REFLECTIONS ON EVENTS PRECEDING THE TANGSHAN EARTHQUAKE OF 1976

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1. INTRODUCTION

In China, extensive attention has been given to the problem of earthquake prediction since the occurrence of a series of damaging earthquakes in the 1960's. Large-scale programmes of earthquake prediction have also been carried out in Japan, the United States, and the USSR. Determined efforts are under way in all of these countries to make earthquake prediction more reliable. Plate tectonic theory, the development of geophysics and the establishment of the global seismological network have improved our understanding of earthquake phenomena. At the same time, social and economic progress in numerous countries has resulted in increasing needs to mitigate earthquake risks. All of these factors have created a favourable environment for promoting earthquake prediction. Nevertheless, prediction is still in an experimental phase, and no reliable system exists for recognizing and interpreting earthquake precursors. Hence, any existing system of prediction is basically a probabilistic rather than a deterministic one, and failures to make predictions will be unavoidable. Although we have recently made several successful predictions of large earthquakes, we also have had some failures. The failure in predicting the Tangshan earthquake (M=7.8) in 1976 is a typical example and will be the subject of this paper.

Tangshan is an industrialized city which is intensively inhabited. In 1976 it was completely destroyed with heavy loss of lives and property. There is a saying in China which states that "Failure is the Mother of Success". In order to learn useful lessons from the Tangshan earthquake, we need to examine the reasons for the failure to predict it. These lessons will be very important for earthquake prediction and risk mitigation in the future. The purpose of this paper will be to review the studies made by Chinese seismologists in Tangshan and the surrounding area, with special reference to the evaluation of earthquake risk at that time.

2. EVENTS PRECEDING THE EARTHQUAKE OF 1976

Tangshan is situated in the northern part of North China which is one of the first regions where earthquake prediction was studied. It has been one of the most carefully monitored areas since the Xingtai earthquake in 1966 (Fig.1), and is consequently an area with a longer period of observations, with the most intensive monitoring and with the most workers in seismology. It was emphasized many time before the Tangshan earthquake that a destructive earthquake would possibly occur in the Beijing, Tianjin, Tangshan and Bohai area (including Tangshan city) although the city of Tangshan had not been definitely identified as a place where a strong earthquake would occur. Chinese seismologists analysed the earthquake trends in North China after the Xingtai and Hejian earthquakes by carrying out investigations on the seismo-tectonic and seismicity patterns. They pointed out a possible trend of earthquake migration along a tectonic zone running north-eastward.

Since the Xingtai earthquake, observations of the seismo-tectonics, geodesy, deep seismic prospecting and other potential precursors were developed step by step in the Beijing, Tianjin and Bohai area. A seismic network with telemetry was first set up in 1966 in Beijing (Fig.2) and a high-accuracy levelling survey was carried out in a large area including Beijing, Tianjin, Tangshan and Cangzhou. After that, stations for measuring crustal deformation, ground water, earth resistivity, geomagnetism and other possible precursory phenomena were established one after another. Replicate surveys at gravity and geomagnetic stations were carried out regularly after the Bohai earthquake of M=7.4 in 1969. The seismic network was expanded after the Haicheng earthquake of M=7.3 in 1975 and some stations for measuring radon in ground water, geoelectricity and geomagnetism were added. All these laid a foundation for monitoring crustal movement in the Beijing, Tianjin, Tangshan and Bohai area.

No earthquake with M<5 had occurred during the four years after the Bohai earthquake. An earthquake of M=5.3 took place on 31 December 1973 in Hejian, and soon after that, two earthquakes with M=4.8 occurred near Changli county in Hebei Province on 7 May 1974. And another earthquake with M=4.3 occurred on 15 December of the same year in Ninghe (Fig.1). During this period, moderate earthquakes were relatively frequent in Tianjin, Changzhou, Luan county and the Bohai area. This brought people's attention to the existence of an abnormal situation. At the time, anomalies of ground deformation, gravity and water radon in ground water were widely

