GROUNDWATER RESOURCES AND THE RELATED ENVIRON-HYDROGEOLOGIC PROBLEMS IN CHINA

MENGXIONG CHEN ZUHUANG CAI

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FOREWORD

This collection of papers in English is a result of rearrangement, revision, complement and edition of papers published in proceedings of international symposia or in periodicals abroad written by professor Mengxiong Chen and his cooperators since 1980s. Although each paper is independent, there exists close relationship among these papers, which form a system and a rather unified entirety. It reflects concisely the process of development of hydrogeology in China, the basic features of regional hydrogeology in the whole nation, the regularities of distribution of groundwater resources, and the main environ-hydrogeologic problems due to development and utilization of water resources.

Besides, these papers focus their discussion on the risk existing in the development of urban water resources, advance a new concept of environmental effects system of groundwater, as well as related countermeasures to mitigate shortage of urban water resources. There are altogether 14 papers in the collection, among them 5 papers deal with investigation on groundwater system in arid and semi-arid regions. Especially the serious influences on eco-environmental system are discussed thoroughly in development and utilization of water resouces of the Gobi and desert regions in Northwest China.

Among the 14 papers, 6 papers are written by professor Mengxiong Chen and his cooperators. In them 3 papers are written in cooperation with Mr. Zuhuang Cai, senior research professor at Institute of Geololgy, Chinese Academy of Sciences. Mr. Zuhuang Cai has been cooperating for a long time with professor Mengxiong Chen in groundwater research, and is one of the two chief editors of this collection. Other hydrogeologists taking part in cooperaton are: Mr. Zhirong Xu, vice-chief engineer in previous Henan Bureau of Geology and Mineral Resources; Ms. Shuqin Jiao, senior research professor at Institute of Hydrogeology and Engineering Geology in Zhengding; and Ms. Aisong Deng, senior engineer in previous Management Section of Geologic Environment of the Ministry of Geolgy and Mineral Resources. All of them made important contribution to related papers.

This collection of papers, systematically introducing groundwater resources and related environ-hydrogeologic problems, is known as the first book in English in China. Particularly, many new viewpoints and new concepts about rational development and utilization of groundwater resources are advanced using the theory of groundwater system and the method of systematic analysis. The great majority of papers in this collection hasn't been published in Chinese at home.

The content of this collection is of value to the colleagues at home and abroad for reference. Especially the colleagues abroad could understand the historical development of hydrogeology, the general situation of regional hydrogeology and groundwater resources, as well as the current situation and existing problems in the development and utilization of groundwater resources in China.

1. The history of hydrogeology in China in recent 50 years is divided into two stages and five periods according to the development of its branches of learning. The former stage (1950s—1970s) is called the stage of traditional hydrogeology , the latter (1970s—1990s)—the stage of current hydrogeology.

2. The main achievements and main experience in general hydrogeologic survey and hydrogeologic mapping in China are summarized concisely and systematically. They include the basic characteristics of regional hydrogeology, the regional regularities of distribution of groundwater resources, the present situation of groundwater development and utilization, and existing environ-hydrogeologic problems in China.

3. The problem of urban water pollution, the negative environmental effects caused by groundwater resources development such as exhaustion of water resources, land subsidence, seawater intrusion, etc are explored with emphasis. The trend of their future development is predicted preliminarily. The groundwater management system based on groundwater environmental effects system is advanced.

4. The aquifer system in Yellow River alluvial plain, especially shallow water system is analyzed thoroughly using the viewpoint of groundwater system. A set of concrete methods for detailed division and detailed description of aquifer system is established. The main ways of controlling an optimal groundwater level for rational utilization of groundwater resources and comprehensive remedy of natural disaster are advanced on the basis of case study in Shangqiu area.

