

# 中华人民共和国

# 多目标区域地球化学图集

## 江苏省

地质出版社



# 中华人民共和国多目标区域地球化学图集

## 江苏省

国土资源部中国地质调查局

地质出版社

· 北京 ·

## 内 容 提 要

本图集是“江苏省1:250 000多目标区域地球化学调查”项目的重要成果之一,它全面展示了江苏省表层土壤与深层土壤、11个主要湖泊表层与深层湖积物、沿海滩涂表层与深层沉积物、射阳河口以南近岸浅海表层与深层海积物中多种元素和指标的空间分布状况及含量水平,是全国目前已经开展了多目标区域地球化学调查的省(区、市)域中数据量最丰富的;所提供的元素地球化学图及土壤地球化学分区图、表层土壤营养元素丰缺图、重金属环境质量分级图、土壤碳密度分布图、土地质量地球化学分等图等多种应用性图件,是土地规划与管护、农业种植结构调整、环境保护、资源勘查、全球变化及第四纪研究的重要基础资料。

本书可供从事地球化学、土壤学、环境学、农学、医学、全球变化等专业的教学和科研人员及制定土地管理相关法律法规的政府部门参考使用。

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# 序 一

新时期地质工作以经济社会发展需求为导向，必须更加紧密地与国民经济和社会发展相结合，更加主动地为经济与社会发展服务。全国多目标区域地球化学调查正是体现了这一战略方向。

多目标区域地球化学调查属于基础性、战略性地质工作，是一项在我国广大平原盆地、湖泊湿地、沿海滩涂、近岸海域、低山丘陵和黄土高原开展的重要基础调查。国土资源部从1999年开始部署，目前已经遍及全国31个省（区、市），调查面积达160万km<sup>2</sup>，覆盖了我国主要农耕区和经济区带。通过系统采集地表土壤、湖积物与近岸海域沉积物样品，取得包括54种元素指标的数以千万计的高精度地球化学数据，查明了各种元素空间分布状况，深入开展资源与环境地球化学评价，取得了一系列重要调查研究成果，主要体现在：

1. 深化第四纪基础地质研究。运用地球化学理论和方法，研究划分第四纪沉积相和成土母质，研究第四纪沉积环境，推断隐伏断裂等区域地质构造单元，为第四纪地质填图增添了大量新参数。
2. 提供资源潜力评价信息资料。在油气、地热等能源矿产及固体矿产方面新发现一大批异常，特别是与能源有关的异常，为资源潜力评价提供基础资料，为能源矿产开发提供重要线索。
3. 丰富土地质量各项评估指标。对我国土地有益与有害元素等进行全面调查与评价，基本查明我国18亿亩土地质量状况，对发掘土地利用潜力，提高土地利用价值，促进土地数量、质量和生态全面管护，因地制宜发展优势农业，具有重要意义。
4. 划分土壤重金属异常分布区。土壤重金属对经济社会发展存在潜在危害，调查工作详细圈定了重金属异常分布地区，确定异常元素类型、组成及强度，研究异常成因和污染程度，进行生态效应评价，为土壤污染治理修复提供科学依据。
5. 精确测定土壤碳储量。土壤有机碳储量及其变化趋势是影响全球碳循环的主要因素，调查获得大量土壤碳储量数据，显示出我国土壤存在巨大储碳空间和固碳能力，有利于维护国家经济社会发展权益，推动全球气候变化研究。

多目标区域地球化学调查成果突出，在国际上处于领先地位。该项目不仅拓展了国土资源领域调查评价的内涵，而且推动了农业地质、环境地质、城市地质及全球变化等新兴领域的发展，这是地质工作落实科学发展观的成功范例。我期待，随着多目标区域地球化学调查在全国范围的持续开展，将不断取得新的成就！

在此，我对《中华人民共和国多目标区域地球化学图集》的出版表示祝贺！

中华人民共和国国土资源部副部长  
中国地质调查局局长 汪民

2010年7月

# Preface I

Geological surveys in the new era, pushed by the demands of economic and social development, are required to integrate closer with and serve more initiatively national economic and social development. The National Multi-Purpose Regional Geochemical Surveying (NMPRGS) program exactly embodies this strategy.

