 km giving a calculated magnitude of 8. 1. The seismological quiescence indicates that the focal area has already recovered. However, as the seismic activities around it have a low level, there is no risk of major earthquake.

2. The Lingqiu Earthquake of June 28, 1626 in Shanxi Province which occurred 364 years ago was originally determinedas of magnitude 7. The meizoseismal area is represented by a small shock quiet (blank) domain which extends E—W for 70 km (Fig. 2). Calculation from empirical formula gives M=7. 2, which is 0. 2 greater than that recorded in history. The focal area has recovered to its normal state, whereas seismic activity in the immediate regions has been intensifying in recent years, giving rise to the M=6. 1 Datong—Yanggao Earthquake in Oct. 1989. Whether or not a major earthquake is expected to occur in this blank domain is a problem requiring further work to ascertain.

3. On Oct. 14, 1709, M=$7\frac{1}{2}$ earthquake took place to the south of Zhongwei. About 281 years later, a small—shock—quiescence domain appears to—day, extending about 100 km westward from Zhongwei (Fig. 4 and 10), coinciding with the focal area of the Zhongwei Earthquake. Calculation from empirical formula gives M=7. 5 which is the same as the historical record. Since the focal area has recovered, it is believed that a potential new seismic focus exists in this area. However, no risk of major earthquake is expected to occur at least in the near future because strengthening of seismic activities has been detected only in the immediate regions and no seismic activities are felt in the quiescence domain.

4. The Artux Earthquake of Aug. 22, 1902 in Xinjiang was originally determined as of magnitude $8\frac{1}{4}$. The isoseismal lines have an NE—SW elongation geometry parallel to the regional structural line. Eighty—eight years has elapsed now, and the small shocks have died out forming a quiescence domain with NE—SW elongation of 160 km (Fig. 11). Calculation from the empirical formula gives M=7. 9 which is slightly lower than the historical record. The modern small shocks of this area had a relatively high level of activity, while seismic activities in the immediate regions had been strengthening continuously and small shocks had begun to appear in the quiescence domain, forcasting the risk of a major earthquake to come. As a result, a M=7. 4 Wuqia Earthquake took place at the margin of the focal area on Aug. 23, 1985, with the seismic rupture trending NW, perpendicular to the strike of the triggering structure of the Artux Earthquake. After the Wuqia Earthquake, seismic activities in this area tend to be weakening.

5. The M=7 Earthquake of May 16, 1941 occurred to the north of Gengma, Yunnan Province, with the isoseismal lines showing a NE—SW elongation geometry. Today, after an interval of 49 years, the focal area has been quiet as depicted by the distribution of the small shocks of 1970—1985. The quiescence domain extends northeasterly for 72 km (Fig. 9), with the calculated magnitude 7. 2 which is close to the historical record. Small shocks had been strengthening around the quiescence domain, suggesting that the historical focal area had recovered entirely and begun accumulating energy, hence it was predicted that there existed a risk of new potential major earthquake in the historical focal area. Eventually, a M=7. 1 major earthquake occurred on Nov. 6, 1988. Now the risk of earthquake is over.

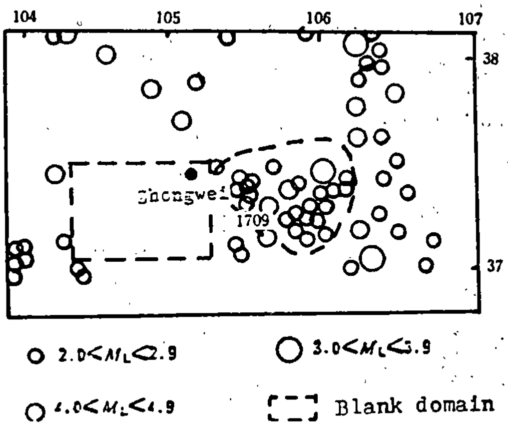

Fig. 10 Small shock activities (M_L 2.0) of 1977—1981 in part of Ningxia Province (The blank area is the focal area of a major earthquake of 1709)

