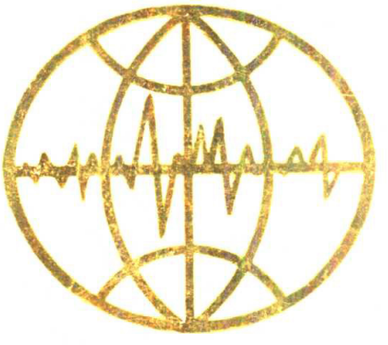

INTRODUCTION TO EARTHQUAKE PREDICTION IN CHINA

中国地震预报概论

梅世蓉　冯德益　等著

地震出版社

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梅世蓉　冯德益
张国民　朱岳清　高旭　张肇诚　著

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内 容 提 要

本书是我国20多年来地震预测工作的科学总结，全书共分5篇35章。书中叙述了我国地震活动特点与地震预测工作特点、思路及工作体制；系统阐述了现行9个学科预测地震的理论基础、观测系统、干扰排除、异常识别、前兆特征、预报方法与效能评价；综合论述了我国地震前兆的基本特征，并对其可能的机制进行了探讨；本书还介绍了地震前兆观测数据的处理与分析方法；全面、系统地论述了各类地震预报方法，包括地震预报的数学方法、物理方法、系统科学方法、经验预报方法及地震预报的计算机系统（专家系统）等。

本书适合于多方面读者的不同需要，无论是地震分析预报人员、地震理论研究者或地震管理工作者、有关大专院校师生，均可从本书读到他们关心的内容。同时也可供地球物理学、地球动力学、工程地震学等有关学科科技人员参考。

中国地震预报概论

梅世蓉　冯德益 等　著

责任编辑：姚家榴

责任校对：王花芝

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序

1966年3月，邢台地震造成解放后第一次大的自然灾害。周总理亲临地震现场慰问，并对我们做了重要指示。中国是多震的国家。自古以来，震灾的记载不绝于书，遗憾的是关于震灾的描述多，关于抗灾、防灾的措施少。一旦大震降临，只有束手待毙，认为这是天命，不可抗拒。远的如1556年陕西华州地震，近的如1920年宁夏海原地震，死伤都是几十万人。此次邢台地震，伤亡也是同样规模。1970年国家地震局成立了，统一领导全国的震灾预测预防工作。本书就是二十多年来我国地震预测工作的科学总结。从中可见到海城地震的成功经验，松潘地震的半成功经验及唐山地震漏报教训。这说明我们离科学预测的目标还有不小距离。不过，现在我们从对地震的来龙去脉无迹可寻状态已前进了一大步。这本书并不企图提供一册预测指南，而是二十几年的工作实录及体会。希望能揭露一些优缺点，并探索出一条最有利的前进方向。

地震预测是百年来尚未解决的科学难题之一。中外虽都有些预测成功的例子，但是都免不了偶然因素，没有取得可信的科学依据。因此不断有人提出，地震预报究竟是否可能的问题。从逻辑上讲，这个问题现在难下结论，不过预测地震是一个造福人类的崇高事业，既然还没有理由说预测不可能，为什么不能作为一个奋斗目标而坚持下去呢？这是一个信念问题，不是必须先有事实证明，然后去做的问题。身为20世纪的科学家，特别是地学家，解决地震预测之谜，人人都有道义上的责任！对经历过或看过大地震所造成的人间悲剧的人，这种提法是不过分的。

地震预测必须根据某种前兆。前兆不外来自三方面：地震台的记录、地面上所显示的异常现象，或由某种产生地震的前兆模式所预期的可能前兆。人们一提到预测地震，首先就会想到地震图里去找信息。然而，必须注意地震波是地震发生之后的产物，如果地震图上有什么信息，那只能是关于后来的地震，而不是本次地震的前兆。测震学的方法是很有用的，但是不应忘记它们的局限性。

地震前，地面上可能发现的现象千差万别，不见得都和地震有关系，何况所认为的异常也未必是真的异常，不过平时不注意而已。为了确认一种异常是否是地震前兆，应当先进行一定程度的对比。这是重要的一步，否则要造成虚报。在30年代，日本学者今村明恒写过一本理论地震学，上面列举了不少地震前兆。本书所列方法中的一小部分那里也提到过，不过不及本书丰富。时过半个多世纪，我们仍然未发现一种前兆可以和地震的发生有确定的关系，即是说，震前地面上的异常现象可能有多种解释，未必是由于地震，我们用作地震先驱的前兆，单独来说其可靠性是不高的，然而若将各种前兆综合起来判断，可靠性会有所提高。