The NMPRGS, as the basic and strategic geological survey, functions as the significant fundamental survey conducted throughout China's vast territory including plains, basins, lakes, wetlands, coastal and shoal lands, offshore areas, hilly lands, and the Loess Plateau.

The surveys organized by the Ministry of Land and Resources have been carried out since 1999, involving 31 provinces, municipalities and autonomous regions across the country. An area of 1.6 million square kilometers, including the main cultivation areas and economic zones of China, has been covered up to now.

Millions of accurate geochemical data of 52 elements, pH and organic carbon were acquired by systematically sampling soils, lake sediments and inshore sediments, the spatial distributions of various elements are studied and the geochemical assessments of resources and environment are comprehensively performed. A series of significant investigation results have been achieved, which are briefly described as follows:

1. Deepen the fundamental study on the Quaternary geology. With the application of geochemical theories and methodologies, Quaternary sedimentary facies and soil parent materials were identified, the Quaternary sedimentary environments were analyzed, some regional tectonic units and concealed faults were inferred, resulting in a great number of new information for Quaternary geological mapping.

2. Provide new materials for evaluation of resources potentiality. A plenty of geochemical anomalies related to energy resources and mineral deposits, especially those related to oil and gas and geothermals, have been newly mapped out, which provides the basic materials for resource potential evaluation and the important clues for energy resources exploration.

3. Enrich various evaluation indexes of land quality. With comprehensive investigation and evaluation on both beneficial or harmful elements, the current land quality status of 1.8 billion mu ( 1 mu=0.066,7 hectares ) land has thus been primarily ascertained. It plays an important role in exploring the land use potentiality, enhancing its value, improving the all-round management and protection of land quantity, quality and ecology. It is also significant to take measures suited to local conditions for developing prevailing agriculture.

4. The distribution characteristics of heavy metals in soils have been studied in detail. The origins of the heavy metal anomalies and pollution level, as well as related ecological effects, have also been investigated during the survey. All of these provide scientific basis for the pollution treatment and remediation of soils.

5. Determine accurately the soil carbon storage. Based on a mass of soil organic carbon data obtained by the survey, soil carbon storage and its changing trend have been studied, revealing the great potential for soil carbon sequestration. The resultant data and further researches will contribute to the establishment of soil carbon sequestration strategy and the study of global climate change.

The great achievements gained by the NMPRGS program have acquired the leading position in applied geochemistry in the world. This project not only expands the contents of geological works, but also promotes the developments of such fields as agro-geology, environmental geology, urban geology and global changes. It is a paragon to implement the scientific development concept in geological surveys. My sincere hope is that with the continuous implementation of the NMPRGS across the nation, greater achievements would be unceasingly accomplished!

Congratulations to the publication of The Multi-Purpose Regional Geochemical Atlas!

Vice Minister of Land and Resources of PRC  
Director of China Geological Survey

Wang Min

July, 2010

## 序 二

30余年来，中国进行了多项地球化学填图计划，包括区域化探全国扫面计划、环境地球化学监控网络计划、西南及南方76种元素地球化学填图计划等，为中国找矿勘探的重大突破作出了巨大贡献，使勘查地球化学成为中国为数不多、能引领全球发展方向的学科之一。上述各种地球化学填图的成功经验为中国多目标地球化学调查的迅速发展奠定了坚实的基础。

多目标区域地球化学调查是国家需求和学科发展紧密结合，各方协同作战的产物，它继承了中国勘查地球化学一贯重视战略研究的思想，坚持科学制订顶层战略设计，统一技术标准和实施方案；坚持科研指导生产，生产促进科研的双反馈机制；坚持野外采样和分析质量高标准、严要求的质量管理体系，保证了全国数据的可对比性和地球化学图的无缝对接，堪称大科学计划和大项目机制的典范。


