Chapter 4
Map Design

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4.1 Introduction

Map design refers to creating a comprehensive plan for the technical specification of the map, the overall structure, the mathematical foundation, the map content and means of expression, the map symbol and color, the production craft and so on. Map design must be based on the visual perception theory and map design principles, aiming at the purposes of the map and the requirements of the user. In general, some principle provisions would be provided in the forms of a map design document, map compilation specifications, map legends or symbols, and so on.

Map design is essentially the process of creating a map. That is, the representation of the colorful and real geographic world on a map. Map design has always been the focus of scientific research on surveying and mapping and is the core problem in cartography. The transference process from the ground to the map consists of two stages: the first is the perception of the objective world, and the second is the formal design for the expression of the perception.

Map design mainly uses modeling methods to understand the drafted objects of the objective world. That is, generalizations are made regarding the drawing objects according to the needs of different users, and the scientific contents of the map are established. The use and regional characteristics of the map and map scale limits must be made clear based on a reduced map model. A person's ability to understand, analyze and generalize are important to semantically select, process, and classify the objective factors and phenomena, and the content fitting for the expression and level of detail must be confirmed. That is, it must be decided what to express and to what extent. Therefore, many factors, such as people's cognitive ability and application needs, as well as the social environment and technical characteristics may play a key role in map design.

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A symbolic method is primarily used in formal design to express people's understanding, to process the graphics of drawing objects and to outline the whole picture of the map. The problems that need to be resolved at this stage are outlined as follows: How do we express various objects and phenomena with map symbols? How can we design symbols and drawings using graphic semiotics and color theory? How do we use graphics technology and crafts to ensure the effectiveness of the map product? At this point, the cartographer's quality, such as the design ability of symbols, the cartographic generalization knowledge of map content, the cultivation of the map aesthetics, the drawing experience and skills, the mapping technology level and ability, etc., may play key roles.

It can be seen from the process and content of map design that not only the objective factors, which include the use of maps, map scale, and the regional characteristics of mapping, but also the subjective factors, such as the map representation methods, the human cognitive ability, the human visual perception and feelings, and the mapping and printing technology will affect map design. Therefore, map design has been the research focus and a difficult problem in the field of map science. It is also one of the bottlenecks restricting automated map production. At present, the way of human thinking and creative inspiration is not clear, nor is the simulation of these operations with a computer. Thus, the map design is also full of challenges and creativity. For 60 years, a large number of theoretical and technical methods and innovations have been carried out in this field by Chinese cartographers, and a series of standards, such as general map compilation specification and schema have been formed. These specifications have been used to guide the compilation and update the national series of scale topographic maps. A high level of general maps, thematic maps and comprehensive atlases were designed and compiled. The corresponding computer-aided map design system and digital mapping system were researched and built, and many multimedia electronic maps and network maps for the country and certain regions were produced and published. These maps provide solid theoretical and methodological guidance for future map design.

4.2 Development Process

For 60 years, the types of cartographic products have increasingly diversified from the static paper map to the dynamic electronic map, multimedia map, and network map; furthermore, an accessible virtual geographic environment has been created. Map contents cover wide ranges from the land to the ocean, from the underground to the air and further to outdoor and indoor spaces. The map production process evolved from manual to computer-aided mapping and then to full digital mapping based on the map database. The changes in map contents, types and production technologies will inevitably lead to the changes in map design theory, map representation method, map design process technology and other aspects. The development of map design, according to the map design method and the main object of map design, can be divided into the following 5 stages.

4.2.1 The Manual Map Design Phase with a General Map as the Mainstay

This stage refers to the period from the founding of new China in 1949 to the beginning of the 1960s. Maps, especially general maps, were mainly designed and produced by hand in this stage. Paper maps were the only form of map, emphasizing the design skills and artistic quality of map works.

This period was just 10 years after the founding of new China (1949–1959). It was also in this 10 years that traditional cartography (before the end of the 1950s and early 1960s) developed and was perfected. Cartography in this period formed as a complete system of map production theory, method, technology and craft.

