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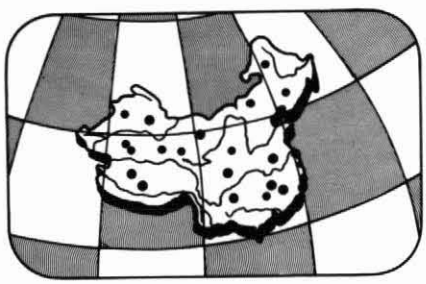

Earthquake Prediction in China

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Summary

This report, based on a visit to China in the fall of 1975, describes the Chinese program for earthquake prediction. An account is given of the prediction of the Haicheng earthquake, M7.3, February 4, 1975.

Introduction

This report describes some of the principal observations made by a Canadian Seismology Delegation which visited China from October 20 to November 10, 1975 at the invitation of the Chinese Academy of Sciences. The visit had its origin in the Science and Technology Exchange Agreement between Canada and China which was announced during the visit of the Prime Minister to China in October 1973. During the course of the negotiations leading up to the agreement, the Chinese requested a visit by a Chinese Seismology Delegation to Canada: this took place in the spring of 1974 and the group toured government laboratories in Ottawa, Yellowknife and Victoria and visited the Universities of Toronto, Alberta and British Columbia. Following the mission Canada proposed a return visit by a seismological delegation in 1975. This suggestion was graciously accepted by the Chinese and led to an extensive tour of China and its earthquake research facilities by the authors of this article.

Following the return of the Canadian Mission to China a substantial U. S. report on "Earthquake Research in China" (Press *et al.*, 1975) was published. We will not repeat the detailed information given in the report on the development of the Chinese program on earthquake research, the description of certain Institutes of the Academy of Sciences and so on. This article will concentrate on those aspects of the program that bear directly on earthquake prediction.

Seismological Research in China

Following the 1966 Hsingtai earthquake, Premier Chou En-Lai and other senior government officials visitied the epicentral area. They were shocked by the magnitude of the catastrophe and knowing that such natural disasters have occurred periodically throughout China's long history decided earthquake prediction should be given a high priority in Chinese science. Such a program in the period following the Cultural Revolution clearly could demonstrate that science can serve the people and could be adapted to the concept that "science walks on two legs", the scientists forming one and the masses of the people the second leg.

During our stay in China we were given an excellent opportunity to see how this 1966 policy decision has been implemented. We travelled some 8000 km by air and 1500 km by automobile and by train visiting institutions in Peking, Harbin, Kunming, and Canton. We made an extensive field trip to Liaoning Province where we visited the epicentral area of the February 4, 1975 earthquake and learnt in detail how it had been successfully predicted. We visited the Hsinfenkiang Reservoir, the site of what has become a classical example of induced seismicity following reservoir impoundment. Finally some of us visited the site of the 1556 Sian earthquake where 830,000 people lost their lives following what is probably history's greatest natural disaster. During these travels we were given a great many briefings on the national and local seismology programs, which together enabled us to form a reasonable understanding of the Chinese earthquake prediction program. Obviously many questions have remained unanswered. In part this is undoubtedly owing to our limited understanding of the socio-economic conditions in China today and in part to the Chinese approach to science which is different to that taught and followed in the West.

Travel arrangements were effectively and efficiently made by the Chinese Academy of Sciences, the Chinese host of the mission. The hospitality extended to the Canadian mission at the official level was remarkable: eleven official dinners or lunches were given by the Institutes of the Academy and by the Revolutionary Committees of the Provinces and Municipalities we visited.

The Earthquake Prediction Program In China

The State Seismological Bureau (SSB), formed within the Chinese Academy of Sciences in 1971, began with a management and coordination function in the earthquake prediction program; but because of decentralization after the Cultural Revolution, some of the central program management functions of the SSB might better now be considered as advisory and facilitative in nature. It appears to be the only central organization having contacts with local and provincial seismological teams, brigades and bureaux: such contacts are not only in scientific circles but are obviously required in political or party circles in view of the shared responsibility for the local or provincial units. The Insitutes of the Academy operate under the umbrella of the SSB.