根据地震孕育模式而预测前兆的性质和发生的顺序，最典型的例子是美国的岩石膨胀和流体扩散模式和苏联的雪崩-裂隙不稳定模式，但这两个模式都存在着一定的局限性。可以说，当代震源物理最主要的根据是断层成因说。然而，这个学说的作用却被大大地夸大了。几乎全部理论地震学都建立在断层成因的基础上，从而使我们的眼界大受束缚。其实，有不少现象是断层成因说所难以解释的，何况真正伴随着成因断层的大地震是不多的。即使如

此，那些大断层是否起了成因断层的作用，抑或是伴生的，也还可以争论。我们认为，地震是地球发展的结果。在地球发展的过程中，既产生了地震，也产生了断层，后者也是结果之一。大地震可以与大断层伴生，也可以不伴生。日本松代地震群震了好几年，也没有震出一个大地震来，这就是明证。我们应从地球发展的观点去寻找可能的前兆，不必拘泥于寻找活断层，这样我们的视野就大大扩大了。

地震学在一个世纪以来由两方面发展：一是以地震波为主导，已经形成一门成熟的应用科学；另一方面则是以研究天然地震为目标，发展则相形见拙。虽然由弹性回跳到震源物理是一个很大的进步，但地震成因核心思想仍然是由断层成因出发。地震预测的思想一直是沿着几十年的老路，未曾有所突破，推究其原因，似应对地震形成的基本概念进行反思。

地震不是一个孤立的事件，震源区也不是一个封闭的系统，它与区外的介质随时都可有能量或物质交换。地震时或地震前，这种交换就可以产生各种固体地球与大气耦合的界面现象：物理的、化学的、生物的都可能发生。在海城地震时，各种地-空耦合的现象曾发生过。其实，若将震源的形成不限于局部地区的岩体的错动，而是广大的地下，则大面积活动的岩石层可作为地震的信息源。它们有些是直接的地震前兆，但也有些是经过与周围物质或大气耦合而产生的，不过源出于地下，有些气象前兆就是如此。另一值得一提的现象是我国地震预测时常进行会商。在会商时，并没有发现可令人信服的前兆，但却使人有地震将要来临的危机感。作为中、长期的预测还有一定的命中率。这可以叫作"地震气候"。对于短期预测这是不能用的，但对于中长期预测，却值得做为参考。分析这种"地震气候"的原因，可能是：（1）对所用的前兆认识模糊；（2）前兆本身是由多种不显著的作用协同组成的，这个问题似乎值得进一步研究。

本书选用资料丰富，有思路，有方法，条理清晰，分析全面，是当前这方面最完备的一部专著。几位著者都是预测第一线工作的专家。本书将成为地震预测工作者必读的参考。但纵观全书，似嫌经典性太强，仍有未能摆脱老框框的痕迹。本文所提的一些不成熟的看法，仅供参考。

傅承义

Preface

In March 1966 the occurrence of the Xingtai earthquake wrought the greatest natural calamity since liberation. The late premier Zhou Enlai went himself promptly to the earthquake stricken area to console the people and gave important directive. China is a nation frequented by earthquakes and there are never interrupted records of earthquake calamities in the Chinese history; but it is a pity that there are chiefly descriptions of earthquake calamities, but few descriptions of measures against such disasters. Once a great earthquake occurs people have to wait to die;taking it as God's will and irresistible; for instance the earthquake of 1556 in Huazhou, Shaanxi in the remote past or the recent earthquake of 1920 in Haiyuan,Ningxia all caused casualties of tens of thousands. Now,this Xingtai earthquake also caused casualties of similar scale. Of such lessons of blood, it is a pity that our predecessors left no scientific record for the reference of their decendants. In 1970 the State Seismological Bureau(SSB) was established to conduct and coordinate unified earthquake prediction and preparedness work of the whole country against such natural disasters. This book is a scientific summary of earthquake prediction work in China in the past twenty years. From this book one can see the success of prediction of the 1975 Haicheng earthquake, the experience of the semi-success of prediction of the Songpan earthquake and the lessons of non-prediction of the 1976 Tangshan earthquake. All this shows that we are far short of the goal of making scientific prediction of earthquakes. Yet we have made a great step forward from a state of ignorance, not knowing the ins and outs of earthquakes. This book is not attempting to provide a guide book for making earthquake prediction, but is a summary of the records and experiences of that twenty years. In this book it is hoped that strong points and weaknesses can be revealed and a favorable path can be found to advance forward.