Map design in traditional cartography aimed at the use of technology to solve the problem of map content abstraction and generalization from the ground surface to the map, map projection, map representation method, map-making art and method and so on. The emphasis was on the technological level of map-making and production and the effect of the map product, i.e., design skills and the art of map work, while focusing on whether the design results met cartographic requirements.

Under the guidance of this kind of thought, the requirements of experience, technology and art level of the design personnel are higher. Designers are required to be able to design and draw a map in compliance with regulations according to the uses of the map, to design map symbols according to the characteristics of color, to choose a reasonable representation method according to the characteristics of features, to make a plan of drawing operation and the print process according to the technical requirements of manual editing, drawing, photographs, reprints, coating, plate making, printing, and so on. To meet those requirements, by the guidance of experts, designers complete many map readings, analyses, designs and practices for a long time and explore the "skills" and "rules" in the process of map design. Designers need to summarize and refine the technologies and methods that can be sensed but not expressed in words to determine what is the regularity of practical significance. Therefore, map design in this period is mainly based on experience and lacks a complete set of design theory and method guidance. The process and results of the design are inevitably subjective, and the design quality depends on the experience, art and skills of the designer. However, this period covers the early days of China's founding, and national construction, especially economic construction, requires many investigations and map productions. To meet the needs of different industries, a large number of general maps need to be designed and produced. Cartographers conducted a large number of investigations and summarized the modeling process from the ground to the map, including what geographical features should be represented in the map? How are the contents of expression sorted? How is each type of object classified? And so on. That is, to study the simplified or recognized abstract model and the assortment and classification model of objects (or phenomena), a number of national wide water systems, a mountain range assortment and classification charts, as well as population density classification maps were compiled. In

the aspect of representation method, after many experiments and statistical analyses, a set of topographic map symbols, including symbol shape, size and color, was designed based on the characteristics of the map elements, color, symbol, reading habits, and so on. It is consistent with the map content (Min 1957). After research, the contents representation principles and methods of the general map in China were basically formed. In addition, a series of common map works were designed, and among them, the design and compilation of China's topographic map and geographic map is representative.

(1) **Design of the topographic map**

There are two characteristics of topographic maps in this period. First, the map symbol is not only very detailed and clear but also has vivid content. The map symbol can fully reflect the real situation of the ground and its roles in the national economy; second, compared with the previous map, the topographic map has improved the timeliness, completeness and artistry of content and representation methods (Wu 1959).

The timeliness is reflected in the aspect that most of the topographic maps at that time were based on aerial photographs. The content that was not shown in the photo had been acquired through field annotation or measurement, such as the population of a residential area, the depth of a river and its flow rate, road traffic conditions, the variety and diameters of trees, and so on. At the same time, a currency check system was initially established to maintain the timeliness of the map. The completeness is reflected in the full consideration of use requirements and convenience. For example, the design of drawings is very complete: a slope ruler was attached outside the border to facilitate the determination of the slope of the terrain; a kilometer network was plotted for the convenience of measuring the area of the ground for the direction and distance between points, as well as the precise coordinates of a point; the three-north direction line was added to distinguish map orientation; and the serial number of the adjoining sheet was labeled on the four edges of the map for the purposes of map matching. The artistry was shown in the two aspects of color design and map surface decoration. First, natural colors are used for the ground features in the design of the map to represent each element of the map, so there is no need to use text to identify the water, vegetation, landscape and other natural elements. Conversely, bright, unnatural colors are used to express the very important geographical elements and to reflect the hierarchical structure of the map elements, and as a result, all kinds of topographic maps were published in multiple colors. This not only can increase the artistry but can also improve map legibility and increase map information loading. Second, the design expectations for map surface decoration are very rigorous and fine; there are strict requirements for the sizes of the map symbols, line number thickness, arrangement of fonts, map layout, and so on. In particular, the use of the scribing method in the 1960s makes the map symbols more sophisticated and beautiful.