5. The basic characteristics of water resources in arid region in Northwest China are analyzed thoroughly. A hydrologic system of the whole river basin with combination of surface water system and groundwater system is established according to the peculiarity of mutual transformation of surface water and groundwater. A new concept of Quaternary basin system is advanced, and a conceptual model of water resources system of the whole river basin is founded on the basis of this new concept. The detailed studies are carried out on the complicated relationship of mutual restriction and mutual influence of hydrologic system, irrigation system and eco-environmental system under the influence of human activities. Especially the process of evolution of eco-environmental system from oasis area to desert is studied in detail under the condition of serious variation of hydrologic and irrigation systems.

6. The geologic disaster and environ-hydrogeologic problems caused by mine development are studied thoroughly. In particular, serious economic damage is caused by karst collapse and water inrush into gallery, frequently occurred in karst mine area. The mechanism of formation and measures for remedy of above-stated geologic disaster are explored in one of the papers.

To sum up, this book is characterized by substantial content, rather wide range of technologies and a rather great quantity of original ideas. In particular, a lot of new viewpoints and new concepts are advanced using the theory of groundwater system and the method of systematic analysis.

These new viewpoints and concepts are of great significance not only theoretically, but also in practical application. This book as the first one in China in English, systematically introducing hydrogeology in our country, is of great value for reference to the colleagues at home and abroad. Especially, it will play an important role in promotion of international academic exchanges. At the time of its publication I am very pleased to make above-stated introduction and wish to extend my cordial greetings to the authors of this book.

Lin Xueyu
Member of Chinese Academy of Sciences
Professor of Changchun University of Science and Technology and Beijing Normal University

PREFACE

Since our country puts into effect the policy of reform and opening, the national economy has been developing rapidly. The contradictions between economic development and environment are becoming increasingly acute under the dual influence of natural factors and human activities. Especially with the continuous growth of population and the rapid development of urban constructions and industries, the demand on water resources grows with each passing day. The contradiction between water supply and demand and related environ-hydrogeologic problems are becoming more serious day by day. Facing the challenge of the new century, for the sake of the sustainable development of the national economy, how to coordinate the relationship between mankind and environment, exploit and utilize water resources rationally, protect and ameliorate eco-environment, has become an important task of hydrogeologists.

As an independent branch of learning in geologic sciences, hydrogeololgy began to be established in 1950s after the foundation of new China. It is one of the youngest branches of learning in geologic sciences in China. So the development of hydrogeology in our country is synchronous with the construction of new China. Professor Mengxiong Chen, the main author of this book, is one of geologists who first engaged in hydrogeologic work and one of founders of hydrogeologic undertaking in China. In the early 1950s, as vice-general engineer of the Bureau of Hydrogeology and Engineering Geology of the Ministry of Geology, he was in charge of nation-wide scientific and technical work of hydrogeology, exercised leadership in nation-wide general survey of regional hydrogeology and hydrogeologic prospecting for urban water supply, irrigation, etc over a long period of time, and has accumulated a wealth of practical experience. Since the 1980s he began to devote himself to research on groundwater resources and environ-hydrogeologic problems. This collection of papers is systematically selected and edited from his papers in English, published in recent ten and more years.

Mr. Zuhuang Cai, the second author of this book, graduated from Leningrad Mining Institute in previous Soviet Union in 1958. As a senior research fellow at the Institute of Geology, Chinese Academy of Sciences, he engaged in hydrogeologic research for a long time. His research fields include mainly environmental hydrogeology, seismologic hydrogeology, isotopic hydrogeology, etc. His study on seawater intrusion, in particular, is of rather large attainments. Since the 1980s, he has been becoming one of important cooperators of professor Mengxiong Chen.

This book is the first one in China in English, rather systematically introducing groundwater resources and related environ-hydrogeologic problems in our country. There are 14 papers in this collection. All of them are related to each other, forming an entirety. The content includes mainly six aspects listed below.