Earthquake prediction has been one of the difficult problems science has not solved in the past hundred years. There have been some examples of success in the prediction of earthquakes but all are not stained with the factor of chance and cannot be reliable scientific evidence. Therefore it is continually questioned whether earthquakes are really predictable. Logically, this problem hasnt got any definite answer at present. But the prediction of earthquakes is a noble undertaking benificial to mankind;why not take it as the object of continued struggle in the abscence of any proof that earthquake prediction is impossible? That is a problem of faith, and one that needs a practical proof before doing. As scientists in the twentieth century, particularly geo-scientists, every one is morally responsible! To those who have experienced or even witnessed such worldly tragedy wrought by earthquakes, this statement is not too much.

Earthquake prediction must be based on some kind of precursors, which usually come from not beyond three sources: the seismograms recorded at seismic stations;anomalous phenomena appearing on earth surface;or the precursors from expected certain models

of seismology. Whenever people think of earthquake prediction, they first think of searching for information from seismograms. But, one must notice that seismic waves are products that are produced by and generated after the occurrence of an earthquake. If there is any information on the seismogram, that must concern with earthquakes that will occur later, but is not the precursor for the present earthquake. Methods of earthquake prediction by seismometrical information are very useful, but one should not forget their limitations.

There is a mulitude of diversified phenomena appearing on the earth surface; some may not be related to earthquakes; not to say that the phenomena we recognize as anomalies may not be true anomalies, only because they have not been noticed before. To distinguish whether an anomaly is really an earthquake precursor, comparative study of some kinds must be made. This is an important step, otherwise false alarms may be made. The Japanese seismologist, Akitsune Imamura wrote a book on theoretical seismology in the 1930s, in which he enumerated many earthquake precursors. Some of the methods mentioned in this book also appeared in Imamura's book. But the precursors described in this book are more rich and varied. Since Imamura to the present more than a half century has passed we have not yet found any precursor that is definitely connected with earthquakes. This is to say that the anomalous phenomena appearing on the earth surface before an earthquake can be explained by many causes and may not be caused by an earthquake. The precursor we take as the forerunner of an earthquake, if taken as an individual phenomenon, is not of high reliability. But if a decision is made by taking comprehensively many kinds of precursors together, the reliability may be higher.

The most typical example of expected property of precursors and their occurrence sequence according to the model of seismogeny is the American DD model and the Russian IPE model. But these two models all have their limitations. It may be said that the basis of contemporary source physics is that of cause by faulting. But the effects of the theory is greatly exaggerated. Almost the entire theory of seismology is based on cause by faulting. Consequently our field of vision is greatly limited. Actually there are many phenomena that cannot be explained by the fault-origin of earthquakes; not to say that earthquakes which accompany causative faults are not many. Even so, it can still be disputed that whether these large faults are really the cause of occurrence of earthquakes or whether they merely accompany the occurrence of earthquakes. We believe that earthquakes are the results of development in the earth. During such development both earthquakes and faults are produced; the latter being merely one of the results. Great earthquakes may be companied by large faults, but also may not. The earthquake swarm of Matsuchiro, Japan had trembled for many years, but no great earthquake followed. This is the evidence. We should try to find possible precursors from the view point of development inside the earth, but not be limited to the search for active faults. If so, our field of view may be greatly expanded.

During the past century seimology has been developing along two direction, one is seismic waves which has formed a mature applied science; the other is research on natural earthquakes, its development is still limited. Although it is a large step from the

theory of elastic rebound to the physics of seismic source, its cental idea of earthquake prediction still follows the old path which is tens of years old and there has been no breakthrough. The reason perhaps lies in the fact that we should reconsider the concept of seismogeny of earthquakes.

