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Learning from the 1966-1976 Chinese Prediction Program

By

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PREFACE

Upon completing this book and seeking more extensive reviews from Chinese experts, and with the aim of having this book published in China, we came to realise, rather late in the day, that we faced some formidable challenges. First, while we were aware of the fact that the Tangshan earthquake was a very painful episode in Chinese history, we realized late the extreme degree of grief that led many at a national and personal level to want to forget. Second, notwithstanding the significant number of our colleagues in China who have been helping us since the beginning of this project, we became aware of the fact that we had only reviewed a small portion of all the written evidence and testimony, and that we may have overlooked voluminous work of others. This may impart a bias and certain inaccuracies to our narrative. Furthermore, where we have not included the work of others, this may cause offence that is entirely unintentional for our part. We came to realise that, as non-Chinese speaking westerners, trying to get an holistic and objective overview of political, personal and technical issues was all but impossible. Third, while we were always aware that Chinese authorities are sensitive about reports on certain parts of Chinese history, we had not appreciated just how deep these sensitivities ran. To all those to whom we may have caused offence, please be assured that this is unintentional and accept our apologies in advance. Our primary motivation was to understand what contributed to the successful prediction at Haicheng in 1975, what caused the failure to predict the Tangshan earthquake in 1976 and what was the nature and cause of the so-called Qinglong miracle . The motivation driving this book is our scientific-based conviction that we need to understand what underpinned these events in order to advance understanding in earthquake prediction methodology and for this to support ambitious programs for earthquake prediction globally, including at the newly launched institute Risks-X at SUSTech in Shenzhen, China, co-founded by one of us as a pilot institute collaboration between ETH Zurich and SUSTech.

FOREWORD

If you want to survive a major earthquake, one very useful thing to have is advance warning of where and when the earthquake is going to strike. Unfortunately, earthquake prediction has made little advance over the decades and, should you be unlucky enough to be in a city that is devastated, there is a good chance you will be killed or badly injured in a collapsed building.

But what if you were given advance warning? What would you do? The first thing you need to know is that your chance of survival is greatly improved if you are outside at the time the earthquake strikes, so that there is no building to fall on you. Better still, you may want to hop on a train and to leave the area all together. But that means abandoning your property, friends and social circle that are immensely important for many of us. At the society level, critical infrastructures can benefit from advance warnings by taking appropriate measures and preparing to temporarily stop operations vulnerable to the disturbances caused by the earthquake.

Not widely known, the Chinese, under the stewardship of Enlai Zhou, in the period 1966 to 1976, launched an earthquake prediction methodology in one of the world's biggest science and social science projects ever undertaken. The effort climaxed with the successful prediction of the M7.6 Haicheng earthquake in February 1975 that saved many thousands of lives.

Eighteen months later on July 28, 1976, the industrial city of Tangshan, 180 kms east of Beijing, was flattened without warning, by an M7.8 earthquake and 240,000 people lost their lives. The jubilation that followed Haicheng success turned to despair. Zedong Mao died in September 1976. China set a new course and the earthquake prediction program was prematurely dismantled and all but forgotten. The recipe for success lay smoldering in hundreds of technical documents and reports.

In this book, we try to reconstruct the recipe for success developed by the Chinese in the period 1966 to 1976. We come to the conclusion that the Chinese came close to predicting the Tangshan earthquake in 1976 and there should be little doubt that, with such a program and with the addition

of modern communications technology and the progressive accumulation of knowledge, it would have been predicted today. We can envision a future in which citizens and authorities will be given the luxurious dilemma of having to decide how to survive a major earthquake when you know with high likelihood that it is coming. This book ends with that recipe for survival.

SUMMARY

The Cultural Revolution from 1966 to 1976 caused the Communist Party of China, the country and people to suffer the most serious setbacks and losses since the founding of the People's Republic of China. This would be a momentous decade in Chinese politics. It was against this backdrop that, in March 1966, the prefecture of Xingtai, that lies 400 kms SW of Beijing, was struck by two strong earthquakes. The earthquakes killed 8,000 and left 38,000 injured. The Communist Party was keen to show compassion to the hard pressed working masses and sent brigades from the People's Liberation Army to assist in rescue and recovery work. Premier Enlai Zhou took a personal interest and visited the area twice. He asked Siguang Li, China's most senior geologist, if earthquakes could be predicted so that, in future, warning could be given to the people. Li gave a cautiously positive response. No one had ever managed to predict an earthquake before. China was about to embark upon the world's largest earthquake prediction project under the watchful eye of Premier Enlai Zhou.

At its peak, the prediction program engaged 35,000 amateur monitoring posts, many located in schools, which would record everything from earth currents, earth stress, and the level of water in drinking water wells to animal behaviour. These amateurs worked alongside professionals who made observations using more advanced equipment, sharing information and experience, in theory at least.

Nature played an important role. The north China plain that borders the Bohai Bay was shaken again in 1969, 1975 and 1976 in the most intense period of seismic activity in northeast China for centuries. The Chinese would reap the benefits of seeds sown a decade before when they successfully predicted the Haicheng–Yingkou earthquake in February 1975. The attendant evacuations of buildings in Yingkou, and rural districts at least, saved many thousands of lives. To this day, the international community hails the Haicheng earthquake as the only successful official prediction ever made. Normally overlooked is the fact that Haicheng itself did not evacuate buildings and suffered a higher casualty rate than neighbouring Yingkou as a consequence.

