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QINGHAI—XIZANG PLATEAU —A SPECIAL TEST FIELD FOR EARTHQUAKE PREDICTION

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At present level of earthquake prediction, each prediction method should be tested in practice. Researchers of earthquake prediction often test the prediction methods in the test field. The test field for earthquake prediction usually can be divided into two kinds. One kind is a developed industry and densely populated region, another kind is a sparsely populated but great earthquake frequently occurred region. Earthquake prediction in the former region has a very important effect on the national economy and people's livelihood, but it will take large risks and may induced unnecessary social panic. However, in the latter region, earthquake prediction needn't consider such social problem. Qinghai-Xizang plateau exactly is an ideal second kind test field for earthquake prediction. The tectonic movement in the Qinghai-Xizang plateau is very strong. Many great earthquakes occurred in this region in history. Many seismologists of China and other countries have made quite some long-term and medium-term predictions on great earthquake in this region from different sides. This paper will make a brief review on this subject.

In 1957, Li Shanbang led a group to compile the first map of seismic risk zoning of China[1]. They made the prediction of earthquake risk in Qinghai-Xizang plateau in that map. To compile the map, the following two principles were applied at that time.

1) Regions of similar geological conditions can be regarded as similar seismicity also.

2) In a given region, earthquake of same intensity that happened previously, may occur again.

Figure 1 is the map of seismic risk zoning of China compiled by Li Shanbang et al. in 1957. The strong earthquakes ($M \geqslant 7$) occurred in this Qinghai-Xizang plateau region since 1957 also are drawn on Figure 1. From Fig.1 we can see that the long-term prediction of earthquake risk in this region made by Li Shanbang et al, is basically right,