The provincial seismological units are responsible for all aspects of the earthquake studies conducted within their region, including the operation of a basic seismological observatory (if the province has one), the operation of a regional seismograph network, and other geophysical observatory instrumentation, construction and distribution of indigenous instruments, collection of data and its analysis, the issuance of earthquake predictions and the dissemination of earthquake information to the people. They thus organize the participation of the masses: although the SSB appears to control the distribution of funds and instrumentation, local governments and party committees appear to share responsibility for the leadship of the provincial seismological units. The slogan "Dual Level Leadership with the Locality in Charge" thus appears to reflect the relationship between the SSB and local governments and the provincial or regional seismological units.

The number of basic seismic stations is 17, with some 250 additional regional stations: these, the research institutes and the provincial or regional seismological units, involve 10,000 technical personnel in earthquake prediction and related research. It was claimed that 100,000 people are now involved in amateur prediction work. These figures and the massive priority effort implied appear reasonable from statistics gathered on our tours.

As the SSB is evolving, it is developing an in-house reseach capability to analyse the huge amount of geophysical data on seismicity, crustal deformation, geomagnetic variation, telluric currents, water levels, radon counts, etc., generated throughout China. The aim is, presumably, to assist the analyst groups which have been created at the provincial and regional seismological unit level in developing procedures for correlating and interpreting precursory earthquake phenomena. It was claimed that the judgment of the analysts at all levels in separating real from false anomalies is improving. Statistical or theoretical analyses of data appear not to have been adequately undertaken in the earthquake prediction program to date. A second aspect of the research is to delineate by long-term predictive methods areas of China for intensive concentrated medium-to short-term and imminent earthquake prediction research.

A number of points of interest noted during our SSB visit were the explicit recognition of belief:

1) that whilst before the Cultural Revolution seismic risk studies were most important they are now relegated to second place behind earthquake prediction;

2) that the earthquake prediction program is heavily phenomenological, following the dicta of Chairman Mao "Knowledge begins with experience", "Learn from the masses", and "Be self-reliant". Most phenomena that are monitored for short-term or imminent prediction are not understood;

3) that the scale of premonitory anomalies in time and space is correlated with the size of the succeeding earthquake and the geophysical structural conditions, providing thereby a rationale for the growth of the amateur station network and the combination of professional and amateur observations.

More than 10 successful predictions have been made since the program started (a successful prediction involves an earthquake of magnitude >5, an epicentral location defined within 50 km, an event time within 2 or 3 days and magnitude correct within 1 unit). The actual prediction of a hazardous situation is a decentralized decision made at the provincial or regional level: any decision to evacuate and/or take other preventative measures is a political decision made at the local county, commune or city level by the appropriate party authorities.

This situation leads to considerable ambiguity with respect to the number of false alarms, or the number of significant earthquakes not predicted. In neither case could national statistics be obtained. The incomplete list of successful predictions known to us suggests that several M6 earthquakes per year are not being predicted: of course many of these occur in Taiwan Province or isolated areas of China. The SSB is very modest in its claims for success and repeatedly insisted that the program is in its very early stages of development.

Earthquake prediction in China is a three phase process proceeding logically from a long to medium and then to a short term prediction where this is appropriate.

Long and medium term delineation of seismically active areas is the responsibility of the Institutes and SSB in Peking. The unique historical record of Chinese seismicity plays a significant role in this process; however other studies of statistical model building for a medium term delineation can be criticized. Indeed some of the phenomena which some workers are attempting to correlate with the migration of earthquakes along belts would not appear to have a plausible physical connection with such earth processes.

Elements of the medium term program involving predictions months to years ahead of an event are very impressive: examples are the network of professional observations, the preliminary work on Vs/Vp, the potential for work on anomalous changes of tilt and strain, the analysis of radon in well waters and such studies as those now underway attempting to measure tensor impedance of focal region material.