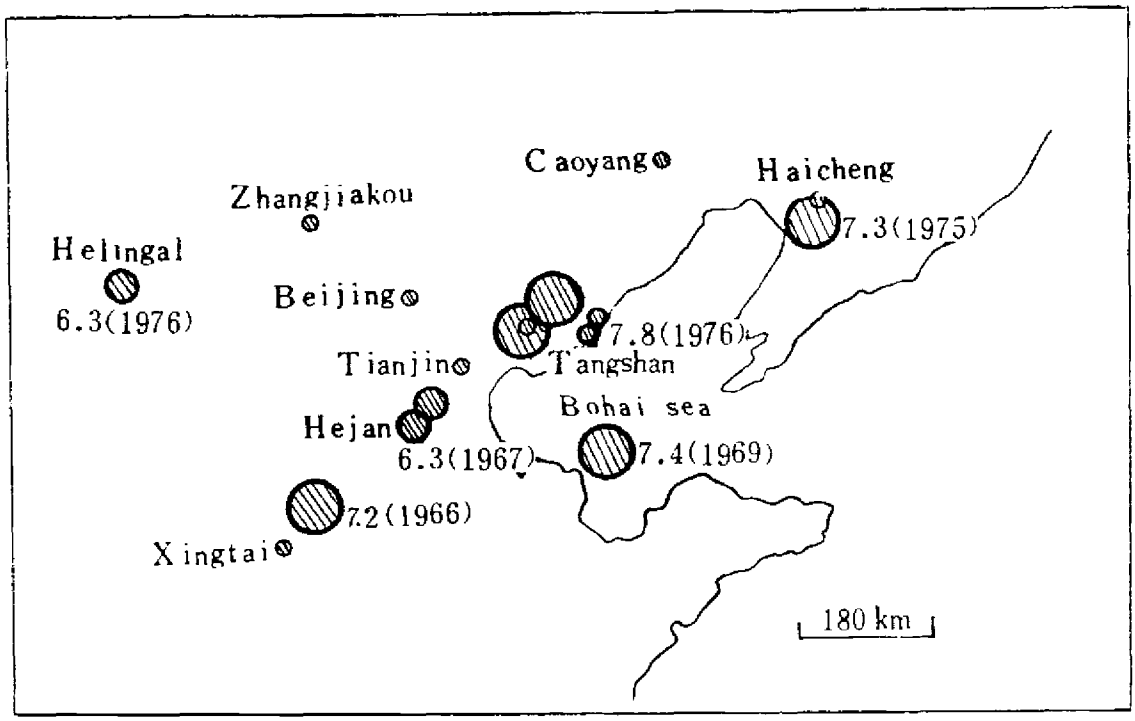


Fig.1: Map of northern China showing locations and magnitudes of major earthquakes between 1966 and 1976.

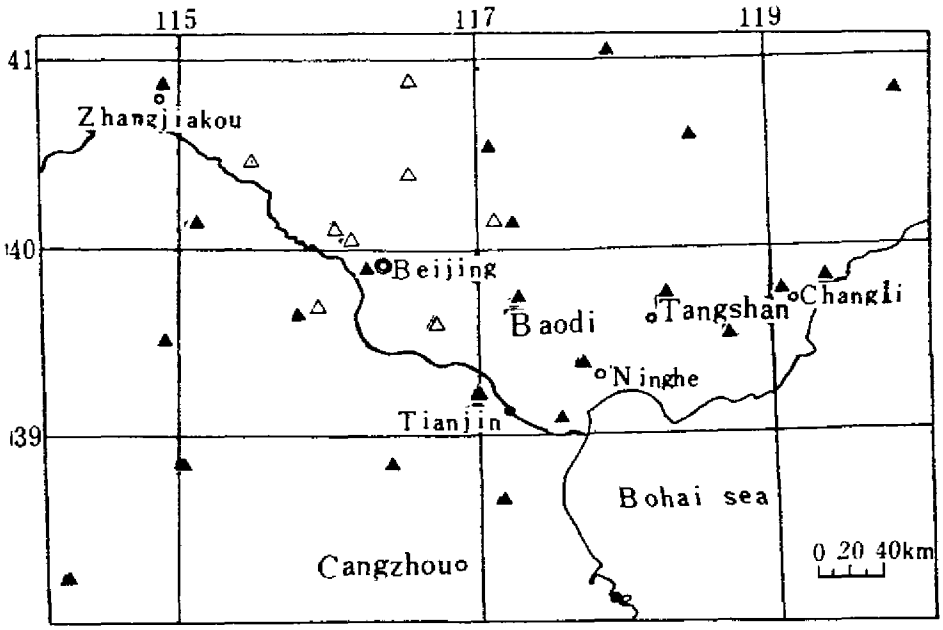


Fig.2: Map of Beijing-Tangshan area showing the network of seismographs. Open triangles indicate stations set up after April 1966, and black triangles indicate stations set up after the Tangshan earthquake of 1975.

observed (Fig.3). As the result of the anomalies in the area between Beijing, Tianjin and North Bohai, the State Seismological Bureau convened a Meeting to review earthquake trends in North China and Bohai area in June 1974.