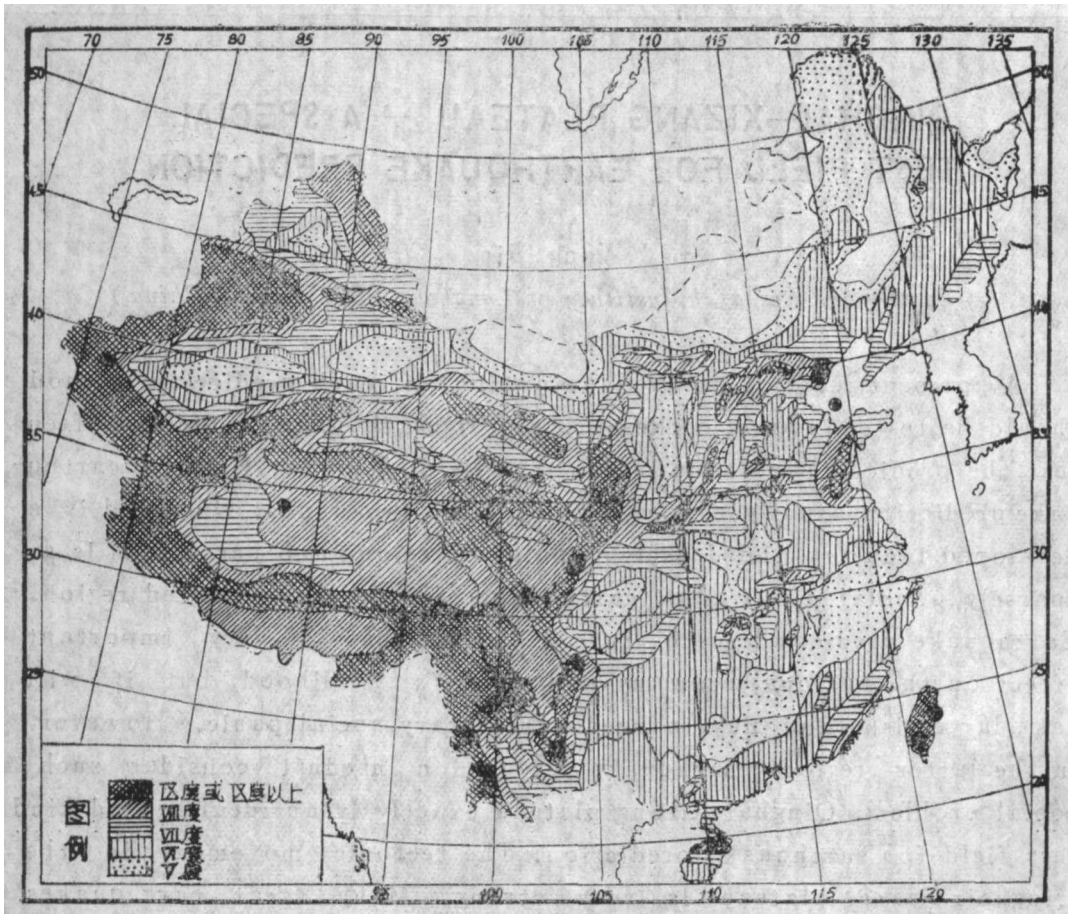

Fig. 1 The map of seismic risk zoning of China compiled by Li Shanbang et al. in 1957

In 1972, Chengdu Seismological Brigade (Now it is Seismological Bureau of Sichuan Province) studied the migration line of earthquakes in the North-South Seismic Belt with $M \geqslant 7.0$ and pointed that the great earthquakes in the North-South Seismic Belt have a regularity of migrating from the south segment to north segment of the belt, and predicted that the North-South Seismic Belt would be in an active period of great earthquakes migrating in next several decade after 1970 Tonghai earthquake ($M=7.8$)[2], Yunnan. They predicted three possible places of great earthquake to occur. The three places would be Mabian and Songpan, Sichuan and Tianshui, Gansu. The great earthquakes with $M \geqslant 7.0$ would occur successively in above three regions from the south to north. In fact, a great earthquake of $M=7.1$ occurred at Yongshan (28°.2 N, 104°.1 E), Yunnan on May 11, 1974 and two great earthquakes of $M=7.2$ occurred at Songpan, Sichuan in August of 1976. Only in the Tianshui region,

Gansu, the predicted earthquake hasn't occurred yet. So the predictions on earthquake occurrence place made by them are mainly identical with the actual situation.

In 1973, Chen Peishan and Lin Banghui applied statistical theory of extreme values to moderate and long-term earthquake prediction[8]. They analysed and predicted the occurrence probability of great earthquake in Qinghai-Xizang plateau and the North-South Seismic Belt. The distribution function of extreme values of earthquake is obtained on the basis of the following two assumptions:

1) The distribution of earthquake frequency against magnitude follows Gutenberg-Richter's magnitude-frequency relation.

2) In a given interval (e. g. one month or one year), the earthquake frequency that is larger than a given magnitude is a Poisson random variable, it follows the Poisson distribution.

Chen Peishan et al. divided the Qinghai-Xizang plateau and its neighborhood into several seismic zones. The modified form of the extreme value distribution function of earthquakes were computed for each seismic zone. The possibilities of the earthquake occurrences during the coming five years in each seismic zone were estimated on the basis of the distribution functions. The predictions made by them in that time have some differences with the actual situation of earthquake occurrences.

Applying the extreme value theory to earthquake prediction, as Chen Peishan et al. written in their paper, there are still quite some problems, although tentative research work were made and some preliminary results were got by them.

In 1980, V.Keilis-Borok, L.Knopoff and C.R.Allen made an attempt to predict the long-term seismicity of great earthquakes in Xizang (Tibet) as well as the central and eastern Himalayas. The region has considerable tectonic homogeneity and encompasses parts of China, India, Nepal, Bhutan, Bangladesh and Burma. Two seismicity patterns, pattern Σ and pattern S, were used in their study[4].