The Communist Party and Chinese seismologists were jubilant. They were invited by the Japanese Academy of Science to exchange information over a three-week long state tour. Zhiyuan Zha, a Deputy Director of the State Seismological Bureau (SSB), would accompany a six strong delegation to Japan in the winter of 1975. Shirong Mei, a Deputy Director of the Department of Analysis and Prediction within the SSB, was part of a delegation to a conference in Paris, where their peers worshipped the Chinese earthquake predictors.

Amidst the jubilation, the Chinese overlooked the fact that they did not fully understand how they predicted the Haicheng earthquake. The foreshock sequence that was used as the principal guide was uncommon and not normal. The fortitude of a handful of key individuals combined with a large dollop of luck lay behind this success. These lessons were never learned and this would lead to the greatest earthquake tragedy known to modern mankind 18 months later.

1976 began badly with the death of Enlai Zhou, who had founded and personally mentored the prediction program. Then in May, an earthquake was predicted for Songpan, Sichuan Province, 1,000 kms to the SW of Beijing. And on 29 May, an M7.4 earthquake occurred at Longling, Yunnan Province. Nothing happened in Sichuan Province for several months, and fear fed chaos. The Chinese would learn a hard lesson in false positive predictions or in predictions with long-lived alarms. On 16th August 1976, the predicted M7.2 Songpan-Pingwu earthquake occurred, but after more than 3.5 months of disruptive waiting.

Throughout the first half of the year, Chengmin Wang, a team leader in the Department of Analysis and Prediction at the SSB would warn of another major earthquake in the Tangshan-Luanxian area of Bohai but would be ignored by Shirong Mei and Zhiyuan Zha, who were his seniors in the SSB. And then in July, the Beijing Seismic Team would join in with a warning of an earthquake in the capital. Predictions would come in thick and fast but no one knew which if any was correct. With the at-risk zone now covering 50 million people or more, it was impossible for the SSB and their political masters in the Central Committee to take any action. This culminated with a meeting at the SSB on 27 July 1976 where Chengmin Wang and others had one final chance to persuade their bosses of the impending danger, which would strike the next day.

Deputy Director Zhiyuan Zha was in charge and allegedly asked everyone the direct question: “would there be a big earthquake in the coming days?”

Having been warned of serious consequences for creating panic in the capital, they all answered no. Less than 12 hours later, at 03:42 am on the 28th of July, most of the inhabitants of the mining and industrial city of Tangshan were at home in bed asleep. The ground shook violently for only 10 to 20 seconds (Wang, J. M., 1985) directly beneath the city that in an instant was reduced to rubble. 240,000 to 650,000 people lay dead or dying under collapsed buildings. One of the most deadly earthquakes ever had just struck “without warning”.

In the aftermath, the finger of blame emerged immediately and all those involved were doing what they could to ensure that it did not point at them. Chengmin Wang was sent to Tangshan on the day of the earthquake to gather evidence and to monitor the many aftershocks. Shirong Mei busied herself with the troublesome Songpan earthquake that eventually struck in August with three large shocks but, because of the prediction, casualties were very light. Deputy Director Zhiyuan Zha carried the can and was sent to a labour camp for 8 years. He was lucky to escape with his life.

Zedong Mao died in September and with him died the Cultural Revolution and the dust would finally settle on the Bohai Bay, for the time being at least. The jubilation of Haicheng turned to despair and, lacking the support of Enlai Zhou and other key figures who had either died or been transferred, the earthquake prediction program was gradually dismantled and more or less forgotten.

Two decades later, in a China transformed by the reforms of Xiaoping Deng, the United Nations would take interest in the case of the Qinglong County Miracle. It would emerge that Qinglong County earthquake office and local party had taken measures days before the Tangshan earthquake to evacuate buildings. In the summertime, school classes were held in the yard and families slept in tents. Lying 80 kms north of Tangshan, Qinglong lay on the edge of the damage zone. Nevertheless, 7000 homes collapsed and no one died. Around 9000 lives may have been saved.

The rumour mill then began. It was obvious to some that the Tangshan earthquake was known about by the authorities who chose to not inform the public and to instead let them die by the 100,000s. This assertion was the exact opposite of the goal of the prediction program.

In the aftermath, the SSB would conduct a thorough post-mortem and publish a weighty technical report in 1982 where Shirong Mei was the

chief technical editor while Zhiyuan Zha was still languishing in a labour camp. This report contains all the technical evidence gathered by the SSB in the lead up to Tangshan. There is a crucial distinction here. The information had been gathered but was not necessarily known to the SSB at the time the Tangshan earthquake struck. Much of it lay unread in notebooks in thousands of amateur monitoring stations scattered over NE China.

2008 was China's Olympic year. We can all recall the splendour of the games that opened on 8th August, a reflection of the economic powerhouse that China had now become. Fewer outside China will recall the Sichuan earthquake of 12 May 2008, striking modern reinforced buildings, which still killed over 100,000 people (dead + missing). The earthquake carnage in China goes on and on. And will go on and on until a reliable prediction methodology is developed and even better reinforced buildings become the norm.