The earthquake is not an isolated phenomenon. The source area is not a closed system. Between the source and the medium around it there may be transference of energy and matter at any time. Such transference may produce various kinds of boundary phenomena of coupling between the solid earth and the atmosphere; physical, chemical, biological and other sorts of phenomena may be produced. During the Haicheng earthquake of 1975 and other earthquakes many kinds of phenomena due to earth-atmosphere coupling were produced. Actually, if we do not limit the formation of earthquake source to the displacement of rocks of a local region, but of a much wider underground region, then the crustal layer in a much larger active area may be the information source concerning the earthquake. Some of such phenomena may be direct precursors of the earthquake, but some are produced by the coupling with surrounding material or the atmosphere, with the initial source under the ground surface, such are the meteorological precursors.

Another thing worth mentioning is that, in China, a consultation conference is held before a formal prediction is made. Sometimes at the conference no convincing precursor is presented, yet there are indefinite ones that make people feel an imminent large earthquake is coming. Such feeling of danger may be termed "earthquake climate"; it cannot be used for short-term prediction; but has some reference value for making medium-long term predictions. Analyzing the cause of such "earthquake climate", it is possibly because: (1) we only have a fuzzy understanding of precursors; (2) precursors are the results of composition of many kinds of effects which themselves are not outstanding. This problem needs further study.

The book is based on rich material collected from all over China. The train of thought is clear; many prediction methods are enumerated; the presentation is clear; the analysis is comprehensive; the book is the most complete treatise at present. The authors are all experts working on the first line of earthquake prediction. This book will be an indispensible reference for all who work on earthquak prediction. But, on whole view of this book, the book seems to be a little scriptural, being not freed from the framework of old studies. The unmatured ideas in my essay are only for reference when the book is to be revised.

Fu Chengyi

前　言

中国地震预报的系统探索从邢台地震开始至今已有26年的历史。探索中不仅积累了大量资料，观测到许许多多地震前的异常现象，而且产生了不少新的预报思想和预报方法。运用这些方法于实践，有过成功，也有过不少失败，这说明我们的认识还存在着局限，乃至错误。为什么有些"前兆"在这个地震前明显，而在另一地震前又不明显呢？在震前异常现象中有无必震信息？如何判定？前兆与地震间究竟有何关系？地震预测中如何考虑这些关系？这些问题是值得研究的。

本书著者通过自己多年的预报实践，一方面发现大震前的确存在着一些普适性较强的地震前兆现象，诸如区域地震活动性的增强，并在增强背景上出现空区与地壳形变速率增加；大震前不久，在未来震中周围出现一些速率变化较快的异常现象等；另一方面又发现前兆存在着地区性，即不同地区，不同类型地震，其前兆的种类、变化幅度与时空分布显示出不甚相同的特征。普适性前兆的存在说明地震的孕育、发生存在着一个基本的物理过程，它控制着地震基本前兆的发生，前兆地区性则增加地震前兆的复杂性。然而，地震的基本物理过程是什么？如何控制基本前兆的发生？区域构造与区域应力场怎样影响地震前兆的发生与分布？显然，这些问题不解决，地震预报水平是难以提高的。

带着这些问题我们参加了1983—1987年的"地震前兆与地震预报方法的系统研究"及1987—1989年的"地震预报实用化方法研究"。从数十次震例资料的综合分析中，我们得到一些有关上述问题的答案，它们发表在有关的论文集中。近三年来，又进一步研究了各学科的成果，在更高层次上，对以上问题做了进一步的深究，本书就是深入研究结果的集中反映。撰写本书时，我们尝试将著者本人的研究结果与有关学科研究结果融合成一个有机的整体，将各学科前兆当作孕震过程中的不同侧面，将震源区作为非均匀介质中的应变能积累体，用场、源统一的观点去说明各类地震前兆的发生、发展，以及如何利用各类地震前兆进行地震预报的方法及前兆数据的处理与分析。在论述这些问题时始终贯彻理论联系实际的原则，避免单纯描述事实而不深究原因，并且尽量利用国内外的有关成果，对某些前兆特征的成因作了初步分析。

本书的全部资料取材于国内，两次攻关研究成果报告是资料的主要来源，同时也吸收了不少发表在各类学报、期刊、论文集中的文献。材料的选择本着少而精的原则，不求全但求精。一些典型震例资料都是经过清理攻关，反复核实，为大家所公认的；似是而非的则尽量删除。