CONTENTS

A Historical Review of the Development of Hydrogeologic Science in New China*

Introduction

Knowledge on the development and utilization of groundwater had a long history in ancient China. The oldest well discovered was built before 5700 years. As early as 2000 years ago, the "karez" known as "kanr-well" for irrigation in desert area and the exploitation of deep brine-wells for salt mines in the Sichuan red bed basin are well-known in the world. A great deal of information about springs may be found in various encyclopedic and geographic writings. A good description of the springs occurs in the early 6th century in the book entitled Records of Strangs Things.

However, the use of geologic science for studying underground water began only in the 1920s to the 1930s of this century. Prof. T. H. Chu (Tinghu Zhu)and Prof. C. Y. Xie (Jiarong Xie) were the earliest geologists to have made geologic investigations for groundwater in Central China and the Nanjing district of Jiangsu Province. Both of them had studied geology in the U. S. A.

Hydrogeology as a branch of geologic science was actually initiated and established in the 1950s after the founding of new China. The hydrogeologic science gained great progress in line with the rapid development of economic construction. According to the changes of the main aspects five periods may be discerned during the past 50 years: (1) the period of regional hydrogeology of the 1950s, (2) the period of agricultural hydrogeology of the 1960s, (3) the period of environmental hydrogeology of the 1970s, (4) the period of quantitative hydrogeology of the 1980s, and (5) the period of information hydrogeology of the 1990s. In the early stage, the new idea of modern hydrogeology was introduced to China from the Soviet Union, while in the later stage international exchange has become common, especially the cooperation with western countries has caused rapid advancement of the hydrogeologic science in China. This paper intends to give a brief account of the major events and main aspects of the development of hydrogeologic science in the different periods.

The First Period of the 1950s——Period of Regional Hydrogeology

This is the period of initiation of modern hydrogeology. This period was characterized by setting up of new organizations and beginning of nation-wide regional hydrogeologic surveying and mapping all over the country. The Bureau of Hydrogeology and En-

* Interchange of Geoscience Ideas between the East and the West

Proceedings of the XVth International Symposium of INHIGEO, 227-234.

The original topic is: The Four Periods of Development of the Hydrogeological Science in New China.

gineering Geology was set up under the Ministry of Geology in 1955, which was responsible for the investigation and research work of groundwater resources of the whole country. It cooperated with related sections of water conservancy and urban reconstruction or industrial sectors in groundwater exploitation for agriculture and industry. All the provincial bureaus set up their own hydrogeology teams to undertake their tasks. To coordinate the prospecting works, three research units were set up, including the Institute of Hydrogeololgy and Engineering Geology in Zhengding(1956), the Institute of Technology and Methodology in Hydrogeology and Engineering Geology in Baoding (1960), both in Hebei Province, and the Institute of Karst Geology in Guilin, Guangxi Zhuang Autonomous Region (1970s). These units are principally engaged in scientific research. In respect of education, all the five geologic colleges have department of hydrogeology and engineering geology to train specialists in that field.

During this period, many Soviet experts visited China as part of intergovernmental cooperation. Therefore basic conceptions or theories, standards or regulations and methodologies for hydrogeologic investigation were introduced or originated from the Soviet Union. The earliest hydrogeologic expert working in the Ministry of Geology was Prof. Losanov in 1954. The progamme of the nation-wide hydrogeologic mapping was mainly formulated under his instruction. A hydrogeologic map of China in the scale of 1 :3,000,000 was compiled and published in 1958, which is the first hydrogeologic map in China. The nation-wide hydrogeologic mapping had promoted the development of regional hydrogeology. A lot of articles or monographs were published, such as The Regional Hydrogeology of China published by the Geological Publishing House in 1958.