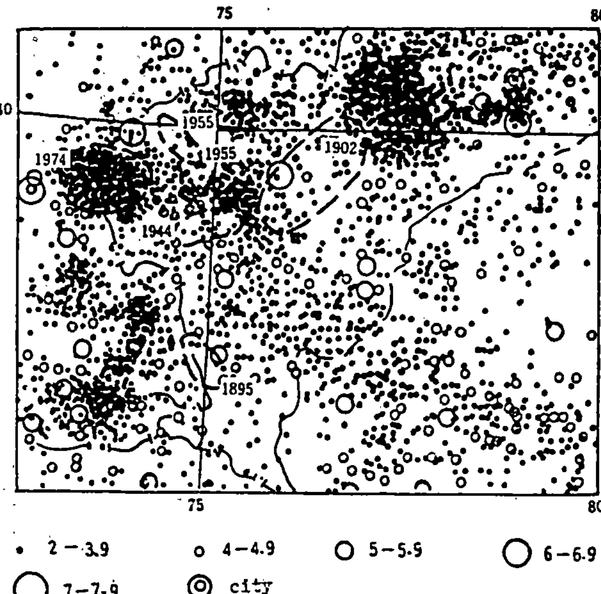

Fig. 11 Distribution of seismic activities of 1970—1985 and the focal areas of historical major earthquakes in Kashi area, Xinjiang (M ≥2)

6. The Mengzhe Earthquake of Dec. 26, 1941 in Lancang, Yunnan Province was originally determined as of magnitude 7 with the isoseismal lines depicting a NW—SE elongation geometry. The blank domain extends also northwesterly for 76 km (Fig.9) with a calculated magnitude of 7.2. In the last decade, seismic activity was strengthening constantly around the focal area and small shocks began to appear even with in the blank domain until a 7.5 magnitude earthquake took place on Nov. 6, 1988. Now the earthquake risk in this area is over.

7. The Diexi Earthquake of Aug. 25, 1933 in Maowen, Sichuan Province was originally determined as of magnitude $7\frac{1}{2}$. Today, after an interval of 57 years, the focal area is seismologically quiet in a high small shock background. This quiescence domain extends E—W for 100 km (Fig.9). Calculation from the empirical formula gives M=7.5 which is the same as the originally determined magnitude. In 1976 when the Songpan Earthquake occurred, this area became a stress adjustment area at the southern tip of the focal area of the Songpan Quake. Now that the stress level of this area has decreased and there is no risk of major earthquake any longer.

8. The Leibo Earthquake of March 17, 1216 in Sichuan Province occurred 774 years ago. The extension of the seismic rupture is not clear. The focal area is no seismologically quiet, forming a quiescence domain with a nearly N—S elongation of 60 km (Fig. 9). Calculation from the empirical formula gives M=7. Seismic energy has been accumulating at a relatively high rate in this area since the occurrence of the Leibo Earthquake a long period of time ago. The appearance of a few small shocks within the focal area may be a sign of re—liberation of energy after recovery of the area, and a potential new seismic focus may have come into being, but no major earthquake is expected to take place in the near future.

9. The Batang Earthquake of April 11, 1870 in Sichuan Province was originally determined as of magnitude $7\frac{1}{4}$. On Oct. 20, 1923, a $M=6\frac{1}{2}$ earthquake took place in the epicentral area. The focal area became a blank domain of

small shock activity by 1985, which has a NW—SE elongation of 88 km (Fig. 9). The calculated magnitude is 7.4 which is close to the historical record. Since the focal area had entirely recovered and the earthquake—triggering fault has a property of faulting segment by segment, therefore re-faulting might occur inducing a new major earthquake. Eventually a M=6.7 earthquake took place on April 16, 1989, and the earthquake danger is no longer in existence now.

10. The Litang Earthquake on May 25, 1948 in Sichuan was originally determined as of magnitude $7\frac{1}{4}$. The rupture of the focal area runs northwesterly, parallel to the structural line of the area. At present; after an interval of 42 years, this forcal area is seismologically quiet, forming quiescence domain extending northwesterly for 76 km.(Fig. 9) The calculated magnitude is 7.24 which is close to historical record. Seismic activity had been strengthening around the focal area until four earthquakes with magnitudes above 6 took place in 1989 (two of which reach 6.7 in magnitude), which collectively correspond to an earthquake of magnitude 7.2. This area is no longer in potential earthquake danger now.

The locations and dimensions of focal areas of 71 historical major earthquakes in China mainland determined with the aid of modern small shock data, and the potentiality of new seismic focuses are listed in the following Table.

Ⅲ. Conclusions on the Characteristics of Focal Areas of Historical Major Earthquakes in China Mainland

The following characteristics can be summarized for the focal areas of historical major earthquakes in China mainland:

1. Controlled by the recent active faults, the spatial distribution of seismic focuses is inhomogeneous

2. In some focal areas, failure occurred all at a time throughout the earthquake- inducing fault, for example, the Ertai Fault of Xinjiang where failure took place throughout the length of the fault (192 km) inducing a M=8 Fuyun Earthquake of 1931. Whereas, in most of the focal areas, failure events took place stage by stage and segment by segment along the regional large active fault, for instance, the Changma- Qilian- Haiyuan fault (Fig. 12), the Fenwei Seismological Fault Zone, the Hebei Plain Fault Zone and the Xianshui River Fault Zone.

