

XXXVIII IAH Congress

**Groundwater Quality Sustainability
Krakow, 12–17 September 2010**

Extended Abstracts

**Editors:
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**University
of Silesia
Press 2010**



abstract id: **522**

topic: **5**
Data processing in hydrogeology

5.3
Groundwater mapping — approach and results

title: **Groundwater resources and environmental geological map of Asia**

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keywords: Asia, groundwater resources, environmental geology, mapping

ABSTRACT

With the rapid economic development in Asia, water resources need more and more. Water shortages have taken place in many countries and become more and more serious. Human activities have impacted groundwater resources and made water supply security threatened in some areas. In order to strengthen international cooperation in Asia and make a better understanding of groundwater resources and environmental conditions, the China Geological Survey organized groundwater resources and environmental geological mapping of Asia. The map compilation mainly includes Map of Hydrogeology in Asia; Map of Groundwater Environment in Asia; Map of Groundwater Resources in Asia; Map of Geothermal Resources in Asia. The work on the compilation started from the comprehensive analysis of groundwater resources and environmental geology in Asia, meanwhile, the remote sensing, GIS and internet have to be used to establish the dynamic information platform of groundwater resources and environment for share. The final fruit is the compilation of Groundwater Resources and Environmental Geological Map in Asia. It is really an important job, which will fill the blank of the continental water resources and environmental geology maps, help to make more effective management of groundwater resources in Asia and build a harmonious international environment.

INTRODUCTION

With the social and economic development in Asia, human activities have become increasingly serious to damage groundwater environment and water resources and geological environment changes threat and impact the living environment and economic sustainable development in Asia. Compilation of groundwater resources and environmental geology in Asia taken as an international cooperative program is of great importance to develop the Asian economy and geological disciplines. Groundwater resources and environmental geology map series is a large multi-objective, multi-level, multi-dimensional and multi-factor system in Asia. This paper looks back and forward in recent decades the status, role and trends of the groundwater resources and environment-related research and proposes a new mapping resources, groundwater environment research levels, meanwhile, the international cooperation and the harmonious development between water resources and environment will be built up in Asia.

THE RECENT DECADES OF DYNAMIC GEOLOGICAL MAP IN ASIA

China started to work on the geological compilation in Asia in the duration of the late 1970s' and 1980s' when Prof. Ting-Dong Li in Chinese Academy of Geological Sciences made the edition of the "Geological Map of Asia" (1:5,000,000), which concluded a systematic summary of the regional geology in China and the development and characteristics of igneous rocks in Asia. It is divided into three geotectonic zones and five evolutionary stages with magmatic activities of inheritance, differentiation, zoning and migration and the characteristics of evolution. In 1990s', a number of Chinese and Russian scientists cooperated together to compile "Map of Asia and Adjacent Area Land and Sea Topography" (1:8,000,000) edited by Prof. Chen Zhiming. This map is not only the contribution to the development of global geomorphology and plate movement, but the important practical value to the other Earth scientific applications, especially earthquakes and volcanoes and other endokinetic disasters and satellite positioning systems etc.

W.F. Struckmeter and W.H Gilbrich et al. made the map "Map of Global Groundwater Resources" (1:24,000,000) in 2006, which described the global distribution of groundwater resources and

aquifers comparison to each other, while the term of trans-boundary aquifers was used firstly in the legend. China Environmental Monitoring Centre compiled “Geothermal Resources Map of Asia” (1:8,000,000), which systematically summarized the distribution of geothermal resources in Asia, and reflected the relations between geothermal water and the regional geological conditions. Prof. Zhang Zonghu edited “Hydrogeological map of Asia” (1:8,000,000) in view of the global water cycle, which described circulation between groundwater and surface water in Asia and reflected groundwater variation in different hydrogeological conditions.

Commission for the Geological Map of the World has organized and compiled a series of geological maps of the continent, the ocean and the world over years and the publication of the maps since 1999 includes Geological Maps of Asia in the following:

- Geological Map of the World (1:125,000,000 in 2000);
- Geological Map of the World (1:150,000,000 in 2001);
- Seismic Structure Map of the World (1:125,000,000 in 2001);
- Seismic Structure Map of the World (1:150,000,000 in 2002);
- Geological Hazards Map of the East Asia (1:177,000,000 in 2002).