Zhiyuan Zha, when released from labour camp and now retired, made use of his time to review three reports produced by the SSB covering the Haicheng, Tangshan and Songpan earthquakes. He summarised his findings in a book, with a blue cover, which was finalised in 2009. Still a controversial character, he was unable to find a publisher. The writing and structure is a little disorganised but Zha makes key observations and reaches some important conclusions. The Chinese had in fact discovered the recipe for successful earthquake prediction in China in the period 1966 to 1976 but did not know it then. It was very hard to recognise success in the wake of the Tangshan slaughter. In the 1982 post-mortem report published by the SSB, the key technical information is consigned to obscure chapters and is not discussed at all in the final summary. Shirong Mei went on to have an illustrious career in the SSB while Zhiyuan Zha languished in prison. The premature abandonment of the prediction program may arguably have led to the 2008 tragedy in Sichuan.

Our book project has been planned in the mind of Didier Sornette for many years (since 2005). Didier has for decades sought of ways to combine the multitudes of precursory phenomena associated with earthquakes into a coherent prediction method. This quest took a new turn when he connected in 1997 with Friedemann Freund who works for NASA Ames and the University of San Jose. Over several decades, Friedemann has conducted fundamental experiments that culminated when showing that, when you squeezed a rock very hard, it generates electrical charge carriers and works as a "rock battery". This discovery and the elucidation of its

underlying physical mechanism opened the possibility to explain and unify the myriads of electrical phenomena that are often reported immediately before (and after) major earthquakes. The most visible of those are lights seen either on the ground or in the air. Didier and Friedemann started to collaborate towards their common goal of a global earthquake forecast system.

In February 2018, looking for complementary expertise and passion, Didier offered Euan to work at The Chair of Entrepreneurial Risks, ETH Zurich, on global risk problems. It was suggested that writing a long paper or short book on the Chinese earthquake prediction program and the Tangshan earthquake in particular would be a fitting introductory project. It should take no more than 4 months to complete, at least, this was the initial plan. Work began in earnest in July 2018 and one year and a half on, the short book had grown into a 200,000-word tome. This short book is effectively an executive summary of the tome. We cover a vast range of topics spanning geology, plate tectonics, political and organisational structures, physical processes that occur during earthquakes and the social, political and scientific history of this unique earthquake prediction program. We try to present all this information in a way that is accessible to the non-expert.

This book begins by trying to place the seismic events of Xingtai, Bohai, Haicheng and Tangshan into the extensional geological setting of the Bohai Bay rift Basin. It draws on the rich volume of petroleum industry stratigraphic and structural data published in recent decades. It goes on to review and summarise published data on anomalies that occurred before the Haicheng and Tangshan earthquakes. It is found that most anomaly classes do not constrain the timing and location of these large earthquakes. The main exception is spantaneous earth currents (telluric currents) that appear at the locations of the epicentres a few days to weeks before the earthquakes struck. Of the range of instrumental anomalies that were recorded, telluric currents alone provide information of time and location. These observations for the first time link the rock battery theory of Freund to precursory anomalies measured in advance of major earthquakes. The telluric current anomalies may be supported by anomalous animal behaviour and variations in well water (ground water) levels. The book also presents an analysis of all anomalies measured using the Log-Periodic Power Law Singularity (LPPLS) theory. In this retrospective analysis of the Haicheng and Tangshan earthquakes, a precise short-term prediction of the timing (with statistical bounds) of the earthquakes based on the super-

exponential acceleration accumulation characteristics of earthquake precursors is shown to be possible.

In January 2019, we made contact with Chengmin Wang in Beijing and met him twice in Beijing on 16 March and 29 July 2019, with the later meeting including Academician Wenjin Zhao who helped us refine our understanding of the geology of the Bohai Bay Basin. Now 85 years old, Chengmin Wang is still active in the China Earthquake Administration in Beijing. He provided us with a large amount of background information and original Chinese documentation that lends our book a unique level of insight.

First and foremost, this short book is designed to inform both the non-experts and experts of the extraordinary sequence of events, of the science as well as of the social developments that underpinned the ten years leading to the Tangshan earthquake. We present the strengths and unique approach of the Chinese prediction program that developed over a decade from 1966 to 1976. We then try to identify the failings of the past and make suggestions for a viable future pathway that could combine the insights and organisation of the 1966-1976 Chinese prediction program with modern technologies to facilitate data gathering, interpretation and sharing. Above all, this book is designed to provide an inspiration to consider earthquakes differently than usually presented. Most of the time, the Earth is sanguine and we go about or daily lives undisturbed. But when a large earthquake brews in the deep, it does give off some clear signals. Knowing how to read these signals could one day save your life.

July 2021

CHINESE AND ENGLISH LANGUAGE NAMING CONVENTIONS

In Chinese, the family name is always placed first followed by the given name. This is the opposite of the English language convention. In the English version of this book, we use the English language tradition to report the names of the characters of our story with given name followed by surname (or family name). All Chinese names follow this convention. Mao Zedong, therefore, becomes Zedong Mao.