The local or provincial seismological brigades or bureaux integrate these professional observations with those from the amateur network, and appear then to be almost exclusively responsible for short term prediction involving a period of days to weeks only. Final responsibility for the prediciton of a hazardous situation appears to rest with the provincial seismological brigade or bureau, or its sub-units closer to the predicted epicentral region, but the

evaluation of this prediction and a decision to evacuate an area is a political one that appears to be made at the commune, county or city level, not necessarily in a uniform way.

This complex process of decision making is unlike any earthquake process proposed in western counties. The process has the merit of involving the amateurs, and thus the local political authorities, in the events leading up to the prediction of a hazardous situation; as a consequence of this and the political structure in China, the people involved appear to accept the enormous self discipline involved in wholesale evacuation, (even at -20°C) and indeed may well have stayed in primitive field conditions for up to 10 days on the occasion of some false alarms. When a successful prediction occurs, such as the Haicheng event of February, 1975, it is noticeable that no one official or scientist or group of these at either the central, provincial or local level claimed this as an individual triumph. The corollary is that the failures of prediction and unnecessary evacuations are not publicly reported in China: indeed it appears that central records of these may be hazy, incomplete or simply not kept, since decisions are the responsibility of local party committees.

The role of the amateur stations is extremely difficult to assess objectively. In China, it is a matter of political faith that amateurs using simple equipment and peasants making observations of natural phenomena, in particular unusual animal behaviour, can detect phenomena which give a premonitory warning of a large impending earthquake. Chinese scientists freely admit that no known scientific basis exists for the presence of many of these precursory phenomena, particularly at larger epicentral distances. The Canadian mission assessment based on the records shown to the mission is as follows:

1) several of the reported changes in seismic velocity, tilt and frequency of occurrence of small earthquakes represent valid premonitory phenomena. However the rather insensitive and relatively unstable tilt measurements at some amateur stations do not appear to contribute significant data.

2) the widespread telluric current observations, in particular those made at amateur stations, do not exhibit anomalies which can be defined in a systematic way and shown to correlate with nearby earthquakes. Several noisy time series records were examined; the responsible amateurs in some cases claimed correlations with very distant events but there appeared to be no adequate definition of anomalies in time and spatial correlations. This criticism should not be misinterpreted: some of the work now underway by the Institutes and professional stations on conductivity in and near to focal regions might well substantiate physically valid precursory phenomena, but no such results were shown the Canadian mission.

3) much the same comments apply to observations on variations of components of the geomagnetic field, a common amateur practice.

4) the only information on variations in the level of the water table, the presence of bubbling or turbidity in wells and the conductivity of well water shown the Canadian mission related to events leading up to a localization of the epicentre of the Haicheng earthquakes. Despite questioning, the mission was unable to establish unequivocally whether a systematic regional or local pattern developed, or to establish clearly any exact or systematic relationship in time to the earthquake.

5) the observations on radon content of well water were often impressive; however no examples were shown of systematically defined anomalies correlating with nearby earthquakes. This work, at least in some locations, is obviously being conducted regularly with great care and with more rigorous definition of what constitutes an anomaly: at one such location, a two-year time series was free of anomalies, but in that period no local earthquakes had occurred.

6) the most intriguing amateur observations related to claims of precursory unusual animal behaviour. Many examples were quoted for the Haicheng event at distances up to 70 km from the epicentre; hibernating snakes leaving their holes, ducks flying high, dogs disturbed and so on. Many of these could be related to the foreshock seismic activity of that event, but time relationships were not always clear. This matter appears to justify further study, and the views of the members of the Canadian mission remain divided and ambiguous on the validity of the technique. Does, for example, the local interest generated by the amateur involvement in the developing scenario induce more reports because the peasants are psychologically keyed up to note such items in the period preceding a large earthquake? Can some of the cases be a consequence of foreshock seismic activity and local ground amplification on certain soils? Do certain animals become agitated from high frequency microcracking prior to a substantial shock?