(2) **Design of the small-scale general map**

Based on the compilation of topographic maps, with a large number of geographical survey and research results, the design of small-scale general maps began to occur. In this period, a variety of small-scale general maps were compiled. The representative results are outlined as follows: 1:1,500,000 National Situation Map, 1:4,000,000 China Relief Map, 1:1,200,000 general map and 1:1,400,000 Southeast Asia Situation Map. Among them, the 1:1,500,000 National Situation Map has beautiful colors and better print quality, which laid a foundation for the subsequent small-scale general map. The 1:4,000,000 China Relief Map uses the two-layer planar method to represent a network of rivers, including primary and secondary tributaries; the contour description is a vivid reflection of the landform, and the special landform symbols are more expressive.

In this period, the production technique for the topographic map and small-scale general map was usually the traditional method, that is, the original publication was obtained through the map compilation and fair drawing procedures.

For a large-scale map with simple content, the cartographic generalization involves a little work, so the method "compilation together with drafting, mapping at one time" was realized in the late 1950s and early 1960s. At the same time, topographic map compilation for parts of provinces also started, and the large atlas and thematic atlas were also prepared. These maps provided important guidance and practical basis for the follow-up compilation of general maps, thematic maps and atlases.

In the practice of designing and compiling general maps, cartographers began to study the quantity and quality standards of mapping for different scale maps, how to fully reflect the geographical features on the map, the cartographic generalization of map content, and other issues. Cartographers stressed designing a reasonable map representation method in accordance with the law of geographic research and improving the objectivity and expression accuracy of ground objects and geographical phenomena. In addition, corresponding research results were obtained.

4.2.2 The Manual Map Design Phase with the General Atlas as the Mainstay

This stage roughly refers to the 1960s to 1970s. In China, to meet the needs of national economic construction, science and culture in mapping, a large number of geological survey and mapping results, especially the published series scale topographic map and general map, provided abundant cartographic data for the design and compilation of the atlas; thus, the compilation of a large national atlas began. The provinces and autonomous regions in which conditions permitted mapping also successively compiled regional atlases.

China's large national atlas is a state key scientific research project co-implemented by the Chinese Academy of Sciences and the State General Bureau

of Surveying and Mapping, which began in 1958, and the atlas consists of four volumes: general, nature, economy, and history. In 1981, the State Council once again listed the national atlas as a state key scientific research project. *The People's Republic of China Agricultural Atlas* was added as the fifth volume in addition to the original four volumes. These volumes were successively published in the 1990s.

The design content and process of the large national atlas including *the People's Republic of China General Atlas* are very complex, involving the overall structural design, the expression method of each element, the symbolic system, the cartographic generalization index, colors, the processing scheme, and so on. Therefore, the design of this atlas was of great scientific significance and application value but also had a significant international impact. The design idea, theory, method and compilation technology were strongly advanced due to the research on the theory and method of map design, and this promoted the compilation of the China's provincial atlas (Liu 1963) and provided theoretical and technical guidance for the preparation of regional Atlases.

In addition, design and editing of the *the People's Republic of China Atlas* began at the end of 1972; after 8 years, bookbinding and a stylebook were completed in the first half of 1980; and finally, the atlas was printed in Octavo by the Chinese Map Publishing House in 1981 (generally referred to as the Octavo, China atlas). This atlas is the largest folio and most detailed Chinese atlas created since the founding of new China.

Overall, through the design and compilation of the general atlas and the research on the comprehensive index of map content, map expression methods, map layout design, color design, and so on, the general rules of map design were discovered and summarized, which laid a solid foundation for the further research on the theory and method of map design.

4.2.3 Computer-Aided Map Design Phase with the Regional Atlas as the Mainstay

This stage generally refers to the 1980s, which is considered to be a period of great technological breakthroughs. In the field of cartography, the technology of computer-aided mapping began to replace manual mapping technology, which provided a new technical means of map compilation. China's reform and opening up had just begun, and national economic construction and national defense construction were undergoing rapid development and various types of maps and atlases were needed to meet the needs of all aspects of economic and transportation construction. Therefore, the objective of map design during this period was creation of regional atlases, that is, provincial (autonomous regions and municipalities directly under the central government) atlases. This period was the second pinnacle in atlas compilation at home, and a series of provincial atlases, including the Shanxi Province Atlas and Shanghai City Atlas were designed and completed.