多目标区域地球化学调查迄今已覆盖中国各经济区160万km<sup>2</sup>的面积，其所取得的3 000余万个高质量地球化学数据在土地开发利用与管护、农业生产、环境保护、资源勘查、全球变化及第四纪研究等方面的广泛应用，远远超出了传统勘查地球化学家的想象，深刻改变了传统勘查地球化学的内涵，充分显示了中国勘查地球化学解决国家重大需求的能力，是近10年来全球最成功的地球化学填图项目之一，为中国勘查地球化学未来数十年继续保持国际领先地位奠定了基础。

《环境工作者》(Environmentalist)早在1990年的社论中就指出：“地球化学图册的制作与分析最终将被证明，它比地质学中最具革命性的板块构造研究更为重要”。化学元素是非生命地球的基本组成单位，类似于生命科学中的基因，而地球上的生命是在周期表中所有元素存在的环境中逐步演化的。中国多目标区域地球化学图集的公开出版，首次系统地向公众展示了中国大地化学元素的“类基因图谱”，具有极为重要的科学价值和现实意义。

图集包含了丰富的元素含量、空间分布与变化的信息，其所展示的农耕区土壤有机碳、江河流域以镉为主的重金属元素异常带、大中小城市以汞为主的土壤污染及富硒土地资源等的空间分布信息等，均是事关中国可持续发展的极其重要的信息。

勘查地球化学为解决国家重大需求所取得的成就极大地激发了中国中青年勘查地球化学工作者的科学热情；对若干重大科学问题的初步探索已获得许多原始创新成果，充分证明了中国中青年勘查地球化学家已具备全球科学视野和引领学科发展的能力。

在《中华人民共和国多目标区域地球化学图集》出版之际，谨向广大中青年勘查地球化学工作者表示热烈的祝贺，并预祝他们在未来的日子里，在勘查地球化学为解决国家重大需求的事业中取得更大的成就！



2010年7月



## Preface II

Elements are the basic unit in planet earth. They are analogous of the genes in living bodies, and life on the earth is evolved progressively in the environment of distribution of all elements in the Periodic Table. The works of geochemical mapping are to collect various earth surface samples, to do multi-element analysis of most elements in the Periodic Table, and to map and study spatial distribution of elements at various scale, in various part of the earth.

Early in 1990, The Editorial of Environmentalist has printed out: “The production and analysis of geochemical atlases, eventually may prove to be of even greater importance than the revolutionary geological studies in plate tectonic.”

China has carried out many big programs of geochemical mapping within these thirty years, including Regional Geochemistry-National Reconnaissance Program (RGNR), Environmental Geochemical Monitoring Network Program (EGMON), Seventy-six Geochemical Elements Mapping in S.W.China and S. China (76GEM, S.W. China and S. China), etc. These programs have made great contribution in mineral exploration, and have rendered exploration geochemistry in China to take the leading position in the development of this applied science in the world.

The accumulation of new ideas and technologies of the above surveying has been the locomotive for the recent rapid development of the so-called National Multi-Purpose Regional Geochemical Surveying (NMPRGS).

The Multi-Purpose Regional Geochemical Surveying, which was commenced in 1999, is bringing closer correlation of national and social needs with scientific development and closer cooperation of enormous number of geochemical survey parties in difference provinces with groups of geochemists from research institutes and universities. The Multi-Purpose Regional Geochemical Surveying, like all the past mapping programs, possesses diverse subprojects highly converged in the aims, ideas, methodology, and technology. It has covered more than one million square kilometres of China’s most industrialized territory, producing gigantic amount of highly qualified several tens of millions analytical data of 52 elements, pH and organic carbon.

The new results of the 10 years Multi-Purpose Regional Geochemical Surveying have leaded to the recent publication of a series of geochemical atlases. The information revealed in these atlases is important for the sustainable development of China’s economy and society, for example, organic carbon storage in farmland, heavy metal pollution in different drainage systems (especially Cd) and in many cities (especially Hg) in China, etc.