Dr. Agabyev, another Soviet hydrogeologist, stayed in China from 1956 – 1960 for nearly 5 years, the longest among Soviet experts. He had visited many places covering almost the whole country. Many prospecting projects mainly concerned with urban water supply and hydrogeologic investigation of mining area were accomplished under his instructions. Dr. P. P. Klimentov was one of the most prominent professors in the Department of Hydrogeology of Changchun College of Geology. Many research students finished their degree thesis under his supervision. During that time, he wrote many textbooks which were translated and published in Chinese, such as The General Hydrogeology, Hydrogeologic Survey and Prospecting, Dynamics of Groundwater and Mining Hydrogeology, all published in the mid-fifties. Basic hydrogeologic theories or new conceptions were introduced from the Soviet scholars and deeply influenced Chinese hydrogeologists, such as O. K. Lange and B. L. Lichikov on the theory of regional hydrogeologic zoning, G. H. Kamensky on the dynamics of groundwater, D. B. Lairokov on the rules of development of karst, H. A. Plotnikov on the evaluation and classification of groundwater resources, A. B. Lebediev on the variation of groundwater regime, A. M. Ovchinikov on the mineral water, etc. In short, the contributions of the Soviet experts were the primary factor in the foundation of the hydrogeologic science in China.

The Second Period of the 1960s——Period of Agricultural Hydrogeology

In the early 1960s, North China suffered a bad drought which lasted for several years. In order to overcome the drought, the main task turned from regional hydrogeology to agricultural hydrogeology including reclamation hydrogeology for developing well-irrigation. Much specialized prospecting works had been accomplished for the exploitation of groundwater and the improvement of saline soil as well as the control of swamps, especially in North China. Experiences also were accumulated in water exploration in mountainous regions and pasture lands. A great number of hydrogeologic maps in the scale of 1:50,000 – 1:100,000 were completed for agricultural water supply or other purposes, which provided a scientific basis for the rational arrangement of groundwater use. In order to meet the needs of agriculture, small scale maps of large areas, such as the hydrogeologic map series of Huang-Huai-Hai Plain and Songliao Plain (1:1,000,000) were compiled and published in the early 1960s on the basis of reconnaissance survey. This was the first group of small scale map series published in China.

As a result, 170 million mu (1mu = 0.06667 ha) of arable land were irrigated with water from wells, and the annual exploitation of underground water has reached 40 billion m^3. In Hebei Province, more than 400,000 irrigation wells have been drilled with an annual exploitation of about 10 billion m^3, for more than 30 million mu irrigation. These areas had witnessed bumper harvests for many years and consequently had become self-sufficient in cereal products. Thus this decade may be called the period of agricultural hydrogeology owing to the great achievement in this respest. In 1965, the first national conference on hydrogeology and engineering geology was held in Beijing, and the Hydrogeology and Engineering Geology Committee was establisted under the Geological Society of China. However, the normal work and many projects were interrupted in the 10 years′ disturbance beginning in 1966.

The Third Period of the 1970s——
Period of Environmental Hydrogeology

During this period, environmental hydrogeology became the main task to meet the needs of the rapid development of urban construction. Enormous investigation works had been undertaken to facilitate water supply in large and medium-sized cities and industrial bases. Many important cities, including Beijing, Xian, Tianjin and Shenyang are largely dependent upon groundwater supply. With the growth of urban population and the rapid development in industry, water demand greatly increased. In the urban areas, environmental problems related to groundwater frequently arise, such as excessive exploitation, water pollution, seawater intrusion, land subsidence, etc. Many monitoring stations were set up in important cities. Research works have been made to study the origin, mechanism, and basic rules of water pollution or seawater intrusion for their control or elimination. Intensified experimental tests and research on artificial recharge had been undertaken in Beijing and other cities in order to expand groundwater resources.