3. The magnitude of earthquake is proportional to the length of the focal area: when M=7, the length of focal area is about 60 km; when $M=7\frac{1}{2}$, length=90—100 km; when M=8, the length is about 180 km; and when M=8.5, the length will be about 300 km.

4. Failure could occur repeatedly at a same seismic focus, producing successively a series of seismic events. The more seismic events there were, the severer the damage and the longer the recovery time. For example, in the historical seismic focus of Daixian, Shanxi Province, a $M=7\frac{1}{2}$ major earthquake occurred in A. D. 512, a $M=7\frac{1}{4}$ one occurred in 1038 and a M=7 one occurred again in 1683. Other examples are Linfen of Shanxi, Gangu- Tongwei of Gansu, and Kangding and Luhuo of Sichuan.

5. Most of the seismic focuses of major earthquakes are distributed at a depth of 10- 35 km, the majority of which are situated at a depth of about 20 km within a granite layer, which is therefore known as a layer of frequent earthquake.

6. The seismic focuses of historical major earthquakes are located largely in the variation zone of the Moho, espe-

HISTORICAL MAJOR EARTHQUAKES IN CHINA MAINLAND

Earthquake	Year	Length of small shock domain (km)	Calculated magnitude	Historically recorded M	Recovery of focal area
Qingshui	734	72 (blank domain)	7.2	7	recovered
Lanzhou	1125	86	7.5	7	not recovered
Leibo	1216	60 (blank domain)	7	6—7	recovered, with new potential seismic focus
Huining	1352	63	7	7	not recovered
Yongsheng	1515	104	7.5	$7\frac{1}{2}$	not recovered
Huaxian*	1556	189 (blank domain)	8.1	8	recovered, with new potential seismic focus
Zhongning	1561	88	7.38	$7\frac{1}{4}$	not recovered
Lingqiu	1626	70 (blank donain)	7.2	7	recovered, with new potential seismic focus
Tianshui	1654	100	7.5	7.5	not recovered
Tancheng*	1668	304	8.5	$8\frac{1}{2}$	not recovered
Pinggu	1679	152	7.9	8	not recovered
Yuanping*	1683	110	7.6	7	not recovered
Linfen*	1695	200	8.1	8	not recovered
Zhongwei	1709	100 (blank domain)	7.5	$7\frac{1}{2}$	recovered
Tongwei*	1718	105 (″)	7.5	$7\frac{1}{2}$	recovered
Dongchuan	1733	100	7.5	$7\frac{1}{2}$	not recovered
Pingluo	1739	160	7.93	8	not recovered
Suiding	1812	152	7.9	7—8	not recovered
Cixian	1830	104	7.5	$7\frac{1}{2}$	not recovered
Yanglin	1833	180	8	8	not recovered
Xichang	1850	100	7.5	$7\frac{1}{2}$	not recovered
Batang	1870	88 (blank domain)	7.4	$7\frac{1}{4}$	recovered, with new potential seismic focus
Wudu	1879	105	7.5	7.5	not recovered
Bohai	1888	96 (blank domain)	7.5	$7\frac{1}{2}$	recovered
Taxkorgan	1895	64	7.1	7	not recovered
Artux	1902	160 (blank domain)	7.9	$8\frac{1}{4}$	recovered
Manas	1906	184	8	8	not recovered
Nan'ao*	1918	65	7.1	$7\frac{1}{4}$	not recovered
Haiyuan*	1920	304	8.5	8.5	not recovered
Dali	1925	68	7.1	7	not recovered
Gulang	1927	200	8.1	8	not recovered
Fuyun	1931	192	8.09	8	not recovered
Changma	1932	112	7.6	7.6	not recovered
Diexi	1933	100 (blank domain)	7.5	$7\frac{1}{2}$	recovered, with new potential seismic focus
Mengzhe	1941	76	7.2	7	recovered
Gengma	1941	72 (blank domain)	7.2	7	recovered
Southwest Kashi	1944	65	7.1	7	not recovered