ABBREVIATIONS AND ACRONYMS USED

SSB	State Seismological Bureau (Chinese)
CEA	China Earthquake Administration (modern version of SSB)
RCL	Revolutionary Committee of Liaoning Province
PLA	Peoples' Liberation Army

Jing-Jin-Tang-Zhang = Beijing-Tianjin-Tangshan-Zhangjiakou

Jing-Jin-Tang-Bo-Zhang = Beijing-Tianjin-Tangshan-Bohai-Zhangjiakou

ACKNOWLEDGEMENTS

The idea of this book started with an email sent to Didier Sornette by his long-time collaborator and friend, Professor Weixing Zhou at ECUST (the East China University of Science and Technology in Shanghai). This email dated September 29, 2005 was meant to attract the attention of Didier to the recently released information in China of the Qinglong miracle and the alarms raised by a scientist, Chengmin Wang, about the imminent occurrence of a large earthquake, which turned out to be the Tangshan earthquake. Over the following days, months and years, Weixing Zhou continued to provide information on these fascinating revelations. We are thus extremely grateful to Weixing Zhou for his generous help.

Researching this book has involved the translation of many documents from Chinese to English and, in communication with Chinese colleagues, translation of correspondence from English to Chinese and vice versa. We are indebted to our Chinese translators, in particular former ETH Zurich master student, Min Yu, Dr. Ke Wu (previous ETH Zurich PhD student, then post-doc and now assistant research professor at SUSTech in Shenzhen), and current ETH Zurich PhD student Ran Wei. Dr. Ke Wu has provided many insights for our better understanding of the geopolitical situation and atmosphere at the time of the Cultural Revolution. Dr. Ke Wu was also our chaperone during our visits in Beijing and was instrumental in organising them and in providing smooth Chinese-English translations in our discussions with Chinese scientists. Two other master students, Shenglan Niu and Zhiyuan (Peter) Zhu, produced very useful early translations of two books only available in Chinese. Our translators also provided useful social, historical and geographic background.

Early in 2019, we established contact with Mr Chengmin Wang in Beijing who provided us with a large amount of documentation and a copy of his memoirs. We also met with Mr Wang and other Chinese seismologists in March and July 2019. Mr Wang was a senior figure in the SSB in 1976 and was in the thick of the action before and after the Tangshan earthquake. We are deeply indebted to the time he gave and for all the information he provided that gives this book a special and historic dimension.

Mr Shangyong Li, author of Dawn of Prediction of Large Impending Earthquake (in Chinese, 大地震临震预报的曙光) is thanked for sharing information and his assistance in arranging meetings in China.

As we dived in the theories that could rationalise earthquake precursors, we engaged into very informative and passionate exchanges with Friedemann Freund, the discoverer of the rock battery effect and the champion of the peroxy defect theory. We are greatly indebted to him for his generous attitude and scientific honesty in explaining the minute details of his ~40 years of research in this field. Didier would also like to acknowledge the long-term collaboration with Dr. Guy Ouillon on the modelling and analysis of earthquake data. Dr. Guy Ouillon also helped in preparing figure 66.

Departmental administrator in the Chair of Entrepreneurial Risks at ETH Zurich, Adriana Schellenbaum, provided support throughout and helped with the final assembly of the many parts into a single properly formatted document.

Dr Jiawei Li, post-doctoral fellow at Risks-X at the Southern University of Science and Technology (SUSTech), provided a review of the English version in May and June of 2020 and provided numerous helpful suggestions that improved the text. Dr Li conducted a very thorough review of the final draft, correcting numerous errors in the translations of Chinese names and other factual errors arising from translations and so on.

PROLOGUE

For millennia, a succession of 17 dynasties saw China lead the world in arts, technology and civilisation but, during the late reign of the Qing Dynasty, social decay had eventually prevailed. With the continuous invasion of foreign troops and the signing of a series of unequal treaties from around 1840 to 1948, China endured a “century of humiliation”. This led to the founding of The Republic of China in 1912 but, unable to make a clean break with the past, social decay continued much as before. Under the leadership of Chairman Zedong Mao, the Communist Party of China defeated the army led by Kai-shek Chiang in the Chinese Civil War (1945-1949). After the Second Sino-Japanese War (1931-1949), the People’s Republic of China (New China) was established in 1949. This ended the wars and disasters of old China and New China started its economic construction and much was achieved in the next three decades (1949-1979), including land reform, the development of an independent industrial system and development of its own nuclear weapons. However, the disenchanting developments of the Great Leap Forward (1958-1960) and of the Cultural Revolution (1966-1976) in this period caused tremendous damage to the national economy, and brought China to an important historical node. In 1966, Mao and his allies launched the Cultural Revolution, sparking a decade of political recrimination and social upheaval that lasted until Mao's death in 1976, making this period an extremely unusual and sensitive decade in Chinese history.

While The People’s Republic of China was in a state of transitory chaos, Nature was plotting to deal the cruellest of hammer blows to the Chinese People in Xingtai, a prefecture level city located in the south of Hebei Province of NE China on the North China Plain (Fig. 1). The North China Plain is as flat as a billiard table and covers about 410,000 square kilometres. It is one of the most densely populated areas on Earth. This alluvial plain of the Yellow and several other major rivers extends offshore beneath the waters of the shallow Bohai Bay (Fig. 1).