The opinion of the majority of participants was that some regions of high hazard existed in North China where earthquakes with magnitude 5 to 6 could occur. The first places to be so designated were Beijing, Tianjin and North Bohai area. Accordingly, the cooperative organization of Beijing, Tianjin, Zhangjiakou and Bohai area was established in order to strengthen the research work in these regions.

On 4 February 1975, the Haicheng earthquake with M=7.3 occurred in the north of the Bohai area. Meanwhile, various anomalies were observed in the area including Beijing, Tianjin, Tangshan and Zhangjiakou. Questions were raised as to whether any other large earthquake would occur subsequently in North China. The seismic activity in North China was extensively discussed at the Nationwide Consultation Meeting on Earthquake Trends held early in 1976, after investigations in detail by the departments concerned.

The conclusion was that an earthquake with magnitude 5 to 6 would possibly occur in 1976 in the Beijing, Tianjin, Tangshan and Bohai area, most likely in the area between Tangshan to Chaoyang and Beijing to Tianjin.

Two moderate earthquakes occurred one after another in April 1976 in Beijing, Tianjin, Tangshan, Changjiakou and the surroundings. The first was the Helingge earthquake with M=6.3 on 6 April 1976, then the Dacheng earthquake with M=4.4 on 22 April 1976 (Fig.1). After these two earthquakes a new consultation meeting was convened in May 1976 by the SSB in order to study the recent earthquake pattern in Beijing, Tianjin, Tangshan, Bohai and Changjiakou area. The situation was complicated in that various different interpretations were proposed for these anomalies. Consequently, it was difficult to reach a definite conclusion on the level of earthquake hazard. Therefore, only the highest priority preventive measures were discussed and those that should be carried out at once were suggested. It was agreed that another consultation meeting would be held in July.

Anomalous phenomena appeared abruptly one after another in June and July 1976 in Beijing, Tianjin and Tangshan area (Fig.4) and this attracted the