Continuation of the table

Xin yuan	1944	85	7.35	$7\frac{1}{4}$	not tecovered	Tong hai	1970	140	7.8	7.7	not recovered
Litang	1948	76 (blank domain)	7.24	$7\frac{1}{4}$	recovered, with new pofential seismic focus	Luhuo	1973	192	8.1	7.9	
Kuqa	1949	88	7.4	$7\frac{1}{4}$	not recovered	South west					
Shan dan	1954	88	7.38	$7\frac{1}{4}$		Wushi	1974	100	7.5	7.3	
Minqin	1954	96	7.5	7		Daguan Yong shan	1974	72	7.2	7.1	
North west * Wushi	1955	64	7.1	7		Hai cheng	1975	80	7.3	7.3	
Kang ding	1955	90	7.4	$7\frac{1}{2}$		Tang shan*	1976	152	7.38	7.8	
Dong jiang, Ningjin	1966	112	7.6	7.2		Long ling*	1976	96	7.46	7.4	
Bohai Bay	1969	94	7.4	7.4		Song pan*	1976	82	7.3	7.3	

* Two major earthquakes or more have taken place in this locality

cially at the flanks or top of an upper mantle rise, where the horizontal and vertical forces are relatively strong, superimposition of these two forces being favourable for the producing of major earthquakes.

1. Fault 2. earthquake faulting segments 3. M=5—5.9 4. M=6—6.9 5. M=7—7.9 6. M=8 7. year of earth quake, magnitude of earthquake and Length of surface faulting

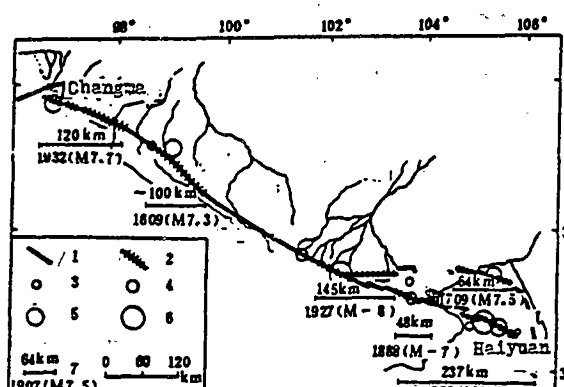

Fig. 12 The distribution of earthquake faulting segments along the Changma—Qilian—Haiyuan fault zone (After Ding Guoyu)

7. The forces inducing the historical major earthquakes of China were mostly acting horizontally although metimes vertical components are also recognizable. Hence the earthquake- triggering faults are largely of a strike- slip type with minor dip- slip component.

8. The seismic focuses are characterized mostly by unidirectional rupture, although conjugated rupture may occur in individual cases.

Ⅳ. Concluding Remarks

This work is based on data of small and middle seisms recorded by the seismologic network throughout China during

1970—1985. In some regions such as Xizang and Qinghai where the seismologic network is not dense enough, small shock data are not sufficient to meet the requirements for delineation and discussion of the focal areas of historical major earthquakes in such regions. This problem needs further work to solve. In the meantime, the authors are indebted to the Lanzhou Seismological Institute, the Seismological Analytic And Forcasting Centre of the State Bureau of Seismology, and the Seismological Bureaus (Offices) of all the Provinces and Regions for their support and also to Guo Zengjian for his generous help in the proceeding of our work. The authors would also like to express their appreciation to Zhu Zhenyu, Yao Meiyin, Chen Dingguo and Wen Kundi of the Guangdong Bureau of Seismology and Li Yarong of Lanzhou Seismological Institute who have taken part with the authors in the research work and in preparation of this paper.

REFERENCES

〔1〕Ding Guoyu, The inhomogeneity of faulting in Holocene, Earthquake Research in China, Vol. 6, No. 1, 1990.

〔2〕Gu Gongxu et al., The earthquake catalogue of China, Scientific Publishing House, 1983.

〔3〕Guo Zengjian and Qin Baoyan, Recurrence of great earthquake and its attenuation effect, Acta Seismologica of Northwest China, No. 4, 1984,

〔4〕Guo Zengjian and Qin Baoyan, The mutual effect of parallel faults——the attenuation of earthquake, contributions to earthquakes of Qinghai—Tibet Plateau, Vol. 1, 1986.

〔5〕Kuo Tseng—kien, Chin Pao—yen, Hsu Wen—yao and Tang Chuan, Preliminary study on a model for the development of the focus of an earthquake, Acta Geophysica Sinica, Vol. 15, No. 2 1966.

〔6〕Qin Baoyan, Chen Jiachao and Feng Xiaying, Determination of locations and magnitudes of great historical earthquakes using activity data of modern small shocks, Earthquake, No. 1, 1989.

〔7〕Yang Yiquan, The Nanpeng small seisms and the 1918 great earthquake in Guangdong Province, South China, Earthquake, Vol. 5, No. 2, 1985.