On the basis of studies of the mechanism, development, and frequency of land subisdence, the city of Shanghai adopted mulitple measures including the reduction of water consumption, adjustment of the order of exploitation of aquifers and aritficial recharge. The interrelations among groundwater output, recharge and watertable fluctuations were also studied in detail, and the subsidence of land surface in Shanghai is now being basically controlled. In order to maintain low temperature water in summer and medium temperature water in winter, the city of Shanghai has creatively developed a method of regulating groudwater storage by "winter recharge for summer use and summer recharge for winter use". This has helped not only to effectively control surface subsidence but also to take advantage of the particular thermo-preserving property of groundwater. This method has now found wide application in many cities.

Hot springs are widespread in China. Many prospecting and exploration works of the geothermal water have been undertaken in urban areas as initiated and supervised by Prof. J. S. Lee and had already obtained significant results. Prominent examples of utilization of geothermal water are in Beijing, Tianjin and Fuzhou. Geotermal water of good quality has been found in large quantities in the urban areas of these cities, and is utilized in many ways, such as medical treatment, space heating, dyeing, air conditioning, bathing, farming and side line production. In this period, regional hydrogeologic mapping mainly in the scale of 1:200,000 was basically completed in the whole country except for some high mountainous regions and desert regions. A great number of hydrogeologic maps in separate sheets and with relevant expositions have been published. Maps or atlases in various scales have been also compiled for provinces and basins according to needs of natitonal economic construction. One of the highlights was the publication of the Hydrogeologic Atlas of the PRC in 1979 compiled by the Institute of Hydrogeology and Engineering Geology in cooperation with the provincial agencies. This atlas is a reflection of the main achievements in the research of regional hydrogeology.

Since the middle of the 1970s, normal international scientific exchangs have been resumed and advanced, especially with the western countries. Among foreign hydrogeologists or delegations visiting China the most important was the French hydrogeologic delegation under the leadership of Dr. G. Castany, one of the prominent hydrogeologists in the world. This was also the first hydrogeologic delegation visiting China from a western country.

The Fourth Period of the 1980s——Period of Quantitative Hydrogeology

Beginning from the 1980s, the Chinese national economy entered a new period of development. An overall evaluation of groundwater resources of the country ws accomplished to meet this new situation. The comprehensive assessment of water resources and environmental quality for major economic regions or river basins and important cities were the main task in this period. Besides, the study of the resources of fissure water and karst water were also emphasized. A monograph entitled Research on the Prediction of Groundwater Resources and Environmental Prolems of the Urban Areas in 2000 was published by the Management Section of Geologic Envirornment, Ministry of Geology and Mineral Resources in 1986.

Because of the open-door policy, intercommunications with foreign hydrogeologists, especially of the western countries, have become more and more often. Thus new ideas or techniques were introduced into our country, such as the theory of unsteady flow, new conception of groundwater flow system and sytematic engineering, electronic computer technique, mathematical modelling, isotopic technique and remote sensing, had been widely applied in hydrogeologic study and groundwater resources evaluation.

Geophysical methods are also widely used for hydrogeologic procpecting. Thus it may be said that the hydrogeologic science has stepped into a new period of quantitative hydrogeology.

In the field of mining hydrogeology, researches were focused on the karst saturated beds, of which many types are recognized. Investigations of thermal water have developed. Success has already been made in the exploration and research of high temperature thermal fields in Tibet and western Yunnan.

In this period many foreign scholars visited China and gave lectures in related colleges or institutes. Among them, Dr. G. B. Engelen, Professor of Free University of the Netherlands, gave a series of lectures on groundwater flow system. Dr. J. Soveri of Finland on environmental hydrogeology, Dr. K. D. Clampe from Germany on compilation of hydrogeologic map. Many research projects were accomplished in cooperation with foreign specialists, the study of the mathematical model on the land subsidence of Shanghai in cooperation with Belgian scientists, the program "Groundwater resources evaluation of the Huang-Huai-Hai Plain" in cooperation with the UNDP, the study of the model of karst water in Guilin in cooperation with French hydrogeologists, and the exploration and utilization of geothermal water in Beijing-Tianjin region in cooperation with the UN experts.