In addition, with the development of the national economy, the preparation of all kinds of city maps and atlases was scheduled. Most of the existing large-scale urban maps were compiled before the 1970s. After entering the 1980s, urban construction developed rapidly and changed significantly. It was urgent to develop a new batch of urban maps to meet the needs of urban planning, construction and management. At the same time, to implement urban planning in a organized and comprehensive way, a map must reflect the status of the city in detail. Therefore, the compilation of the current situation maps in some cities began in this period. The problem of using color infrared aerial photograph for compiling the current situation map of city was discussed (Pan 1989).

The design and preparation of a large number of provincial atlases met the needs of economic construction, especially urban construction, and promoted the theory and method of map design. Prof. GAO Jun (an academic of the Chinese Academy of Sciences) recommended the theory of cartography from Europe and the United States in 1982 and first introduced the cartographic visual perception theory in China in 1984; he proposed that cartographic visual perception theory should be used to guide map design to improve the communication efficiency of the map (Gao 1984). This proposal marked the deepening of research on the related theories and methods of map design in China, such as cartographic perception theory, cartographic communication theory and cartographic semiotics theory. After that, map design gradually transformed from purely empirical and results-oriented methods to the map design theory, as well as the map user's needs and the visual perception effect.

4.2.4 The Human-Computer Interaction Map Design Phase with the Electronic Map and Comprehensive Atlas as the Mainstays

The human-computer interaction map design stage occurred just after the 1990s. In this period, full digital mapping technology and multimedia technology became mainstream technology. At the same time, multi-resolution, multi-temporal satellite image data covering the whole country, as well as the globe, became important information sources for general and thematic maps. The types of cartographic products expanded.

In the 1990s, the electronic map editing and publishing system came out and broke the traditional division boundaries of mapping and publishing. This system marked a new turning point, where the traditional manual production mode was replaced with the emergence of entirely digital mapping and publication. An integrated digital mapping and publishing system has the functions of map design, map compilation, color separation netting and film output and has been applied to produce a number of maps and atlases. The new technology of direct digital map plate making also led to fundamental changes in mapping technology. The compilation and publication

of maps and atlases realized the fundamental transformation from the traditional process to full digitalization and automation.

(1) **Research on the theory of map design**

In the field of map design theory research, the applied study of cartographic visual perception theory, cartographic spatial cognition theory, cartographic transmission theory and cartographic semiotics theory began in the 1990s. The research on cartographic expert system technology has also progressed. Expert systems with a certain use value emerged in succession. These systems provided a new technical means for the design of thematic maps, the selection of map projects, the rapid creation of the design scheme and the rapid generation of statistical maps. In addition, the scientific nature, accuracy and design efficiency of the map design was improved, and map designs changed from manual mode to the intelligent design of human-computer interactions (Zhang 1990; Gao 1993).

In terms of map representation, symbol design, legend design, and color design, some scholars expounded the basic structure and characteristics of the thematic map legend system from the viewpoint of system theory (Liu et al. 1992); the concept of symbolic constitutional elements was put forward based on map transmission theory, and its design pattern was summarized as "Selection, Matching, Superposition, Strengthening, Weakening, Stretching and Compression". In addition, an example was provided to illustrate the design pattern and process of symbolic constitution elements (Ma 1995). Some experts believed that a deeper understanding of map symbols and better development of its information function from only the perspective of practical technology was not enough. The essence, characteristics, functions and application rules of the map symbol should be analyzed at the height of ideology, culture and philosophy. It was considered that the essence of the map symbol was the artificial referent of the objective entity and the expression medium of the cartographer's ideology. Compared with other symbols, there are similarities and dissimilarities. For that reason, the multiple functions of map symbols in human expression, cognition, thinking, culture and aesthetics were discussed, and the aesthetic study of the map was included for the beauty of the map and to explore the issues of creative thinking and methodology. The role of artistic thinking in map creation, the relationship between map science creation and the creation of beauty were also discussed. At the same time, the research content of map aesthetics and art education for map workers were described (Yu 1990, 1995).