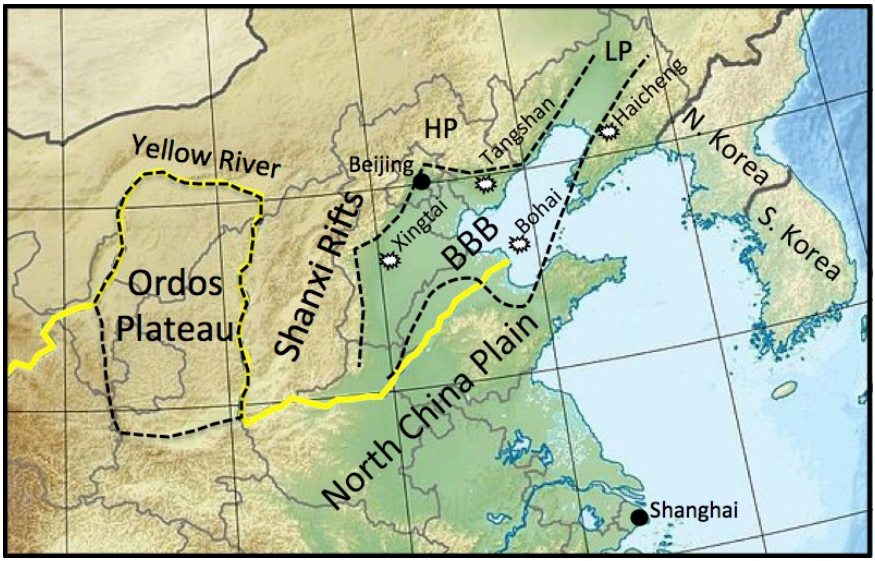

Fig. 1 Map of North China Plain showing the locations of the four main earthquakes discussed in this book (Xingtai, Bohai, Haicheng and Tangshan); the course of the Yellow River almost circumnavigates the Ordos Plateau; and the main structural units – the Ordos Plateau, the Shanxi rifts and the Bohai Bay Basin (BBB). HP = Hebei Province and LP = Liaoning Province. Base map accessed through Wikipedia attributed to naturalearthdata.com.

The earthquakes begin

In early March 1966, Xingtai was emerging from the cold winter that affects this part of China. Barely noticed by the inhabitants, the area was shaken by a series of small earth tremors. Not known at the time, these small tremors foretold of momentous events that were to follow and that would last for over a decade. At 05:29 am on 8 March 1966, the ground shook violently in Longyao County, Xingtai Prefecture as the area was struck by a magnitude 6.5 earthquake (See Appendix 1 for explanation of the Richter magnitude scale). This was a strong earthquake centred on an area about 45 kms to the NE of the city of Xingtai (Fig. 1). The modest intensity and largely rural setting meant this was not a major catastrophe, and yet thousands lay dead or dying, trapped as they slept, in the rubble of poorly constructed houses.

The Chinese garrisoned in the area mobilised immediately to assess the damage and casualties and quickly located the epicentre in Longyao County. Xin Xu, deputy commander of the 63rd Army, and Changyuan Cai, the Political commissar, filed a report to the State Council in Beijing where Premier Enlai Zhou convened an emergency meeting to discuss and implement emergency rescue measures. Units from the Beijing military region were sent to assist the 63rd Army in rescue and relief operations. Premier Enlai Zhou flew to the area by helicopter, arriving on the afternoon of 9th March (account from Bo, Z., 2010).

Not known at the time, the earthquake of 8th March was the trigger for a series of larger events that would cascade through the Bohai region in the course of the next decade. A larger M6.8 earthquake would strike Xingtai on the 22nd March. Once again Premier Enlai Zhou would visit the epicentre in Ningjin County on 31 March to comfort the people. Three further shocks >M6 would strike on 22nd, 26th and 29th March. The Bohai Bay was severely shaken, but not yet stirred. At the end, it was estimated that over 8000 were dead, 38,000 were injured and that millions of houses were damaged or destroyed (Houston China Consulate).

Siguang Li, one of China's most senior geologists, was present at the emergency meeting convened by Premier Zhou on the evening of 8th March 1966. He dispatched a 32 strong team of geologists and seismologists to Xingtai to monitor the situation while establishing a Seismic Geology office within the Ministry of Geology to oversee the operation. Meanwhile, it is alleged that Premier Zhou on one of his visits to Xingtai had a conversation with an old man who asked why it was not possible to give the people some advance warning (attributed to Mei, S., 2008).

At one of the meetings held to discuss the Xingtai earthquake during March 1966, Premier Zhou asked Siguang Li if it was possible to predict earthquakes and to provide some advanced warning to the population. Everyone knew that earthquake prediction had been studied by more advanced countries like the USA, Japan and the Soviet Union for decades and they had all failed to make any significant breakthrough. But Siguang Li responded on a cautiously positive note:

> *"An earthquake is a natural phenomenon and, in terms of its origin, it is the product of the internal movement of the earth's material itself. There is a process of its occurrence, and there will be certain mechanics. As long as we grasp it and master the laws of its changes, earthquake prediction and forecasting is possible, but a lot of exploratory work is needed.". From Ma., T.*

In this way, the seeds of an extraordinary experiment to monitor and predict earthquakes were sown, the likes of which had never been seen before or since. The experiment sought to use traditional Chinese methods, such as observing anomalous animal behaviour and anomalous well water level and compositional variations, and to combine these with western technologies like seismic monitoring, ground levelling, gravity and magnetic field measurements. The experiment sought to combine professional expertise with one of China's largest resources – its vast population – referred to as the masses. At its peak, over 35,000 amateur monitoring stations were established making simple measurements like spontaneous electric currents in the earth, the resistivity of soils and soil stress. This book seeks to tell this story of the biggest earthquake prediction program in world history, to record for the first time, in English language, many of the findings of this project, to tell the story of some of the people involved and to document some of the successes and failures. At the heart lies an assumption that an earthquake gestating in the sub-surface must give off physical signals that can be detected and used in prediction. The problem then, that persists to today, is knowing what physical signals are important. In the 1960s, the Chinese were taking a great leap into the dark.