The Fifth Period of the 1990s——Period of Information Hydrogeology

In order to provide a great quantity of hydrogeologic records and data for establishing models, it is necessary to establish related information search system and data base. As a result of study on the data management system in recent years, groundwater resources data management system in Henan Province and groundwater balance test and monitoring data processing system were developed by Henan General Environ-hydrogeologic Station. They are running normally. Shanxi General Environ-hydrogeologic Station has also established groundwater regime data base (GWD) management system in Shanxi Province, which could input, revise, inquire, count and process the regime data, as well as print report forms and draw figures. The data base and data management system are also established in many other cities such as Qinhuangdao, Shijiazhuang, Xinxiang, etc.

On the basis of geographic information system (GIS), study on specialist decision system for the urban water resources and environment management is being carried out in China. As a result of study on information data base, knowledge base, inference-interpretation system and knowledge gaining system, a current specialist decision system for urban water resources—environment management could be established. The complicated systematic engineering of water resources-environment management could be computerized and automated. A technical tool easy for operation could be provided to the department of urban water resources management. Using this tool, one could not only carry out real time analysis, process simulation and information output for the state of water resources, but also realize optimal decision for water resources management.

Study on information system has become one of necessary and important topics of water resources research. It includes data management system, regime monitoring information system, remote sensing information system, development of specialist decision system, and application of 3-dimensional GIS to model study, etc. Hydrogeology is gradually developing towards information hydrogeology, in which water resources management and protection become the main objects.

Meanwhile, China has joined some important international organizations and become a country member of the International Association of Hydrogeologists (IAH) and the International Association of Hydrological Science (IAHS). The China National Committee for IAH and of IAHS were established. Chinese hydrogeologists have visited foreign countries and attended international symposiums including the IAH Congress and the Scientific General Assembly of IAHS. Many papers in the proceedings of these symposiums have been translated and published in Chinese. Moreover, some important international meetings were organized successfully in China, such as the 21th Congress of IAH and the Symposium on Karst Hydrogeology held in Guilin in 1988, and the Symposium on Hydrological Basis for Water Resources Management held in Beijing in 1990. In addition, Chinese hydrogeologists have also joined some working groups of the scientific projects of the International Hydrological Programme (IHP) of UNESCO, e.g. project A2.8 "Developments in the Analysis of Groundwater Flow Systems" and project 11.1a "Side Effects of Water Resources Manàgement". The results of these projects have been already published by IAHS. Through the active collaboration between Chinese and foreign institutions, academic intercommunications have been successfully conducted in China.

Conclusion

In conclusion, the history of the development of hydrogeologic science in China may be subdivided into four stages, including ancient China, as follows.

<table>
<tr><td>I</td><td>Primitive stage</td><td colspan="4">ancient China (prior to the 20th century)</td><td rowspan="2">hydrogeology as pre-science</td></tr>
<tr><td>II</td><td>Preliminary stage</td><td colspan="4">beginning to use geology in studies of groundwater (1901 – 1950)</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Foundation stage (mainly under the influence of USSR and on the basis of geology)</td><td>1</td><td>1950s</td><td>period of regional hydrogeology</td><td rowspan="2">traditional hydrogeology</td><td rowspan="5">modern hydrogeology</td></tr>
<tr><td>2</td><td>1960s</td><td>period of agricultural hydrogeology</td></tr>
<tr><td rowspan="3">IV</td><td rowspan="3">Development stage (mainly in cooperation with the western countries and with application of cross sciences)</td><td>3</td><td>1970s</td><td>period of environmental hydrogeology</td><td rowspan="3">current hydrogeology</td></tr>
<tr><td>4</td><td>1980s</td><td>period of quantitative hydrogelolgy</td></tr>
<tr><td>5</td><td>1990s</td><td>period of information hydrogeology</td></tr>
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Main Features of the Regional Hydrogeology and the Development of Hydrogeologic Mapping in China*