1) Pattern Σ　This pattern was introduced by Keilis—Borok and Malinovskaya in 1964. It is the summation of all earthquake energies released in the region within a given sliding time window and within a given magnitude range. The function is assumed to be:

$$\Sigma(t) = \Sigma 10^{[d(M-f)]}$$

when $\Sigma(t) \geqslant c \times 10^{[d(M_0-f)]}$

Pattern Σ is diagnosed that a great earthquake of $M=M_0$ should occur.

They selected earthquakes with $6.0 \leqslant M \leqslant 7.8$ since 1900 and drew the function $\Sigma(t)$ curve. In the curve distinct peaks have occurred twice within the test region during the 78-year-long test period: one is in 1948—1949, prior to the 1950 Dangxiong great earthquake ($M=8.6$), Xizang and another in 1976.

2) Pattern S (swarms) This pattern was introduced by Caputo et al. in 1979 and consists of a clustering of earthquakes during a time interval when the seismicity is above average. Pattern S is diagnosed when:

$$N(t) > C_1,\ n(t) > C_2 N(t),\ r(t) \geqslant C_3 n(t).$$

$N(t)$ is the total number of earthquake in the magnitude range $M \geqslant M_L$, $n(t)$ is the maximum number of epicenters which can be surrounded by a small rectangular area of size $\Delta\phi$ in latitude and $\Delta\lambda$ in longitude. In this study, take $M_L=6$, $C_2=1$, $C_3=0.5$, sliding time window $s=5$ years, $\Delta\phi=0.4$, $\Delta\lambda=0.8$. The results are that the peaks in pattern S have occurred three times: in 1932—1933, prior to the great 1934 Bihar-Nepal earthquake ($M=8.3$); in 1949, prior to the great 1950 Chayu earthquake ($M=8.6$), Xizang, and in 1978.

On the basis of experience here and elsewhere, V. Keilis-Borok et al. thought that the peaks in both Σ and S suggest the likelihood of an $M=8.0$ event within 6 years or an $M=8.5$ event within 14 years from 1980.

In 1981, Qin Baoyan, Guo Zengjian and Liu Guangyuan discussed the great earthquake prediction in the Qinghai-Xizang plateau and its vicinity[5]. Some seismic characteristics and related phenomena before the occurrence of great earthquake in this region with a view of finding some clues or possible precursors of a forthcoming major event are got by them as follows:

1) Seismic gaps appeared before the most of the great earthquakes ($M \geqslant 8$).

2) 1 or 2 years before the occurrence of great earthquake in the Qinghai-Xizang plateau, the earthquakes with $6 \leqslant M \leqslant 7$ usually occurred in the active volcanic region which is the border region of Qinghai-Xizang plateau.

3) There usually occurred earthquakes of $M=6$ along an extension of the seismogenetic structural trend 1 or 3 years before the great earthquakes ($M=8$).

4) There are apparent correlation between the great earthquakes in the Qinghai-Xizang plateau and the earthquake activity along the

western boundary of the Pacific Plate.

5) There are some correlation between the great earthquakes in the Qinghai-Xizang plateau and global volcanic activity, polar wobble amplitude.

on the basis of above characteristics and phenomena, they pointed:

1) The possibility of occurrence of future great earthquakes is larger along the plateau's boundary than in its interior.

2) More attention should be paid to the study of the gaps surrounded by earthquake of magnitude 5.5—7, in which great earthquakes (M=8) will probably take place.

3) Serious studies should be made on the seismic activity in the northern part of the plateau, namely, in the volcanic region with a view to predict great earthquakes in the near future.

In 1984, the first nationwide meeting on seismology and earthquake tendency of the Qinghai-Xizang plateau was hold in Xi'ning City, Qinghai Province. In the meeting, the study on the historical great earthquakes, seismology and seismicity of the Qinghai-Xizang plateau were reported and discussed[6].

On basis of the periodicity of earthquake sequence, seismicity level, earthquake migration and seismic gap in the Qinghai plateau, He Wei predicted that earthquake activity would be in an active period round about 1990. Within this interval, there would be earthquake occurred with $M \geqslant 7$ in the Qinghai-Xizang plateau, especially in the south part of the plateau.