7) the role of foreshock activity is undoubtedly most important. Indeed it appears to be a key indicator in many of the successful predictions in China (with at least one exception).

Among Chinese scientists, attitudes vary from acceptance of nearly all the reported anomalies as valid, useful premonitory phenomena to the more detached view that a large body of data needs to be collected and analysed before the more valid techniques can be chosen, and anomalies more systematically defined and correlated in space and time. The impression gained by the Canadian mission was that the latter, pragmatic view prevails among the more experienced scientists.

In any case, the role of the amateurs in educating the local people about earthquakes and precautions which can be taken to minimize loss of life is both important and fundamental to the success of an earthquake prediction program in the Chinese socio-economic system. In particular the widespread involvement of middle schools provides a fascinating example which the western world might find useful to consider and adopt.

The Haicheng Earthquake of February 4, 1975

The events leading up to the prediction of the February 4, 1975 earthquake provide an excellent example of the manner in which predictions are made in China. We received two briefings by the Liaoning Seismological Bureau and had an extensive field trip in the epicentral area to see damage and reconstruction and to visit faults, as well as a regional observatory and an amateur predicition station. The sequence of events as described to us and as recently presented by Chinese seismologists to

the UNESCO Conference on the Assessment and Mitigation of Seismic Risk is as follows.

Long-Term Prediction. On July 18, 1969 the Po Hai Sea was the location of an earthquake along a large active fault believed to strike NNE continuing into Liaoning Province. The research institutes and the SSB from their work on earthquake migration concluded that northward migration to Liaoning of earthquake activity was probable. The SSB (or its predecessor) suggested the intensification of observations in Liaoning in 1970 at which time the work of the Liaoning Provincial Seismological Brigade (now a Bureau) started. Seismo-tectonic field work was started including tilt and deformation observations. Levelling started across the Yingkow fault in the southern part of Liaoning Peninsula. A second fault, the River fault to the east of the Yinkow fault was also thought to be active in the southern part of eastern Liaoning.

It is believed that seismic and other observations demonstrated that indeed these faults were active in 1971-72, and so an amateur prediction network was developed making the usual types of observation. Extensive development of this network took place in 1973 and especially after June 1974 when the short baseline levelling indicated that the peninsula was tilting to the northwest.

The mission was told in Liaoning that a level line of a few hundred metres showed an increase in the rate of tilting in September 1973 and from September 1973 to 1974, cumulative tilting equalled that in the previous 20 years. It was not clear how the latter had been estimated, and at least one member of the Canadian mission had difficulty in understanding this interpretation of the data shown. The tilting reversed direction shortly before the earthquake. The short orthogonal level lines were about 200 km south of the epicentre. The reported magnetic anomaly consisted of an anomalous increase of 22γ in the vertical field component in six months at Dairen, equally distant. Perhaps as significant, the number of small earthquakes recorded by the growing seismic network increased in 1973-74.

Medium-Term Prediction. In June 1974, the SSB predicted that "in the Northern Po Hai Sea region of northern China, an earthquake with magnitude 5 to 6 may occur within one to two years", thus confirming and making more precise the earlier suggestions. As a result of this, the Provincial Party convened a conference and gave orders to intensify the amateur network and to educate the people. The aim was to focus in on the epicentral region using an amateur network in factories, mines and communes: observations of telluric currents, water wells and animal disturbances were added to the earlier amateur station efforts.

By December, the number of water-well anomalies had increased together with reports of snakes and rats coming out of the ground. It was claimed that changes in water level (both up and down) and changes in turbidity were reported at numerous sites in three or four areas within 40 km of the later epicentre. On December 20, an emergency provincial consultative committee met and based on these observations and reports suggested that "an earthquake M4 to 5 would occur within a few days in the eastern part of the region or at the head of the Gulf". Temporary seismic stations were installed and on December 22, an earthquake M4.8 occurred on the margin of the region.