The study on groundwater resources and environment exists in big difference in different countries in Asia. The compilation lies the same with big difference. The regional research results are not many and most of the maps are confined to one's country or region such as the Map of Hydrogeology of Soviet Union, Map of Hydrogeology of India, Map of Hydrogeology of Japan, Map of the Regional Distribution of Geothermal Resources occurrence. However, the previous studies still have some shortcomings. The compilation of groundwater resources and groundwater environment is still blank. Groundwater resources and environment compilation in Asia is reflecting the mapping status and summary of Asian countries for decades. The geological, tectonic, geomorphological conditions in the new compilation will conduct the geological research summary, analysis, preparation of water resources and environmental geology of Asia series map with great necessity and practicality.

BASIC PRINCIPLES OF THE COMPILATION

Groundwater resources and environment compilation in Asia has the basic principles as follows:

- Principle of unity for mapping technical specifications: work out the specific mapping method for groundwater resources and environment compilation with the Asian geological features as zoning compilation and summing up the zoning maps with unified principles;
- Principle of International mapping technology combined with groundwater resources and environmental characteristics in Asia to learn from the recent international publication combined with characteristics of groundwater resources and environment in Asia;
- Principles of both the traditional compilation and the technological innovation to apply the past geological mapping method, while the technological innovation of mapping content, concepts, methods and technical means for compilation should be reflected in the maps;
- Principles of the Asian countries and regions which co-ordinate the information of groundwater resources and environmental studies whether they have rich information or

poor information concerned with their research level, make an arrangement of compilation of both in high degree of information-rich countries and outline mapping technology, and at low levels of co-ordinating research, data compilations in the information-lacking regions;

- Principles of coordinating zoning compilation and summing-up the total results can be strengthening the international cooperation with the unified outline of compilation, organizing the full work through the unified mapping outline in the Asian region.

MAIN CONTENT OF THE ASIAN GROUNDWATER RESOURCES AND ENVIRONMENT

The map series include Hydrogeological map in Asia, Groundwater Resources Map in Asia, Groundwater environment map in Asia, Geothermal Resources Map in Asia and the content is expressed as follows:

- **Hydrogeological Map in Asia:** The main content of the map describes shallow groundwater distribution and migration, reflecting the different groundwater storage in the hydrological circulation alternating with water yield capacity. Mapping follows the three types of pore water, fissure water, karst water, and the hydrogeological conditions based on different water yield capacity will be divided into five grades. The recharge, runoff and discharge form of groundwater reflects the unique structure of the aquifer. There are special types (multi-layer structure porous aquifer, karst fissure water and pore water distribution basin). Natural outcrop of groundwater (big spring, underground rivers, hot springs, lagoons, etc.) is leading to the special characteristics of groundwater.
- **Groundwater Resources Map in Asia:** This map is to evaluate groundwater resources in various countries or regions based on the results of data. The basis comes from the ocean, large-scale hydrogeological control structure for the unit and the main river system. It also takes into account the large region's (country) results of groundwater resources evaluation. Zoning: groundwater resources, groundwater types and other boundaries. Mapping is based on the different groundwater types, natural groundwater recharge area for the modulus of the basic evaluation unit, in the map form to express groundwater and its exploitation, the spatial distribution of resources. Groundwater resources based on topography, climate, hydrology, aquifer recharge media can be divided into five grades. And the deep groundwater should be evaluated by the storage capacity of groundwater.
- **Groundwater Environment Map in Asia:** The map shows the appropriate spatial distribution of groundwater quality, original chemical components that threaten to human existing environment, unreasonable exploitation of groundwater induced environmental hazards. It includes the spatial distribution of groundwater quality status, chemical composition anomalies, hydrogeochemical zoning according to the main chemical types and groundwater quality to represent the sub-regional level. It can express the special vertical distribution.
- **Geothermal Resource Map in Asia:** The map shows the geological structure and features, and it is divided into three zones as volcanic geothermal areas, uplift fissured geothermal areas and sedimentary basin geothermal areas. The main features are thermal structure lines, typical hot springs, well outcrop and the point special chemical composition.

GEOLOGICAL FEATURES OF GROUNDWATER RESOURCES AND ENVIRONMENT MAP SERIES

This map series reflects guiding theory of the academic hydrogeologists in Asia, who consider the content of the maps. The maps show the recent study of groundwater resources and environment in the form of the map expressions in Asia. Groundwater resources and environment is of great importance of the research (Longrui et al., 1995).