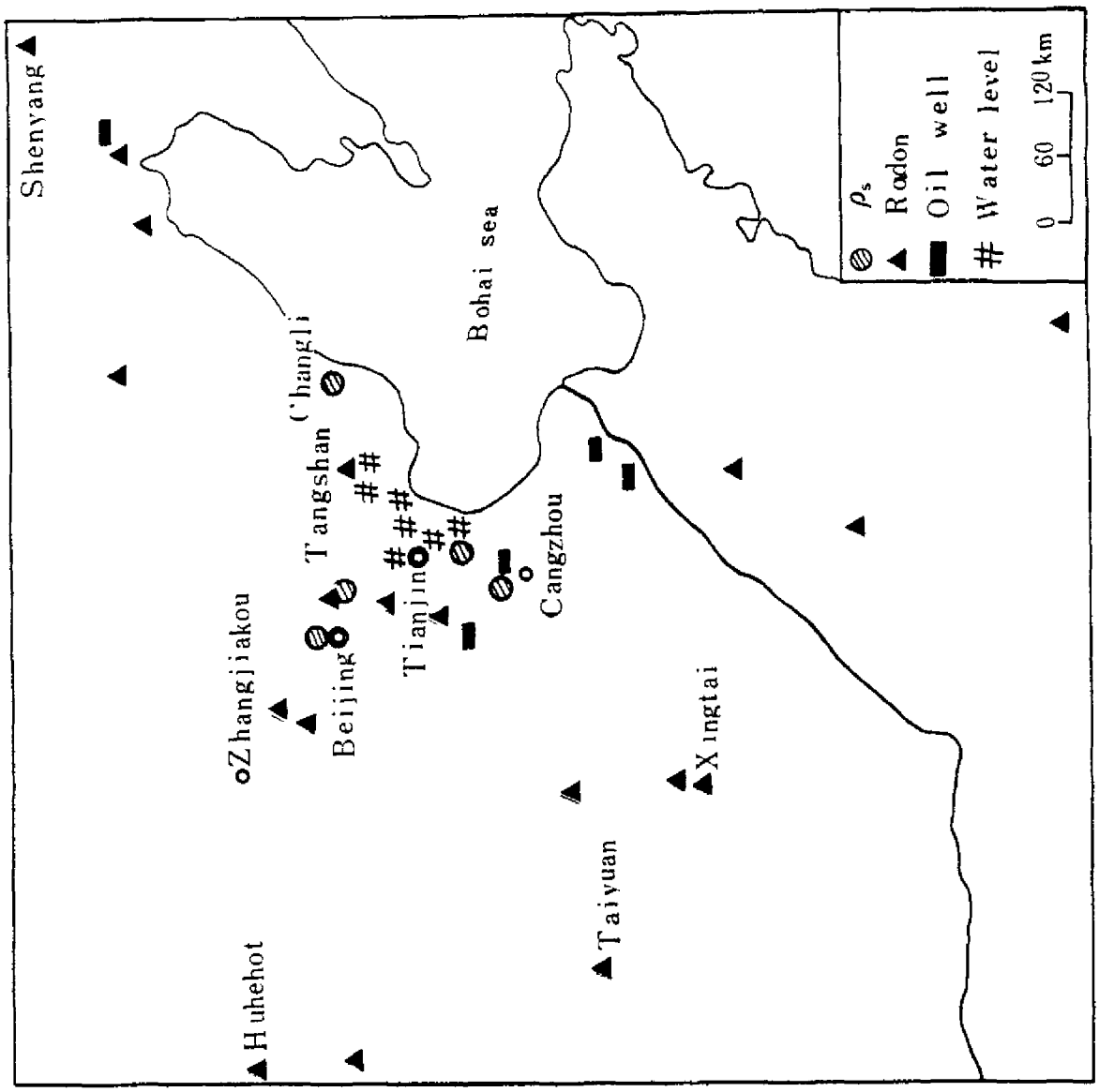
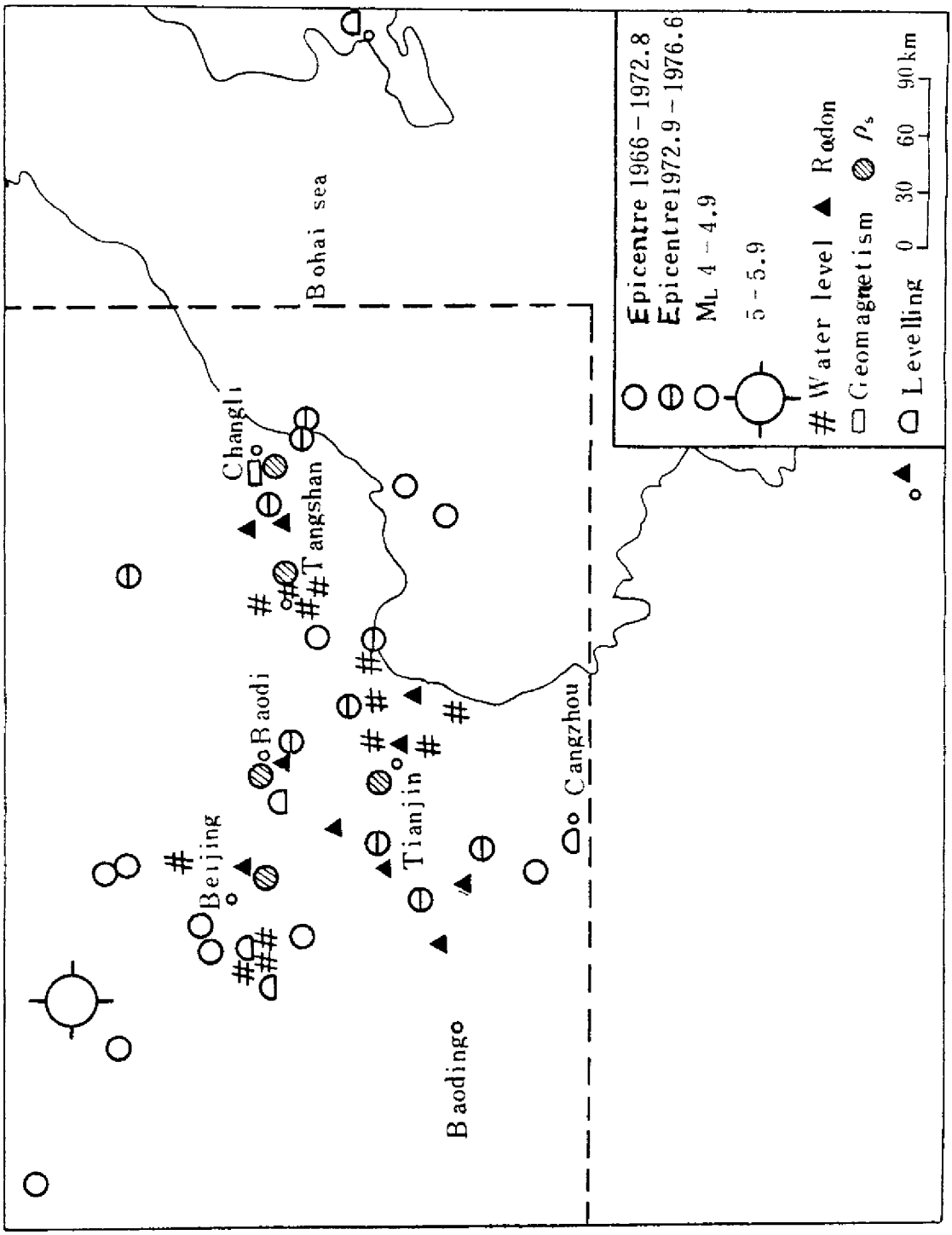