全书包括五篇：

第一篇，绪论，概述我国地震活动概况和地震预报研究概况，邢台、海城、唐山、松潘大地震的考察与研究对地震工作的推动，80年代地震监测预报工作的进展，中国地震预报的思路、途径、特色与工作体制。

第二篇，地震前兆的观测与分析，分9个学科逐章进行了概述。对测震学前兆重点叙述地震空区、条带、b值、前震与诱发前震、震群与前兆震群、地震波波速异常、地震波动力学参数、品质因素与震源机制异常等。对于其他几个学科，则从理论基础、观测系统、干扰排

除及信息提取、异常识别，到前兆特征、预报方法与效能估计等方面进行了系统论述。第九章是大震前动物异常特征与机制。第十章是中强以上地震震例的综合分析。

第三篇，地震前兆特征与机理探讨，本篇将地震前兆的分学科研究与分震例总结研究相结合，并作了一次更高层次的分析与综合，是迄今为止最全面的有关我国地震前兆特征的认识。进而应用国内近10多年来开展的实验与理论研究成果，对上述特征形成机理进行了初步探讨，提出了一些有价值的看法，指出了存在的疑点与问题。

第四篇，地震预报方法论，包括了地震预报概率统计方法、地震预报的灰色系统理论方法、地震预报的模式识别方法、地震预报的物理方法与系统科学方法、地震预报的经验方法、地震预报的专家系统。该篇集中了我国20年来自己发展的或引进后发展的几乎所有预报方法，既讲原理，又讲方法和实例。

第五篇，论述地震前兆观测数据的处理，从数据分类评价、前兆数据的常规处理到前兆数据的数字滤波、谱分析等，从原则到具体实例进行了全面介绍。

本书著者都是自邢台地震以来长期从事地震预报工作的研究人员。他们亲自参加了两次攻关研究，且目前正投身于"八五"攻关研究之中，对地震预报的历史与现状都很了解。为写好本书查阅了大量文献、资料，对各章作了多次修改。

各位著者负责的篇章如下：梅世蓉：第一篇1—5章，第二篇1—9章，第三篇1—2章；冯德益：第四篇1—6章，8章；张国民：第三篇3—6章；朱岳清：第五篇1—5章；高旭：第一篇第6章，第四篇第7章；张肇诚：第二篇第10章。全书的编著思想、总体结构、各篇章的内容安排及总审均由梅世蓉负责。

虽然为了写好本书，著者竭尽了全力，但由于学识有限，且撰写一部综合性强、内容丰富的有关地震预报的书籍是一次全新的尝试，疏漏之处在所难免，真诚地期望广大读者批评指正。

梅世蓉

Foreword

It has been 26 years since systematic probing of earthquake prediction in China began after the Xingtai earthquake of 1966. Not only a great amount of observation data has been accumulated and many anomalous phenomena before earthquake has been observed but also many new ideas and methods of earthquake prediction have emerged. By applying such methods to practice, there have been succeses, and also many failures. This shows that our knowledge about earthquake is still limited or even erroneous. Why some "precursors" are very distinct before one earthquake but not distinct before other earthquake? What's the reason? Is there any certain indication before an earthquake? And how to distinguish it? What is the real connection between a precursor and an earthquake? How to deal with such problems before making an earthquake prediction? Such problems are worth further study.

The authors of this book through many years of earthquake prediction practic have found, that there are really universal earthquake precursors before large earthquakes, such as regional intensification of seismicity and, on the background of this intensification, a gap of seismicity and the acceleration of crustal strain rate may appear; and not long before the occurrence of the large quake there may appear some anomalies with rapid rate of change around the epicenter of the coming earthquake. Furthermore, we have found that precursors show regionality, that is, at different places and for different earthquakes, the kinds of precursors, the variation of their amplitude, their spatial and temporal distribution, exhibit not quite similar features. The existense of universal precursors shows that there is a fundamental physical process which controls the occurrence of fundamental earthquake precursors while the regionality of precursors adds to the complexity of earthquake precursors. But what is this fundamental physical process of earthquakes? How does it control the occurrence of earthquake precursors? How do regional tectonics and regional stress field influence the emergence and distribution of earthquake precursors? It is obvious that without the solution of such problems, the ability of earthquake prediction is difficult to be improved.