Guo Anning discussed the interval time of great earthquakes ($M \geqslant 8$) in this region and found that the intervals have commensurability[7]:

$$T = n \times 8 \pm 1.5 \text{ (year)}, \quad n = 0, 1, 2, 3 \cdots\cdots$$

Based on this expression, he predicted that a great earthquake with $M \geqslant 8.0$ would occur in 1991 ± 1.

In 1985, the research project to judge the risk regions of great earthquake in the north-south seismic belt for near future (1986—2000) was finished by Guo Zengjian et al, and their research group. About 100 articles on this research project were presented by tens researchers. The research contents include seismology, deep structure and crustal structure, environment factors, statistical prediction and comprehensive analysis and so on. The prediction map of great earthquakes was complied. There are five risk regions of great earthquake in North-

South Seismic Belt to be pointed. In one of those region, Gengma-Lanchang area, a great earthquake with M=7.6 occurred on Nov. 16, 1988. So the prediction for this region is successful.

In 1988, Guo Zengjian and Qin Baoyan made a prediction on earthquake risk regions in Qinghai-Xizang plateau in next few years using the stereographic model which was introduced by them. According to the model under the action of the same regional tectonic stress field, the fractures having different behavior will be generated respectively in upper and lower lithosphere. In the lower lithosphere, some of fractures are concided with the fractures in the upper lithosphere, some of them are not with. Because the creep faulting in the lower lithosphere propagates to very far distance along a straight line, it may trigger those forthcoming earthquakes which are located at various faults and boundaries of units in the upper lithosphere and form the earthquake migration at far distance, the migratory line crosses many of various tectonic units. If we found three moderate earthquakes with the arrangement on a straight line, it should be considered that a strong earthquake may occur in the location where the migration line or the extension line crosses the fault in the upper lithosphere in the near future. The estimated magnitude is determined by follow expression:

$$M = 1.55 \text{ Lg } T + 4.6$$

here T is the years since starting time of earthquake migration line.

By means of stereographic model, they predicted three possible regions of great earthquakes in the near future. Also they predicted that the possible occurring time would be in April to May, 1989 and June to July, 1990. Actually, in one of the predicted area, four earthquakes with $M \geqslant 6.0$ occurred in Batang region, Sichuan in April, 1989. The maximum magnitude is 6.7 and minimum magnitude is 6.2. The total energy released by those earthquakes is corresponding to the energy of an earthquake with M = 7.

In summary, many attempts to predict the great earthquakes in Qinghai-Xizang plateau have made. Some of those predictions are successful, some of them are not, and some of them should still be vertified in future. In any case, Qinghai-Xizang plateau is a good special field for earthquake prediction.

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析。统计时段中平均地震年频度为1.2次，统计时把发生地震数大于二倍地震年频度的年份称为大频度年，则地震大频度年份共出现过7次，它们分别是1920年、1937年、1941年、1951年、1955年、1972年和1976年。1920年、1941年、1951年、1955年和1976年均处于由12年周期所划分的地震活跃期内（其中包括两个地震频度最高的年份）。由此可见，不仅我国8级以上地震与12年周期相关，而且7级以上地震也与12年周期相关显著。因此，12年周期可能是一种长期以来客观存在的周期因素。

12年周期很早就被我国用于甲子纪年，用不同的12种属象显示年景，反映自然灾害呈周期性出现的规律。地震只是其中自然灾害之一，多出现在卯、辰、巳、午、未、申等年份之内。

这种12年周期可能是宇宙多因素共同作用的一种综合效应，但从某些方面的数据显示，木星运行对此周期可能起主要作用。因上述12年周期数恰好与木星公转的周期数11.86年十分接近。

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STUDY ON RELATIVITY OF GREAT EARTHQUAKES（M≥7）IN CHINA AND THE 12-YEAR PERIOD IN SOLAR YEAR

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