This was discounted as the significant earthquake by the Liaoning Seismological Bureau (LSB) because the reported anomalies were developing further. On January 3, the Provincial Revolutionary Party Committee convened another meeting with personnel from districts of south Liaoning. The Yingkow-Haicheng area of about 50 km radius was selected as the probable epicentre at the intersection of the NNE trending structural fault and a line across the base of the peninsula, and orders were given to conduct emergency exercises. For example in Yingkow city, emergency measures for hospitals, stores and transport were practised, the evacuation of mines was planned at Anshan, and the movement of people in the densely populated areas of Anshan was studied.

In January, microseismicity increased, and tiltmeters at the Yingkow Municipal Observatory were claimed to show anomalies: the latter were difficult to understand when examined later.

Another Provincial conference was called by the LSB on January 10: the outcome was the prediction of an M6 earthquake in one or two months either in the Yingkow-Haicheng area or at the eastern end of the Liaoning Peninsula.

On January 13, the SSB convened a conference dealing with prediction for all China, but paid special attention to the

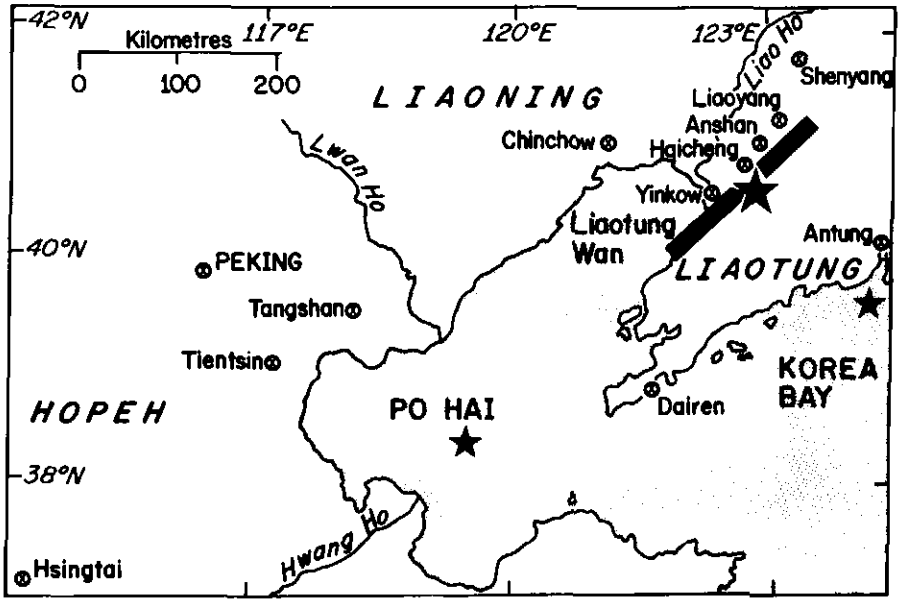

Figure 1
Map showing Po Hai Bay, the Liaoning Peninsula and the location of the Feb. 4, 1975 earthquake near Haicheng.

Liaoning data and that in neighbouring regions. This conference confirmed the LSB suggestion, predicting an M5.5 to 6 earthquake in the first half of 1975 in one of the two areas of the peninsula mentioned above. At yet another meeting on January 28 with responsible personnel from all districts in the peninsula, the LSB passed on the concurrence of the SSB and asked that preventative measures be taken.

Microseismicity increased dramatically at about 20 km from the Yingkow Municipal Observatory on February 2. In early February, a hot spring at Tan Kang, 10 km south of Anshan, stopped three times: the only previous record of such an event was before the M4.8 earthquake. During the microseismic period in early February, at communes 40 to 50 km from the epicentre, water sprang out through the ice cover, and deer were disturbed.