(2) **Research on electronic map design**

As a new form of expression, the electronic map has its own characteristics and rules in map design and expression. In the design of the electronic map, the visual variable and its perceptual effect is one of the key research fields of theoretical cartography. Through much research and practice, relevant results have been achieved and used to guide the design of the electronic map.

The emergence of the electronic map has changed the way of reading the map. Considering the dynamic, interactive and multimedia characteristics of the electronic

map, the display mechanism, expression scope, representation method, visual variable and perceptual effect of the map have changed greatly. The roaming function of the map, which goes beyond the limits of reading on a sheet map, expands the scope of mapping. The dynamic nature of the map extends its expressive pattern, taking map develop from static browsing to dynamic interaction and so on. The research on the modern map has been beyond the scope of the Earth and extends to the study of the relationship between other planets and stars, as well as various aircraft tracks in the sky. Therefore, how to scientifically design the electronic map of the screen, including the dynamic symbol composition rule of the electronic map, visual variables, dynamic mapping technology, and so on, as well as a series of theoretical and methodological issues, require further studied. In addition to the visual variables and the perception effect, the visual perception research on the electronic map also includes the visual perception effect of legend design (online legend, legend arrangement, animation map legend), the perception effect of the series screen electronic map, the animated map and the 3D map (Chen et al. 1999). Based on the Bertin symbolic parameter system, four dynamic parameters were extended by Ai (1998), that is, the interval length, change rate, change order, and rhythm. These results indicate that the method of map representation has been changed from a simple static method to hybrid representation methods that include a combination of static and movement, a combination of pictures and texts and a combination of multimedia. The performance of the map and the effect of the information transmission have been improved. Based on analyzing the development status and multimedia electronic map trends at home and abroad and aiming at the special geographical region of the Arctic, Pang et al. (1999) used the MapInfo platform to explore a new means of making a multimedia electronic map based on a color map electronic publishing system. The result is of greater use value to electronic map production. Xu et al. (2007) thought that the design principle of the network map was embodied in interface design, layer display design, symbol design, annotation design and color design. Network map design involves many aspects, such as the network service platform, network map data source, network map expression form, network map design technology process, and so on. Wang et al. (2008) put forward the technical requirement of the design and expression of the network electronic map from the viewpoint of map cognition.

(3) **Study on the urban atlas design**

Due to the rapid development of cities, urban construction, urban development and planning, urban tourism, urban external contacts, and others, need to prepare a series of maps and atlases, various electronic versions of the atlas and a multimedia electronic atlas.

Compared with the previous atlas, these urban atlases had breakthroughs in terms of design features and representation methods. The design of the "*Beijing Tourism Atlas*" broke through the monotonous representation of only a flat map. This tourist attraction map used an aerial photo map, perspective view map, topographic shading map, bird's eye view and sketch map to represent three-dimensional phenomena on a two-dimensional map according to the different natural and humanistic landscape

characteristics of tourist attractions, causing the elements expressed on the flat map to produce the stereoscopic effects and have a strong sense of reality (Qian 1992). At the same time, modern advanced technologies and methods, such as a remote sensing analysis system and geographic information system, were applied to the design and compilation of the atlas, especially the thematic analysis atlas. This has revolutionized the printing technique of the atlas and promoted the development of modern atlas compiling technology. Yin (1992) also introduced the method and skill of making an urban planning atlas using an integrated map compiling, designing and printing system.