This was not the first time the Bohai Bay had been rocked by a large earthquake. The most recent events occurred on 1 August 1937 when two M7 events shook the area west of Heze, approximately 230 kms SSE of Xingtai (35.2 : 115.8 decimal degrees) (Muller, P. M., 1976) (Fig. 2). These events were part of a long sequence that can be traced back to September 1303 when a large earthquake shook the South end of the Shanxi rifts, a geological structure adjacent to and lying to the west of Bohai Bay (Fig. 1 and 2). In total, 37 strong to great earthquakes (see Appendix 1 for the nomenclature) have struck this area since 1303 and the Xingtai earthquake would not be the last. Two events worthy of special mention were the 25th and 26 July 1668 Tancheng earthquakes followed a decade later by the 2 September 1679 Sanhe-Pinggu earthquake that would rock the area immediately to the east of Beijing (Fig. 2). The earthquake of 25 July 1668 was estimated to be M8.7 and the 1679 Sanhe Pinggu event to be M8, making them great earthquakes in the seismological nomenclature (See Appendix 1). There are a number of sobering lessons to learn from this history. First, earthquakes in this area often occur as clusters as was the case with Xingtai. Second, they often occur as sequences as was the case with Tancheng and Sanhe-Pinggu, and third, the region is capable of producing great earthquakes of M>8 that may lead to total destruction of property in the affected area. As we will shortly learn, Xingtai was the first in a sequence of 4 major earthquakes that would strike Bohai in the

coming decade, and at the time of writing 45 years have passed since the last major earthquake struck and totally destroyed the city of Tangshan on 28 July 1976.

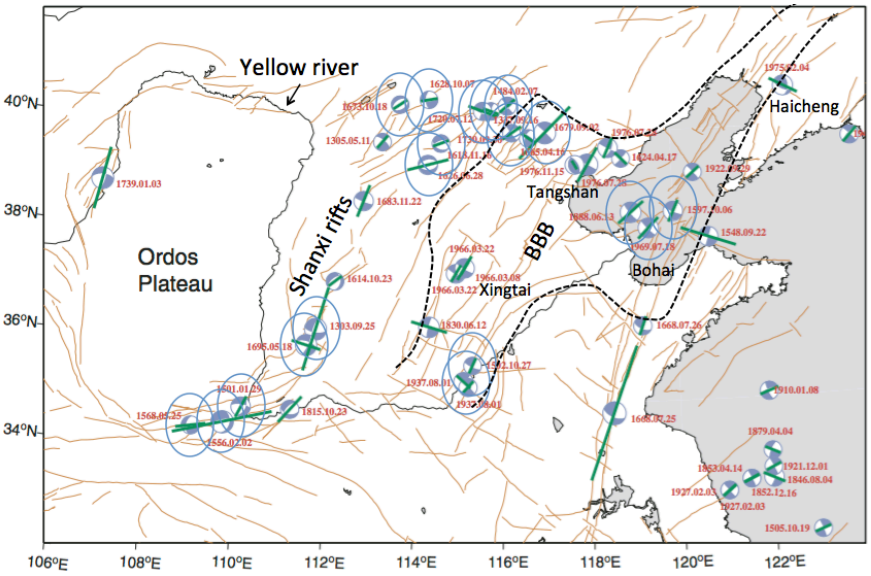

Fig. 2 Map showing the locations of 37 major earthquakes to strike the Shanxi Rift-Bohai Bay Basin (BBB) area since 1303. The dashed lines mark the outline of the BBB. The geology and tectonics are described in greater detail below. The locations of the four main earthquakes discussed in this book – Xingtai, Bohai, Haicheng and Tangshan - are labelled. The oval circles mark ~ 50 km radius zones around large earthquakes. Base map modified from Fig. 12 of Liu, M. et al. (2007).

The year after Xingtai, on 27 March 1967, a relatively small M6.3 earthquake struck the area of Hejian (38˚3’ : 116˚3’) to the NNE of Xingtai. And then in 1969, a much larger M7.4 earthquake struck the offshore area of Bohai Bay (38˚12’ : 119˚24’), simply called the Bohai earthquake in Fig. 1 and Fig. 2. There were no casualties from the Bohai earthquake since it was offshore and distant to population centres. However, all of this activity, not far from the capital Beijing, had the fledgling earthquake office and Communist government concerned. The idea had taken root that a sequence of earthquakes was marching northwards towards the densely populated Liaoning and Hebei Provinces (Fig. 1).