With these problems in mind we participated in the project of "systematic study of earthquake precursors and methods of earthquake prediction" of 1983—1987; and the project "study of pragmatization of earthquake prediction methods" of 1987—1989. From the comprehensive analysis of the material of dozens of earthquake cases we got some solutions of the above problems which have been published in relevant treatises and collected works. In the past three years we further studied the results in relevant disciplines and probed deeper. This book is a reflection of such studies. We have attempted to

combine the research of the respective authors and results in different disciplines into one organic entirety and take the various precursors as certain aspects of the seismogenic processes and take the source region as the body that accumulates strain energy in a non-homogeneous medium, using the view point of unity of field and source to explain the occurrence and development of various precursors,to analyze and process the precursory data, to use the various precursors for earthquake prediction. In the disscussion of such problems, we always stick to the principle of integrating theory with practice, refraining from purely describing the facts without asking the cause, trying in every way to use relevant research results at home and abroad to make a preliminary analysis of the causes of certain features of earthquake precursors.

The materials used in this book are takenmainly from the results of the above mentioned two organized study projects and absorbing ideas published in many academic periodicals or treatises. The materials are chosen according to the principle of concise but excellent, even at the risk of incompleteness, and are repeatedly cross-checked and universally accepted.

The book contains five parts:

Part one is an introduction which briefs the seismic activity and earthquake prediction in China;the investigation and study of the Xingtai,Haicheng,Tangshan and Songpan earthquakes which pushed the seismological work of China; the progress of earthquake monitoring and prediction work in China in the 1980s; the line of thought, the approaches, features and system of earthquake prediction.

Part two describes the observation and analysis of earthquake precursors according to the above mentioned disciplines. For precursors of the discipline of seismometry it stresses seismic gaps,seismic bands,the b-value,foreshocks and induced foreshocks,swarms and foreshock swarms, the anomalies of wave velocities. For precursors of other disciplines it stresses the corresponding observation systems, the elimination of disturbances, the retrieval of information,the recognition of anomalies,their respective features,the prediction methods and efficacy.Chapter 9 of part 2 briefs abnormal animal behavior and chapter 10 gives the comprehensive analysis of earthquakes of medium strong and over.

Part three discusses the features and mechanisms of earthquake precursors. It combines the study of precursors according to the different disciplines to which they belong and according to earthquakes cases; and make an analysis and synthesis with a higher standing. It represents at present our most comprehensive knowledge concerning earthquake precursors. By utilizing the experimental and theoretical results obtained during the past 10 years, it makes a preliminary discussion about the formation mechanism of features of precursors, putting forward valuable ideas besides pointing out some doubtful points and questions.

Part four is a discussion of the methodology of earthquake prediction. It contains sections on the probabilistic statistical method of earthquake prediction, the gray system

theory of earthquake prediction, the pattern recognition used in earthquake prediction, the physical methods and the systems sciences methods, the empirical method of prediction, and the expert system for earthquake prediction. This part concentrates on all the native methods developed in China and those first imported from abroad and then developed in China in the past 20 years. It discusses not only the principles but also gives the methods with examples.

The fifth part depicts the processing of precursor observation data, from the classification and assessment of data, the conventional methods of precursor data processing, to the method of digital filtering, spectral analysis etc. It makes a comprehensive discussion of the principles and also some concrete earthquake cases.

All the authors of this book have been working on earthquake prediction since the Xingtai earthquake; have participated in the two research projects; and are now taking part in the Eighth Five-Year-Plan project of tackling the key problems of earthquake prediction. They all have a clear understanding of the history and the present situation of earthquake prediction. For the writing of this book they have consulted large amounts of materials and literature and they have made revisions of manusripts of the book many times.

The authors have separately written the chapters as follows:

Mei Shirong: chapters 1—5 of part one, chapters 1—9 of part two, and chapters 1—2 of part three;

Feng Deyi: chapters 1—6 and 8 of part four;

Zhang Guomin: chapters 3—6 of part three;

Zhu Yueqing: chapters 1—5 of part five;

Gao Xu: chapter 6 of part one and chapter 7 of part four;

Zhang Zhaocheng: chapter 10 of part two.