Introduction

Since the establishment of new China, great attention has been paid by the government to the investigation and development of groundwater resources. In the 1950s, the Bureau of Hydrogeology and Engineering Geology was set up in the Ministry of Geology. This Bureau is chiefly responsible for the regional hydrogeologic mapping throughout the country. An institute was founded at the same time. Hydrogeologic teams were set up in the geologic bureaus of both provinces and autonomous regions. Since the 1950s, regional hydrogeologic mapping, mainly on the scale of 1:200 000, has been carried out according to plan under the directoin of the Ministry of Geology. So far, a great part of China has been covered by regional surveys, with the exception of the Qing-Zang Plateau, some desert regions and high mountainous regions.

In the last ten years, a great number of hydrogeologic maps on separate sheets at the scale of 1:200 000 and their accompanying explanatory notes have been published. Hydrogeologic maps or atlases have been compiled at various scales for provinces and basins, according to the needs of the national economic construction. At the same time, the Atlas of Hydrogeologic Maps of the People's Republic of China was also published. All of these played an important role in promoting the development of the national economic construction.

This paper presents a brief outline of regional hydrogeology in China. It reviews the process of development in compiling hydrogeologic maps with various aims and scales (including map series or atlases) on the basis of the hydrogeologic mapping which has been carried out all over the country in a planned manner following the founding of our People's Republic and explains the important role of these maps in the course of constructing the national economy. The principles and methods of compilation of hydrogeologic maps and the major experiences as well as present problems are discussed in this treatise.

An Outline of Regional Hydrogeology

China is a country with a vast territory of 9.6 million km^2. The various regions differ greatly in climate, geology and geomor-phology. The whole country not only em-

* Hydrogeological Mapping in Asia and the Pacific Region Proceedings of the ESCAP-RMRDC Workshop, Bandung, 1983.

The original topic is: Development and Achievements of Hydrogeological Mapping in China. This paper is substantiated with new content.

braces various climatic zones at different latitudes but also features varied geomorphology, ranging from coastal plains to uplands and the Qing-Zang Plateau, the roof of the world. Our country is, therefore, characterized by great complexity of regional hydrogeologic settings and by differing hydrogeologic characteristics within the various regions.

The Qinling Mountains are located in the centre of the country and range in a latitudinal direction. It forms a natural boundary between North and South China and produces the very different geographic conditions which distinguish the two areas. At the same time, the longitudinally oriented, zonal distributions which natural conditions display in eastern China and western China are clearly due to the influence of the Pacific Ocean monsoon.

Geographically, the country is divided into six hydrogeologic regions. In the north, from east to west they are: i) the Great East Plain, containing mainly the Songliao Plain and Huang-Huai-Hai Plain; ii) the Inner Mongolia Plateau and Loess Plateau; iii) the western inland basin — a typical, extremely dry Gobi desert region, mainly consisting of the Hexi Corridor, Zhungeer Basin, Talimu Basin and Chaidamu Basin. In the south, from east to west the hydrogeologic regions are: i) the southeastern and southern central uplands; ii) the southwestern karst uplands; iii) the Qing-Zang Plateau.

The chief hydrogeologic characteristics of the area to the north of the Qinling Mountains are as follows: i) the wide expanse of the great plain, including the vast piedmont plain with very thick deposits of Quaternary sand and gravel, forms a good and thick aquiferous bed; ii) precipitation in the region of the Great East Plain amounts to almost 800 mm; thus, the groundwater there receives its main recharge by precipitation through vertical percolation. To the west the climate changes to that of a typical inland dry climatic zone, but the piedmont plain is recharged by mountain stream infiltration, therefore it has plenty of groundwater; iii) the Inner Mongolia Plateau and Loess Plateau form the intermediate zone between the semi-humid zone in the east and the dry desert zone in the west and suffer seriously from lack of groundwater due to restrictions imposed by geologic conditions; only in some places in the faulted basins, for example in the Guanzhong Plain and the Hetao Plain, is there abundant groundwater; iv) the chemical property of the groundwater is more complicated than that of the south.