In the late 1960s, the earthquake prediction program was embryonic, but under the watchful eye of Premier Zhou, staff, expertise and activity were growing. Two more major earthquakes were about to strike this area. At 19:36 on 4th February 1975, an M7.3 earthquake would strike the Haicheng-Yingkou area of Liaoning province but, despite extensive damage, casualties were relatively light. Hours before the earthquake struck, a public warning was issued and the city of Yingkou and many rural areas were evacuated. This was the pinnacle of success of the Chinese earthquake prediction program and the evacuations at this time are hailed to this day as the only major earthquake ever to have been successfully predicted officially. In this context, evacuation means moving people from in doors to out of doors since the main hazard comes simply from buildings collapsing. But it was -20˚C in Liaoning province at this time and so it was no trivial task asking populations to live in the open, and many died from exposure.

The Chinese authorities were jubilant at the prediction success, but the authorities were to pay a high price for this exuberance that gave the impression the earthquake prediction problem had been solved. In fact, a large amount of luck was involved in the successful Haicheng prediction. The following year, a catastrophe was going to strike the city of Tangshan where at 03:42 am on 28 July 1976, an M7.8 earthquake struck without warning issued to the population. Between 240,000 and 650,000 were killed on the spot or would die in the following days trapped by fallen rubble. This was one of the most deadly earthquakes of all time and the tragedy is inscribed on the souls of the Chinese people. Why was no warning given? The focus of this book is to tell the stories of Haicheng success and Tangshan failure with the aim of understanding the science, geology, social and political dimensions in the hope of laying the ghosts of Tangshan to rest.

Tangshan, a warning from History and the Documentary Buried

In the wake of the perceived success of the Haicheng prediction, the Chinese authorities were keen to publicise the success and invited a number of foreign delegations to examine the evidence. New Zealander R. D. Adams was first in September 1975 followed by a Canadian delegation led by K. Whitman in October 1975. The largest and best organised delegation was led by American B. Raleigh in June 1976. Each of these delgations published English language reports enabling non-Chinese to gain insight into the political, social and technical aspects that led to the

Haicheng success. The work of these delegations was then summarised and expanded upon by the Canadian delegation led by Kelin Wang in 2006.

Following the Tangshan disaster in 1976 and the political turmoil that ensued with the death of Zedong Mao a few months later, no such foreign delegations were invited to China and the lead up to, and aftermath of the Tangshan earthquake, remained obscure to the western world. And then decades later, in 2008, disaster would strike once again with the great Ms~8 Wenchuan earthqauke that was estimated to have killed over 100,000 (dead + missing). This was in China's Olympic year.

Qingzhuo Zhang wrote a report in the year 2000 called "Tangshan, a warning from History" that was published in 2006. This inspired a documentary film called "Buried" (from now on The Documentary) that was directed by Libo Wang. The documentary won a prize at the 2009 Beijing documentary film festival before being banned in China. Both book and documentary adopt a conspiratorial theme and level accusations at the Chinese authorities along the lines that it was known for sure that a large earthquake was going to strike Tangshan but nothing was done to warn the people. Readers should learn from our book that nothing could be further from the truth.

The documentary that is still available on line in the west has English subtitles and provide English speakers with a window into the Tangshan tragedy. While the documentary contains many technical weaknesses, its strengths include a time line of key events, an introduction to some of the main characters at the time and a window into the staff who manned thousands of amateur monitoring stations. These physical measurements of presumed earthquake precursors were not compiled and analysed in time to avert disaster but constitute a focus point of our exposition.

Because the documentary is an obvious source for English speakers, let us stress its great weaknesses that include: 1) it develops a conspiratorial story line along the lines of "the political authorities knew an earthquake was coming and did nothing to save the population"; 2) the documentary is weak on technical understanding and accuracy; and 3) it gives a lot of air time to Chinese earthquake expert Qingguo Geng who provides many pieces of testimony that lacks scientific credibility.

Chengmin Wang, Zhiyuan Zha and Shirong Mei

It is time to meet a few of the key characters of this story. One of the main characters was Chengmin Wang, who at the time of the Tangshan earthquake in 1976, was a team leader within what had grown to become the State Seismological Bureau (SSB). Born in December 1935, he had studied seismology in The Soviet Union 1956 to 1960 and, at the time of the Bohai earthquake, he worked for the growing Seismic Geology office established by Siguang Li in 1966. We established contact with Chengmin Wang via social media and email early in 2019 and met with him twice in Beijing on 16 March and 29 July of the same year. Mr Wang, now 85 years old at the time of writing was hale and hearty and was enthusiastic to engage with us. Through numerous email exchanges, Mr Wang provided us with a wealth of information from his memoirs and privately held documentation, but all of it in Chinese. His contribution greatly enhanced the scope and quality of our own book. We coped with the large volume of translation work through the generous assistance offered by current and past Chinese post docs and students at the Chair of Entrepreneurial Risks, ETH Zurich (see acknowledgements).

One of the valuable insights Chengmin Wang provided was that, in the wake of the 1969 Bohai earthquake, crustal deformation and damage to property were observed to be greater at two sites more remote to the epicentre compared with areas that were much closer by. One of these sites was towards the north end of the Liaoning peninsula in the vicinity Xiongyue close to the small cities of Yingkou and Haicheng. The other was across the Bohai Bay in the vicinity of the city of Tangshan. These important observations were explained by what was termed *the aftereffect anomaly field*, a theory attributed to Siguang Li. The stress released by the Bohai earthquake had increased the stress at Haicheng and Tangshan (Fig. 3). These two areas were therefore marked as being particularly at risk and were therefore monitored in great detail in the following years.