The idea of writing, the overall structure and the substances of each chapter of the book are all designed and arranged by Mei Shirong. She also shouldered the final go over of the complete manuscript of this book.

The authors have done their best in the preparation of the manuscript of the book. But because of the limitedness of their learning and experience, in the writing of such a comprehensive book of substantial content about earthquake prediction is a new challenge, omissions or errors are hard to avoid. The authors sincerely welcome comments and criticisms from the readers.

Mei Shirong

目　录

第一篇　绪　论

第一章　地震活动与预报研究概况……（1）
§1.1　地震活动概况……（1）
§1.2　古代至解放前的研究简况……（3）
§1.3　解放后至邢台地震前的工作……（5）
§1.4　邢台地震后的20年……（7）
§1.5　近五年的工作发展……（9）
第二章　几次大地震的研究意义与价值……（10）
§2.1　邢台地震预报研究的开创性……（10）
§2.2　海城地震预报工作的指导意义……（10）
§2.3　唐山地震的科学价值……（12）
§2.4　松潘地震的经验与教训……（15）
第三章　80年代地震预测预报研究工作的进展……（17）
§3.1　地震观测仪器的改善……（17）
§3.2　地震前兆观测台网的优化……（18）
§3.3　干扰因素的识别与排除……（18）
§3.4　地震预报方法指南的编制……（19）
§3.5　地震综合预报的确立……（19）
§3.6　地震短临预报新方法的探索……（20）
§3.7　系统科学在地震预报中的应用……（21）
第四章　地震区划工作概况……（22）
§4.1　1957年的中国地震烈度区划图……（22）
§4.2　1977年的中国地震烈度区划图……（23）
§4.3　1990年的中国地震危险性区划图……（24）
§4.4　中国地震灾害损失预测图……（25）
§4.5　5—10年地震危险区划图……（25）
第五章　中国地震预报的特点与途径……（27）
§5.1　基本认识与基本思想……（27）
§5.2　地震预报的途径与方法……（28）
§5.3　地震预报的程序……（35）
§5.4　地震综合预报……（36）
第六章　中国地震预报的工作体制……（39）
§6.1　预报工作体制的建立与发展……（39）

§6.2 现行的地震预报工作体制……(40)
参考文献……(42)

第二篇 地震前兆的观测与分析

引论……(44)
第一章 测震学前兆……(49)
§1.1 概述……(49)
§1.2 地震空区……(49)
§1.3 地震条带……(57)
§1.4 b 值时空扫描……(65)
§1.5 前震与诱发前震……(69)
§1.6 震群与前兆震群……(74)
§1.7 地震波速度异常……(78)
§1.8 地震波动力学特性异常……(81)
§1.9 震源参数及品质因子变化……(86)
§1.10 较大地震前的震源机制变化……(91)
第二章 地震地形变前兆……(96)
§2.1 地壳形变异常产生的物理基础……(96)
§2.2 大地形变的观测系统与分析方法……(97)
§2.3 大地形变的干扰排除与异常识别……(101)
§2.4 几个大地震前的地壳形变异常特征……(103)
§2.5 震前地形变特征与地震预报……(111)
第三章 地震地倾斜前兆……(115)
§3.1 地震地倾斜前兆的观测系统……(115)
§3.2 地倾斜异常的分析方法……(117)
§3.3 地倾斜短时异常分类与特征……(120)
§3.4 地震地倾斜前兆的实例……(123)
§3.5 地震地倾斜前兆阶段特征……(124)
§3.6 异常判定与地震三要素预测……(126)
第四章 地震重力前兆……(128)
§4.1 重力方法预报地震的理论依据……(128)
§4.2 地震重力前兆的观测系统……(129)
§4.3 地震重力前兆信息的提取……(131)
§4.4 唐山地震前后的重力变化……(131)
§4.5 重力方法预报地震的依据与效能……(133)
第五章 地震地磁前兆……(135)
§5.1 孕震区震磁异常的物理基础……(135)
§5.2 震磁前兆信息的提取……(137)
§5.3 震磁信息的观测系统……(138)