The production of the urban atlas during this period was mainly based on the map database, which used computer-aided mapping technology. For example, Zou et al. (1998) discussed in detail the method of digital mapping production based on MicroStation and pointed out that digital mapping is the only way to realize the foundational transformation of map production toward digital, rapid, modern, and automated mapping. He et al. (1999, 2003) described the creation method for the electronic atlas and introduced the computer-aided mapping and plate making techniques and atlas processing. Hong et al. (2006) introduced the method of using new technology to compile a geographic base chart, a group of thematic maps, and a group of general maps.

Furthermore, the content, structure and development trend of the urban atlas were also discussed, it was pointed out that the content of the urban atlas should show the "present" and "future", and the development direction of a city; the structure of an atlas should have individuality, highlighting the characteristics of the city; it needs to achieve the unification of content and form for a specific map; the color design should be scientific to reflect the regularity; it requires the development of a series of large-scale city maps to be conducive to facilitating the planning and construction of a city (Ding 1992). The research of the content, function, representation and symbol system of an urban map should be strengthened for modern urban mapping to make it develop toward comprehensive mapping (Zhan 1993).

(4) **Study on electronic atlas design**

The electronic atlas emerged as a new cartographic work at the end of the 1990s. On the one hand, the multimedia electronic atlas became a new means for the transmission of geographic information. On the other hand, it put forth the concept of "geography" and "space" for traditional electronic reading materials, which makes the expression and transmission of geographical information more direct and effective. In addition to the characteristics of the traditional atlas, due to the application of computer technology, multimedia technology and visualization technology, the electronic atlas is easier to modify and update, the production cycle is shorter, and the cost is lower. The flexibility, selectivity, reality and dynamic nature of the electronic map, with automatic map subdivision, automatic establishment of mathematical foundation, automatic generalization of map data, map database storage and management, map symbol library, and other functions, frees the user from the limitations of the map sheet and fixed scale. In addition, spatial data can be extracted from elements

and layers according to the practical requirements. More importantly, image generation technology can be used to visually represent some scientific phenomena, natural landscape and even abstract concept in a vivid, intuitive, and dynamic approach. It is convenient for people to understand, judge and analyze from different viewpoints and perspectives. At the same time, the analysis function of the atlas can be used for the deep processing of information to obtain conclusive thematic maps or thematic data sets; so the functions and values of the atlas should be fully exhibited. These kinds of works (electronic version) are outlined as follows: '*National Nature Atlas of the People's Republic of China*', '*National Economy Atlas of China*', '*National General Atlas of China*' and '*Population Atlas of China*', '*Hong Kong Electronic Atlas*', '*Shenzhen Electronic Atlas*', and so on. These atlases have various functions, such as a zoom window, dynamic representation, query and search, statistical analysis, superposition and comparison, cartometry, and so on. They are gradually developing towards an integrated geographic information system.

Compared with the previous paper atlas, the electronic atlas has undergone great changes in various aspects of the concept, characteristics, classification, composition, production technique and so on. From the aspect of the map display mechanism, the electronic atlas database storage structure and management technology, automatic map subdivision technique, automatic generalization of map content and multi-scale display technology need to be studied. From the aspect of data expression, in addition to consideration of the characteristics of a single electronic map, the completeness, logic, and consistency of the map symbol need to be studied. Zhang (1996) introduced the application of the electronic map (atlas) at home and abroad, and discussed the development trend of the electronic map (atlas); based on the practical design and production of several urban multimedia electronic atlases, Xu et al. (2003) summarized the basic ideas for the designing and realization of an urban multimedia electronic atlas; Wang et al. (2005) discussed the automatic map subdivision of the electronic atlas, database storage structure and management technique, automatic generalization and multi-scale display technology; Shi et al. (2008) proposed a super media network information organization structure based on 'graph group-thematic-map sheet' to reflect the basic geographical features of a region, and they described the content framework of an integrated electronic atlas for an urban area that considers the distribution law of all kinds of natural and social economic factors and their relationships to be the main content.