The difference of NMPRGS program from the past mapping programs is the transmission of leading agency to a new generation of younger geochemists. I am glad to see that. It means China could keep her leading position in the newly born “Applied Geochemistry” for many years to come.



July, 2010

# 前 言

全国多目标区域地球化学调查是国家基础性、公益性、战略性地质调查工作，《中华人民共和国多目标区域地球化学图集》集中体现了这项调查工作的主要成果。

进入21世纪以来，中国地质工作以经济社会发展需求为导向，更加紧密地与国民经济和社会发展相结合，更加主动地为经济社会发展服务，积极拓展地质工作服务领域。正是在这一背景下，全国多目标区域地球化学调查开始实施。

1999~2001年为全国多目标区域地球化学调查试验研究阶段。首先选择代表中国东、中、西部典型地质地理景观区的珠江三角洲、江汉平原与四川盆地进行试点，工作比例尺为1:250 000，采用双层网格化采样布局进行土壤、湖积物及近岸海域沉积物地球化学测量，辅以水地球化学测量，在重要地区开展持久性有机污染调查。采用现代大型精密仪器和最佳配套分析方案测试54种元素指标，通过标准控制样监控分析质量，全面提高了测试数据精密度和准确度，实现省内、省际和全国多目标区域地球化学图的无缝拼接。统计地球化学系列参数，绘制元素地球化学图，圈定各类地球化学异常。查明元素区域分布分配特征，查证重要地球化学异常，结合经济社会发展需求进行应用评价等。通过试点工作，在调查方法与测试技术、数据处理系统与成果应用领域等方面取得了突破性进展。通过系统总结试点工作成果经验，逐步形成《多目标区域地球化学调查规范》，使这项调查工作置于现代技术和标准方法基础上。

2002年开始，国土资源部中国地质调查局与各省（区、市）人民政府以省部合作方式，由地质大调查专项和地方财政联合支持，全面实施多目标区域地球化学调查。2004年，国土资源部正式批准中国地质调查局《关于农业地质规划要点》，按照“覆盖中部农业主产区，重点安排东部经济区，优选西部农牧区”的部署原则规划多目标区域地球化学调查工作。2005~2008年，财政部设立“全国土壤现状调查及污染防治”专项，进一步加大对多目标区域地球化学调查的支持力度。

截至2009年，全国多目标区域地球化学调查面积已经达到160万km<sup>2</sup>，覆盖了我国部分东中部平原盆地、湖泊湿地、沿海滩涂、近岸海域、低山丘陵、黄土高原及西部重要经济区。

经过10年不懈努力，调查工作取得了丰硕成果。取得土壤54项元素指标高精度地球化学调查数据，统计背景值、基准值等系列地球化学参数，制作元素地球化学图及各类应用图件，新发现大量可供经济社会发展各方面利用的地球化学基础信息资料。依据元素区域分布特征，研究第四纪沉积环境与成土母质，推断隐伏地质构造，为第四纪地质填图增添新内容、新方法和新的指标依据。新发现一大批能源矿产和固体矿产异常，特别是与油气、地热等能源矿产有关异常，为进

一步开展矿产资源潜力评价提供重要线索。对中国土地营养元素、健康元素和有害元素等进行全面调查与评价,查明中国土地质量状况,发掘土地利用潜力,提高土地利用价值,发展优质高效农业,促进土地科学管护。研究土壤环境地球化学状态与变化特征,研究重金属异常成因和污染程度,对水、大气、农作物等生物地球化学系统进行延伸分析和评价,推动土壤环境污染治理修复。获得大量土壤碳密度数据,深化中国土壤有机碳储量及其变化趋势研究,为推进中国土壤储碳潜力和固碳能力研究,建立土壤有机碳监测网络系统,促进全球气候变化研究提供基础资料。