After the actions of 1966, 1967 and 1969, the Bohai Bay fell silent for a number of years but the expansion of the earthquake monitoring and prediction program progressed. One of the aims was to engage lay people to make simple observations and measurements who should work alongside professionals. In a sense, this was to establish Communist ideals of equality. The program was also there to demonstrate that the Communist Government cared for its people, which is one of the great ironies of the time since this was a period of great violence and suffering, in part due to the developing Cultural Revolution. A third objective of the program was to

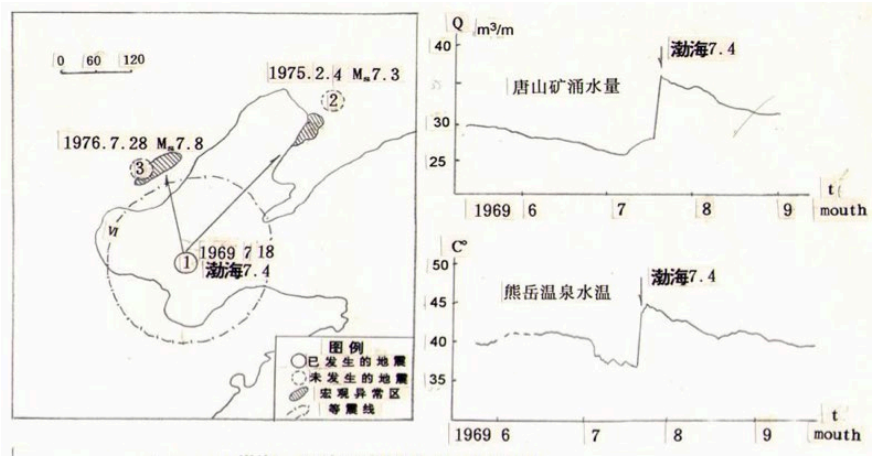

Fig. 3 Slide 5 from a Power Point file we received on 11 February 2019 (Chengmin Wang, personal communication). The map shows the location of the Bohai earthquake 1969 and anomaly fields (shaded) that appeared in the Xiongyue area (2) and Luanxian – Tangshan area (3) coincident with the Bohai earthquake. 2 and 3 mark the locations of the subsequent Haicheng and Tangshan earthquakes. The lower right panel shows the temperature profile for a hot spring in Xiongyue. A decrease of ~ 3˚C occurred throughout June and early July and, then coincident with the Bohai earthquake, the temperature increased ~ 4˚C. This indicates long-range changes in hydrological regimes responding to changes in regional stress fields. The upper right panel shows the change in water flow in a Tangshan mine, displaying a 30% increase broadly coincident with the Bohai earthquake.

geologist Siguang Li, meteorologist Kezhen Zhu and petrology expert Wenbo Weng. The program would even employ historians who would go on to examine thousands of ancient records to compile a detailed chronology and history of Chinese earthquakes:

> *"The seismologists of our country, with the cooperation of historians, systematically consolidated and studied the large bulk of historical seismological records. After several years of work they had investigated 2,600 historical writings and 5,600 local journals and 15,000 records concerning earthquakes, and provided us with an important set of data for the historical understanding of seismological activities in our country." (Zha, Z., 1976).*

A conference convened on 4th January 1970 established a precedent and the first National Conference on Earthquakes was held from January 17th to February 9th 1970 (Bo, Z., 2010). This would become an annual fixture that persists to the present day. While parts of the country were being patrolled by the Red Guards, the heroes of the earthquake program were enjoying the splendor of State hospitality at a 24-day conference!

The growing numbers and activities of the earthquake program required a new organization and, in 1971, the State Seismological Bureau (SSB) was formed within the Chinese Academy of Sciences (CAS).

It is time to meet two more of the main characters in our story. The first is Zhiyuan Zha who is one of the most intriguing, controversial and tragic characters. Mr Zha would rise to become a Deputy Director of the SSB, but, in the wake of the Tangshan catastrophe and the failure of the SSB to provide any forewarning to the public, the blame would fall on Mr Zha's shoulders. Still alive, he lives a reclusive life in Beijing.

The main sources of information we have for Mr Zha is his unpublished book (Zha, Z., 2009) dated 2009 and the transcript of an interview he gave in 2014 to the Science Network Blog (Zha, Z., 2014). The book provides some personal background but focuses mainly on summarizing three reports published by the SSB. These reports (all in Chinese) summarise the technical details of precursor anomalies observed prior to the Haicheng (1975), Tangshan (1976) and Songpan (1976) earthquakes. Mr Zha's book is bound in a blue cover and we simply refer to it as The Blue Book. We had the book translated to English by students at SUSTech in Shenzhen, where the Chair of Entrepreneurial Risks (ETH Zurich) has a flagship collaboration. Our English translation of the title is: "*Using precursors and the people to predict large earthquakes in China in the 1970s".*

> *"In the summer of 1971, Mr Zha was Deputy Director of the Revolutionary Committee of the Institute of Geophysics of the Chinese Academy of Sciences, and was responsible for the scientific research of the institute." (Zha, Z., 2009).*

This establishes Mr Zha's political credentials but there may also be a dark side to this political activity since, in his memoirs, Chengmin Wang refers to Zhiyuan Zha as the leader of the Rebel Group. Chengmin Wang has low regard for Zhiyuan Zha's technical abilities that later in the story may have interfered with their ability to work together.