Hydrogeologists use the map as a language to tell groundwater resources and environmental information in Asia to the planners, decision-makers how to use groundwater resources and to protect water environment. Symbols on the map are almost graphic. Map as an objective awareness and research results, may reflect a variety of natural and social phenomena of the spatial distribution. And it is objective awareness and research tool to gain new knowledge (Jun, 1986). Groundwater resources and environmental geology map series with the content of hydrogeology, groundwater resources, groundwater and geothermal resources in different colors, lines, symbols, digital etc. can guide the reader, and it has the following characteristics:

- A comprehensive range of services: It serves the entire Asian region, involving the whole Asia, water resource management to maintain the sustainable development of ecosystem services and to keep the steady development of the economy in Asia.
- To reveal the major issues of groundwater resources and environment: water is the basis of socio-economic development, environmental protection. However, poor management of water resources often exists, so people must manage it properly. Better management of water issues achieves better solutions (UNESCO, 2008). Groundwater resources and environmental geology maps for the country or between countries can develop sound water resources management policy.
- Water and ecological security: In recent decades, declining water quality, over-exploitation, hydrology and land deterioration and threats to river basin have negative impact on human health and the economic and social development. The map series can be a very good understanding of the human-environment systems to provide better ecosystem management. The lack of water can threaten social sustainability, especially in arid and semi-arid areas, coastal regions and small islands and the area with population density, industrial active regions. The maps will provide scientific support to achieve the minimum energy demand and ensure supply security.
- Informative and wide-ranging: Map covers the whole Asia groundwater resources and environmental geology. Compilation with full contents of the Asian continent groundwater and geological environment may reflect the conditions of groundwater storage, groundwater quality and environmental impact by human activities on groundwater situation. It also reflects the natural geological environment in Asia such as lithology, geological structure, hydrogeological conditions, groundwater resources, water chemistry and so on. Thematic content researches on the adjacent transboundary and transregional aquifers, analyzes regional groundwater resources and environmental geology related to current situation, problems and causes. During economic construction and development, the potential geological disasters, such as land subsidence, seawater intrusion, karst collapse, the soil saline and so on may occur.

- It demonstrates the characteristics of groundwater resources and environment in Asia. The mapping content and methods is fully based on the characteristics of topography and geological structure, groundwater media division, water resource amount, water environment, which display the comprehensive evaluation of resources and environmental features, especially for thick Quaternary aquifer, Mesozoic pore-fracture aquifer, water quality, and involves in the innovative characteristics.

MAPPING TECHNICAL METHOD

This compilation reveals the main characteristics of geological environment and groundwater on the Asian continent. The map will reflect the objective conditions of groundwater storage, groundwater resources, geothermal resources and so on. Collection of national data can keep the future international cooperation and organization and coordination.

The Asian continent can be divided into East Asia, Central Asia, West Asia, North Asia, South Asia and Southeast Asia by geographical location of which each region can select a lead country responsible for collecting the groundwater resources and environmental geology information. After the data collection, it should be classified into the national distribution of groundwater resources, groundwater type, chemical types and distribution of groundwater quality etc. In addition to geological phenomena, there are some special information, such as spring, land subsidence, volcanoes, lagoons and so on. The remote sensing can help the low study level country for more information what we need. Analysis of data and integrating with the same method, according to different regions of groundwater resources and environmental geology, can prepare for a working basis of the map series.

Use of existing mature technology, combined with Asian characteristics of groundwater resources and environmental data and requirements, can establish data processing and application system and the initial construction of groundwater resources and environment dynamic information platform. In the process of establishing the database, the formation of a database can be set up. Through its new database, using geographic information system (GIS) technology, a dynamic groundwater resources and environment information management system will be birthed for international sharing and updates in Asia.

Establishment of an international cooperation organization for mapping needs expert consultation to develop the outline, standard, uniform terminology and accuracy to harmonize map content and mapping method.

Mapping innovation should be on these points: 1) make full use of satellite remote sensing to address the low level research and the issue of lacking information areas to supplement the existing data in the compilations of the deficiency; 2) use of geographic information systems (GIS) and network set up groundwater resources and environment and dynamic information platform for data sharing and update; 3) analog technology should be used to balance the relevant information for intercontinental difference in regional compilations at scales; 4) Comparison of trans-border aquifers technology, research in the same river basin for water resources between countries can solve the development and utilization of environmental and geological problems; 5) In the hydrogeological map, some special types such as multi-structure of porous aquifers, fracture-pore groundwater may often be ignored or their definition of ambiguity can be expressed through symbols in the map.

APPLICATION OF THE MAP SERIES

Groundwater resources and environmental geology map series for the Asian countries can provide a scientific basis on groundwater development and utilization of natural resources, resource planning, environmental protection and disaster prevention to improve understanding of groundwater resources and environment.

Mapping by the advanced idea and methods can enrich the map content. The new set of the outline and the unified standard for the future small-scale maps may provide a useful reference value. The study on transboundary aquifer makes a proposal for settlement of groundwater pollution caused by human activities. On the international front, multi-national cooperation needs through the equality of sharing international cooperation.

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International Association of Hydrogeologists



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2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0