通过全国多目标区域地球化学调查全面实施,形成的新思路、新理论、新方法及新技术正在推动建立生态地球化学科学体系,在地球系统各种尺度上研究元素生态地球化学表生过程、作用及环境效应,进行变化趋势预测;逐步形成土地质量地球化学评估的方法技术体系,实现土地质量与生态的有效管护。积极开拓成果应用服务领域,推进土壤碳源-碳汇研究及重金属污染防控等关键技术研究,极大地提升地球化学解决经济社会发展重大科学问题和现实问题的能力。

《中华人民共和国多目标区域地球化学图集》依托“多目标区域地球化学调查与评价”计划项目成果进行编制,按省(区、市)与重要经济区带分别出版,主要内容包括工作背景及地区概况,数据来源及各项技术指标,各类地球化学参数统计,各类元素地球化学图与成果应用图,概略论述了区域地球化学特征及主要经济社会效益等。

《中华人民共和国多目标区域地球化学图集》属首次正式出版,充分体现了国家公益性、基础性地质工作的先行作用,展示了地质大调查以来国土资源部中国地质调查局与全国各省(区、市)人民政府合作开展多目标区域地球化学调查取得的丰硕成果,是我国广大勘查地球化学工作者10年来辛勤劳动的结晶。

《中华人民共和国多目标区域地球化学图集》不仅为地学领域,同时为环境学、生态学、生物学、土壤学、农学、医学等自然科学领域提供具有原始创新意义的地球化学信息,广泛服务于土地、环保、农业、卫生等经济社会发展各行业部门,取得显著的经济和社会效益。

《中华人民共和国多目标区域地球化学图集》的出版得到了有关部门领导的支持,众多相关领域的专家和学者提出过许多宝贵建议,在此一并表示感谢。由于编者水平有限,难免存在疏漏和不足,恳请各位读者不吝赐教,以期进一步修改和完善。

编委会

2010年8月

# Foreword

The *Multi-Purpose Regional Geochemistry Atlas* embodies the essential achievements of the National Multi-Purpose Regional Geochemical Surveying (NMPRGS), a basic, public benefit and strategic geological survey.

With the advent of the 21<sup>st</sup> century, the geological survey has integrated even closer with and more proactively served the national socio-economic development under the influence of fast development of social economy, its application fields has been expanded tremendously. An overall NMPRGS has been launched under such circumstance.

During the period of 1999 to 2001, the trial stage of the NMPRGS program, Pearl River Delta, Jiangnan Plain and Sichuan Basin were first chosen as the representatives of the typical geographical landscapes for pilot geochemical surveys on a scale of 1 : 250,000 in eastern, central and western China respectively. Soils, lake sediments and coastal sediments were collected with a method of two-layer gridding sampling, as well as the auxiliary method of water geochemical survey. POPs in soils and sediments were also investigated in some important areas.

The contents of 52 elements, as well as organic carbon and pH, were determined by using large-scale modern instruments, with an optimum combination of analytical methods. The precision and accuracy of analytical data were greatly enhanced by controlling analytical quality with blind control samples, so as to realize seamlessly sheet splicing of multi-purpose regional geochemical maps within a province, inter-province or even nation-wide. Consequently, the statistics of geochemical parameters were systematically calculated; geochemical maps of elements were compiled and a variety of geochemical anomalies was delineated; the regional distribution features of elements were ascertained; and some important geochemical anomalies were followed up and evaluated in the light of economic and social development. Through the pilot geochemical surveys, a breakthrough was made in respect of surveying methodology, analytical methods, data processing and applications of results, etc. Based on the result of pilot geochemical surveys, the Regulation for the Multi-Purpose Regional Geochemical Survey was progressively formulated, which ensured the survey to be conducted on the basis of modern technology and standards.

Financed by the fund of New Round of Nation-Wide Geological Survey and local public capital, the NMPRGS program has been launched in full swing since 2002 by China Geological Survey (CGS) of the Ministry of Land and Resources (MLR) collaborating with the provincial (municipal and autonomous regional) governments.