§5.4 1976年唐山地震前的震磁信息……(139)
§5.5 地震地磁前兆特征与预报……(141)
第六章 地震地电阻率前兆……(144)
§6.1 地电阻率法的理论依据……(144)
§6.2 地电阻率法的实验依据……(147)
§6.3 地震地电阻率前兆的观测与分析……(148)
§6.4 地震地电阻率前兆的主要特征……(150)
§6.5 地电阻率预测地震三要素的方法……(157)
第七章 地震地下水动态异常……(160)
§7.1 地震地下水动态异常的理论基础……(160)
§7.2 地震地下水动态变化的观测与分析……(161)
§7.3 地震地下水动态异常的基本特征……(168)
§7.4 地震地下水动态异常预测地震的依据……(172)
§7.5 地下水动态预报地震的方法……(173)
第八章 地震水文地球化学前兆……(175)
§8.1 地震水文地球化学前兆的理论基础……(175)
§8.2 地震水化前兆的观测……(177)
§8.3 地震水化前兆干扰因素的排除……(180)
§8.4 地震水化前兆的特征……(181)
§8.5 水化前兆预报地震的指标与方法……(189)
第九章 地震前动物异常的特点与机制……(193)
§9.1 震前动物异常的特点……(193)
§9.2 震前动物异常的原因……(197)
§9.3 动物非震行为异常与震前行为异常的区别……(200)
§9.4 动物异常的观察分析……(202)
§9.5 震前某些动物异常的机制……(203)
第十章 中强以上震例的综合分析……(211)
§10.1 7级以上地震的典型震例……(212)
§10.2 中强地震（5.0—6.9级）的典型震例……(220)
§10.3 60次震例前兆异常的统计分析……(228)
参考文献……(236)

第三篇 地震前兆特征与机理探讨

第一章 地震前兆的规则性与复杂性……(241)
§1.1 地震前兆的普遍性与多样性……(241)
§1.2 地震前兆的持续性与阶段性……(244)
§1.3 地震前兆空间分布的集中性与非均匀性……(246)
§1.4 趋势异常的稳定性与短临前兆的多变性……(248)
§1.5 地震前兆的时空转移性……(250)

§1.6 前兆异常特征量与震级、震中距的关联性……(256)
§1.7 短临前兆与外因的相关性……(257)
§1.8 地震前兆的统一性与多源性……(258)
§1.9 异常与地震关系的不确定问题……(259)
§1.10 不同地区和不同类型地震前兆的差异……(260)
§1.11 短间隔地震前兆的不重复现象……(261)
§1.12 地震前兆与后效的难以分辨问题……(262)
第二章 地震前兆共性与复杂性的成因分析……(264)
§2.1 岩石变形的阶段性与地震前兆的阶段性……(265)
§2.2 岩石变形、破裂的分区性与地震前兆的空间分布……(269)
§2.3 岩石变形的局部化与近源区地震前兆场的变化……(272)
§2.4 外因对震源过程的作用……(281)
第三章 地震活动时间特征的力学成因……(292)
§3.1 地震活动的轮回性……(292)
§3.2 地震活动的周期性与震前的增强活动……(295)
§3.3 强震活动的指数型分布……(296)
第四章 岩石的流变特征及中长期前兆机理……(302)
§4.1 应用流变理论的必要性……(302)
§4.2 流变模型与应力、应变、能量的时间变化……(302)
§4.3 对孕震过程中地震前兆的讨论……(305)
第五章 地震短临前兆的物理机制……(308)
§5.1 地震短临前兆的几种可能机制……(308)
§5.2 走滑型地震前断面位错的加速运动……(309)
§5.3 岩体失稳准则与地震的发生……(314)
第六章 岩石破坏的两种机制与两类地震的对比……(321)
§6.1 完整岩石的破裂……(321)
§6.2 含有断裂面岩石的粘滑……(322)
§6.3 地震前兆地区差异性分析……(323)
参考文献……(325)

第四篇 地震预报方法论

第一章 地震预报的概率统计方法……(328)
§1.1 综合概率方法……(330)
§1.2 时间序列分析预测方法……(333)
§1.3 地震发生的随机分布模型与相应的预报方法……(336)
§1.4 地震发生的随机过程模型与相应的预报方法……(340)
§1.5 地震间隔的统计分布模型与相应的预报方法……(344)
第二章 地震预报的模糊数学方法……(350)
§2.1 地震预报的模糊模式识别方法……(351)