Short-Term Prediction. The determination of a more concrete location and time appears to have depended upon the fortuitous location of the Yingkow Municipal Seismic Observatory some 20 km southwest of the later epicentre. On February 1 only one earthquake was recorded and on February 2, seven with an (S-P) time of 2.2 to 2.7 secs. A felt earthquake M2.4 occurred on February 3, and after 18:30 February 3, more than 500 earthquakes were recorded, with eight >M3, one at M4.3 and one at M4.7. The observatory personnel reported to the LSB and the Revolutionary Committee that a large earthquake may occur within one to two days. Presumably this report was made

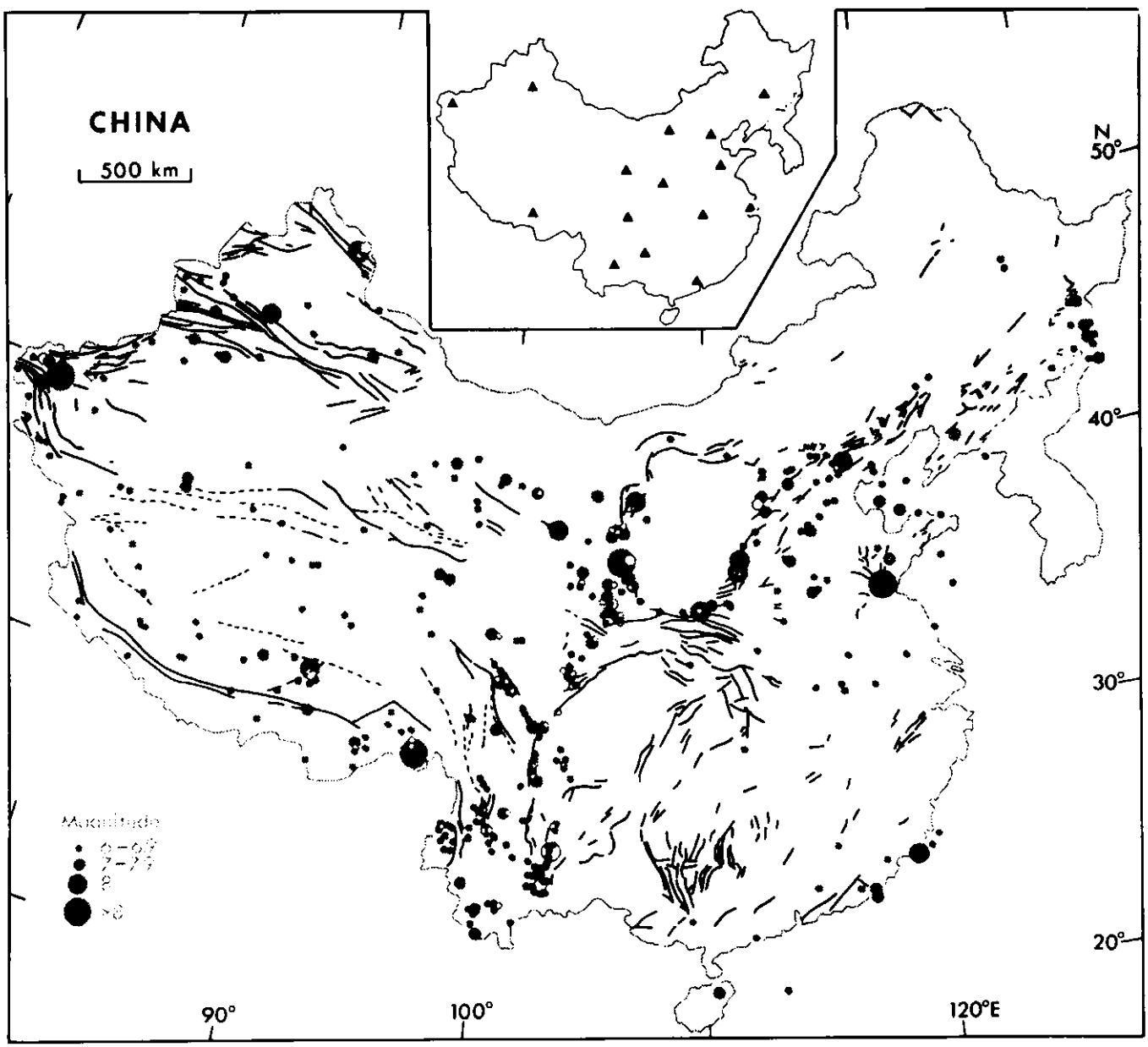

Figure 2
Map showing the epicentres of the known historical earthquakes in China superimposed upon the traces of the known tectonic lineaments. The inset map shows the location of the standard seismograph stations.

late in the evening on February 3, when a total of some fifty earthquakes had been recorded with maximum magnitude at that time of M3. During this microseismic period at communes 40 to 50 km from the epicentre, water sprang out through the ice cover, and deer were disturbed.

It was claimed that nearby amateur stations showed a drop in telluric currents measured with indigenous equipment. In any case at 00:35 on February 4, the LSB reported to the Provincial Party Committee that a major earthquake might soon be expected in the Haicheng-Yingkow area.

At 10:00 February 4, the Provincial Party Committee gave telephone orders to the Haicheng-Yingkow party committees to take instantaneous preventative measures, and the whole province was informed. At 14:00 February 4, the LSB called a conference at Haicheng with responsible party members to carry out emergency measures: stores were closed, and the masses on communes were ordered to construct simple outdoor shelters and leave their houses. Militiamen patrolled to enforce evacuation from houses to shelters despite the very cold weather. The new was broadcast that a major earthquake would soon occur, production teams showed films out of doors and animals were evacuated. Most of the disbelievers who returned to their homes were forcibly evacuated.

At 19:36 the earthquake occured with M7.3 at 12 km focal depth, approximately 30 km SSE of Haicheng in a hilly area. On the communes many people would have been in bed at this time without the evacuation. Furthermore the shaking was so strong that had people been in houses, they would not have been able to walk out.