Fig. 3: Map of the Beijing-Tangshan area showing stations for measurement of gravity (large circles with diagonal lines), radon in groundwater, oil well and water levels.



Fog. 4: Map of the Beijing-Tangshan area showing locations and types of anomalies observed in June and July 1976.

people's attention. Many seismologists from various organizations went to investigate in the field to check these anomalies. Six persons of the seismotectonic survey group from the Seismological Bureau of Hebei Province went to Tangshan and carried out extensive studies in Tangshan and its surroundings. Tragically, all of them were killed by the earthquake. In addition to making greater efforts in the field, the organizations concerned convened a series of consultation meetings. An evaluation was made by participants that earthquakes would occur in the latter half of 1976. A consensus of this kind had very seldom been reached in the past. But notions of how large the magnitude would be, and when or where the earthquake would occur, varied considerably. Possible locations included the areas NW of Beijing, between Beijing and Tianjin, Tianjin to Tangshan and the Bohai area. The consensus for the probable magnitude was about 4 to 5, while the occurrence time was not exactly specified. It should be said that some anomalies were detected but were insufficiently large to cause major reactions. In the outcome, an earthquake with M=7.8 struck Tangshan on July 28.

3. CONCLUSIONS

The occurrence of the Tangshan earthquake illustrated to us how complicated the earthquake phenomenon is and how difficult it is to predict. It also raised a series of questions which set people thinking. For example, why should an earthquake with intensity XI strike Tangshan where no previous damaging earthquake had ever occurred historically and where previous events had not exceeded intensity IV? Why had the recurrence period of recent strong earthquakes in North China become so short compared with that of earlier historical earthquakes? Why did aftershocks of the Tangshan earthquake include so many strong earthquakes? Why were the precursory anomalies distributed in such a large area? Why did the precursory activity occur so late? Why were the post-seismic changes so much stronger and more complicated than the pre-seismic ones? The above issues merit serious discussion.

The first important step towards earthquake prediction is to collect relevant observations. An effective prediction theory must be based on the available observations. The Tangshan earthquake occurred in an area which is intensively inhabited, and where various kinds of observations had been made

for more than ten years. So we had obtained many kinds of data, including pre-seismic, coseismic and post-seismic observations for previous large events, as well as data in the epicentral and in more distant areas, microseismic and macroseismic data, geophysical observations for shallow and deeper layers, and so on. These data are very valuable. Soon after the Tangshan earthquake, scientific investigations were made in many fields under the leadership of the SSB. These included investigations on seismo-tectonics, on the physical conditions of earthquake genesis, as well as research on the preparatory process , the mechanism of precursory phenomena, the factors responsible for triggering, and studies based on the comparison of the Tangshan earthquake with major earthquakes in other regions of the Chinese mainland and elsewhere. Some primary results have been obtained. Some of these results are already published in the book "Tangshan Earthquake of 1976". Certainly, what we have obtained to date are only preliminary results and the data need to be studied further. Through co-operation with our colleagues from all over the world, we shall surely be able to achieve our goals more quickly. These goals are to reveal the secrets of earthquake generation; to elucidate the entire physical progress of strong earthquakes; to discover effective ways for predicting strong earthquakes, and thereby to make a significant contribution to mankind in the mitigation of earthquake risks.

DISCUSSION

In response to questions, Dr. Zhu announced that a book entitled "The Tangshan earthquake of 1976", on scientific studies of the Tangshan earthquake, would be published in the near future. He observed that scientific conclusions reached before the earthquake could not be considered sufficient to make an exact prediction.

When asked whether there was any quantitative way of assessing anomalies observed prior to the earthquake, Dr. Zhu replied that judgement was rather made on a qualitative basis. He stated that the public was not informed about the anomalies which had been observed.