The main characteristics of the area to the south of the Qinling Mountains are as follows: i) bedrock is widely exposed and forms hilly uplands, while the area covered by plains is smaller, so that fissure water dominates in this region; ii) the southwest is characterized by widely distributed carbonate rocks, and karst water is the main form of groundwater with well developed subterranean streams; iii) precipitation generally measures between 1000 and 2000 mm, but some places, such as the Mesozoic red bed basins and coastal plains, suffer serious lack of water; iv) the hydrogeologic character of the Qing-Zang Plateau is entirely governed by its altitude, and its groundwater is mainly of the permafrost or glacial genetic type.

In North China

The E-W Qinling mountain range is the natural dividing line between the North and South China. In areas north of the Qinling, the annual precipitation is less than 800 mm, and the amount is gradually reduced from east to west. In the semi-arid region east of Mt. Helanshan, the annual precipitation is commonly about 200 to 500 mm., while in the region to the west of Mt. Helanshan, which is known as an extremely dry Gobi area, the annual precipitation gradually decreases to below 100 mm.

As flat plains cover a large area in N. China, the area of cultivated land there makes up more than 50% of the total of the whole country. But there the water resources are not sufficient, for the runoff of the surface water is only 6 per cent of the total of 2600 billion m^3. On the contrary, groundwater is comparatively plentiful and plays a more important role in N. China.

Geologically, those major plains, such as the Songliao Plain, the Huang-Huai-Hai Plain, the Hetao Plain, the Guanzhong Plain, the Yinchuan Plain, etc, are mainly Mesozoic or Cenozoic down-faulted basins with enormously thick unconsolidated sediments which provide favourable conditions for the preservation of plentiful groundwater. These plains are the principal cereal areas in China. Building motor pumping wells has already become one of the important ways to bring all the farm land under irrigation. With such wells already built, remarkable results have been achieved in combating drought and in promoting the increase of food-grain production.

In northwestern China (chiefly west of Mt. Helanshan), although rainfall is scarce, yet groundwater in the vast piedmont plains such as those in the Hexi Corridor and along the southern border of the Zhungeer Basin is mainly recharged by the streams originating from the melting snow on the high mountains known as the Qilianshan and Tianshan. Almost 60 – 80 per cent of the runoff is penetrated into the ground of the piedmont Gobi region, where the gravel beds formed of alluvial and delluvial deposits several hundred meters in thickness, serve as a large natural subsurface reservoir for the storage of large volume of groundwater, which then discharges onto the surface in the form of spring clusters in the frontal part of the alluvial fan and flows into the so-called "karez" to become chief water source for irrigation.

In South China

In areas to the south of Mt. Qinling (excluding the Tibetan Plateau), the annual precipitation is 1000 – 3000 mm, which is much higher than that in Northern China. Lakes and rivers here are densely distributed, hence the surface runoff accounts for about 75 per cent of the total of the whole country, The wide-spread mountains and hills are the chief physiographic features in the south. The mountains formed of the bedrock yield mainly fissure water and the development of groundwater is therefore much restricted. The plains in South China are relatively small in area. Although the Quaternary aquifers are also found having great thickness and abundant in groundwater in such plains as the delta-plain of the Yangtze River, the Jianghan Plain, the Chengdu Plain, etc, yet there is no acute demand for groundwater in agriculture. On the contrary, the groundwater level there generally is too high to favour the cereal production and therefore how to lower the level of groundwater has become the chief hydrogeologic problem in these regions.

Although South China is quite rich in surface water, yet because of its unbalanced distribution, some areas are still seriously short of water. These waterdeficient areas can be classified into three types:

1. Coastal plains: Rainfall in the coastal areas is comparatively scarce, and it is of-