The survey has been planned to cover main agricultural production areas and economic zones in central and eastern China, and selective farming and stockbreeding zones in western China, which was stimulated in the document of “Essentials of Agro-Geological Planning” approved by the MLR in 2004. The program got more powerful support from the Ministry of Finance by a special fund of “National Soil Investigation and Pollution Prevention and Control” during 2005–2008.

By 2009, the NMPRGS has already covered 1.6 million km<sup>2</sup>, including plains, basins, lakes, wetlands, coastal and shoal lands, offshore areas, hilly lands, and the loess plateau across the country.

Undergone ten-year unremitting efforts, a fruitful harvest has been yielded, including high precision geochemical data of 54 elements and indicators of soils, a series of geochemical parameters, geochemical maps of elements and a variety of application maps, providing a mass of basic geochemical information needed in economic and social development.

Based on the analysis of regional distribution features of elements, the Quaternary sedimentary environment and soil parent materials could be analyzed and concealed geological structures could be inferred, new information has been acquired for Quaternary geological mapping.

At the same time, a plenty of anomalies of energy and mineral resources were also delineated, in particular those related to oil and gas and geothermal, which are important for evaluation

of potential mineral and oil and gas resources.

In addition, the exhaustive survey and overall evaluation on beneficial or harmful elements of soils resulted in clarifying the status quo of land quality, ascertaining land resources potential, enhancing its value in use, developing ecological agriculture, and promoting scientific land management.

Furthermore, studies have also been made on heavy metals in soil-water-atmosphere-crops, origins of heavy metal anomalies, soil pollution level and contaminated soil remediation. A mass of data about soil carbon density acquired in the survey have provided basic information for further investigation of soil carbon storage and sequestration, and establishment of monitoring network system of soil carbon.

Through the full implementation of the NMPRGS program, some new thoughts, theories, methods and technologies have emerged, and they pushed forward the establishment of scientific system of eco-geochemistry. The methodology of land quality geochemical assessment has been progressively put forward, which will be useful in effective land quality management and ecological protection. The researches in such areas as soil carbon source/sink, and the prevention and control of heavy metal pollution have been pushed forward, they have greatly enhanced the capability of geochemistry in resolving substantial problems related to economic and social development both in practice and science.

Organized by the program team of the NMPRGS, the *Multi-Purpose Regional Geochemical Atlas* has been compiled and published separately for individual provinces (municipalities, autonomous regions) and major economic zones. The contents included in the atlas are the introduction, general situation of survey area, data sources, statistical geochemical parameters, geochemical maps of elements, application maps of survey results, brief description of regional geochemical characteristics, as well as economic and social benefits, etc.

Officially published for the first time, the *Multi-Purpose Regional Geochemical Atlas* manifests adequately its pioneering role in basic and public benefit geological work, and demonstrates the fruitful achievements of the NMPRGS program conducted by CGS under the MLR collaborating with governments of provinces (municipalities, autonomous regions). It goes without saying that the atlas embodies the fruit of hard working of the mass of workers in the field of geochemical exploration for ten years since the beginning of the survey.

The *Multi-Purpose Regional Geochemical Atlas* provides the basic and innovative geochemical information not only for earth sciences, but also for environmental science, ecology, biography, soil science, agronomy, medical science and other fields of natural sciences. With the information widely applied to a variety of industries and sectors concerning economic and social developments such as land management, environmental protection, agriculture, and public health, the atlas has assisted all of them to achieve remarkable economic and social benefits.

Our sincere acknowledge is given to all supports from department leaders concerned, to the invaluable suggestions of experts and scholars from related fields, for the publication of the *Multi-Purpose Regional Geochemical Atlas*. We also cordially ask our readers not to spare your comments for improving and perfecting our work by pointing out the omissions and deficiencies in the atlas caused due to our editors' limited expertise.

Editorial Board  
August, 2010

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