At the SSB, the Canadian mission was told this was an example of a successful prediction in space and time (but wrong magnitude) of the LSB under the SSB and made by Revolutionary Party Committee of Liaoning. The nuances explain the situation.

More than one million people live in the epicentral area of the earthquake and were subject to evacuation: two-thirds of the communes were badly damaged and 50 per cent of the houses badly damaged or destroyed. The city of Haicheng with a population of 100,000 was about 30 km only from the epicentre. It was completely destroyed.

Because of the effective preventative measures taken, the death toll was remarkably light, between 250 and 300 only in two countries near Yingkow with a stated population of 1.6 million people. The figure appears quite reasonable from other data gathered. For example in the badly damaged Tiger Village Commune of 35,000 in 18 work brigades only 20 people were killed. In another village, 20 km from the epicentre, there were three fatalities in a population of 2500. In the Ting Chao-Gao Advanced Brigade of Pailow Commune, although 80 per cent of the houses were destroyed no animal or person died during the shock.

Conclusions

While it is entirely fair for the SSB to state that the Chinese earthquake prediction program is still in its infancy, the occurrence of major unpredicted earthquakes such as those in the Tang-shan - Peking area in July and August of 1976 are undoubtedly embarrassing. It seems most likely however, that with a record of more than 10 successes and with the very considerable achievement at Haicheng where tens of thousands lives were undoubtedly saved, the program will continue to gain momentum. As described above it is a largely phenomenological program and as such seems somewhat suspect to the western trained scientist. However, in the context of Chinese society where manpower is the most plentiful resource and the population is largely rural and highly organized, the program has a degree of success. It seems certain that a direct transplant would be doomed to failure from the beginning in western society. Nonetheless, the successes suggest that we can look forward to new insights and results in the study of earthquakes from the country that gave the world its first seismoscope nearly 2000 years ago.

References

Press, F. *et al*, 1975, Earthquake Research in China, EOS, v 56, p 838-881.

M S received August 30, 1976