(5) **Study on the image atlas design**

Satellite image data has become an important data source for the general map and thematic mapping and promotes the design and preparation of an image map (atlas), and so on. In the process of the design and compilation of an image atlas, how to retain the integrity of image information and overlay more cultural information is a problem that requires an atlas designer to address. According to the practical needs, designers have put forward some design ideas, such as "highlight the map and supplement with the image" (*Shenzhen Photo Atlas* as a typical case), "highlight the image and supplement with the map" (*Image Atlas of Shanghai City* as a typical case) and the

"map and image fusion with each other" (*Image Atlas of Suzhou City* as a typical case). The vector representation principle of the image map (atlas) features and the design principle of the symbol system and image map color were summarized, and many image atlases have been designed and compiled, such as the *Shenzhen City Photo Atlas* (China Map Publishing House, 1999), *Lanzhou City Image Atlas* (Gansu People's Publishing House, 2003), *Nanjing City Image Atlas* (Chengdu Map Publishing House, 2004), *Hong Kong Street* (compiled and published by the Survey and Mapping Office of the Lands Department, government of the Hong Kong Special Administrative Region, 2005), and so on. At the same time, through the design of *Image Atlas of Shanghai City* (Huang 1992) and *Image Atlas of Suzhou City* (Wang et al. 2007), the theory, method and technology of image atlas production based on a high resolution aerial (remote sensing) image were studied and tested, the principles and methods of the overall design, color design, symbol design and others for the image map (atlas) were put forward to guide the making of an image map (atlas).

(6) **Study of the national atlas design**

In this period, the compilations of the *Great National Atlas of China* were completed progressively: *The National Agricultural Atlas of People's Republic of China* was completed in 1990; *The National Economic Atlas of People's Republic of China* was completed in 1993; and *The National General Atlas of the People's Republic of China* was completed in 1995. The national atlas reached the international level of cartography at the time in terms of content selection, overall design, expression method, technique and technology, as well as in other aspects. This atlas promoted the research of the theory and method of map design and provided guidance for the compilation of the provincial atlas (the expression contents and methods of each atlas have been described in detail in the map works).

4.2.5 Human-Computer Cooperative Map Design Phase with the Coexistence of Many Varieties of Maps

Since entering the 21 century, with the further improvement and extensive application of GIS technology, as well as the application of virtual reality technology, visualization technology, and multimedia technology in cartography, great changes have occurred in the map production process; meanwhile, the variety of maps has been greatly expanded, so that the digital map, electronic map, dynamic map, three-dimensional map, accessible map and the like have emerged in succession (Gao 1997). Map design must be carried out on the visual human-machine collaboration platform, which is based on the integration of various technologies. At the same time, in the production of an electronic atlas, it can quickly produce a paper map (atlas) and establish a map information system. Therefore, map design in this period can be called the human-computer cooperative map design phase with the coexistence of many varieties of maps. The main objective is the design of an electronic map,

network map and large comprehensive atlas (system). The aim is to improve the human and computer collaborative map design, and collectively accomplished the complex geographic information fusion, process and display, while emphasizes the scientific nature, accuracy, systematicity and authenticity of the design results.

After decades of development, China's cartography has caught up with the advanced countries in the world. Especially in the past 10 years, cartography has entered a period of rapid development. Mapping technology has realized the historical transformation from traditional manual mapping to digital and integrated mapping. In addition, the product has realized the transformation from single paper map to digital map, electronic map, network map, geographic information system, virtual geographic environment and so on. The theory, technology and method of map design have changed greatly. These changes force us to study the cartographic experts' way of thinking in the production and design of a map, to pay attention to whether the results of design meet the requirements of users, and to consider people and map as a whole; that is to say, we are not only concerned about the process from spot to map but also concentrate on the relationship between reader and map. As a result, we need to explore the theory and method of map content design, expression mode design, representation design, layout and its effect design to adapt to the new changes in map demand. This change in the design concept lets us pay more attention to the guiding role of a human's cognitive ability and map perception effect on map design and gradually places map design under the guidance of theory instead of experienced supervisors.

For map design, the goals are to design a map to let the users of the map obtain more information and knowledge, make people have the feeling of pleasure, make the map reflect well-known information and support the discovery of unknown information and knowledge. In a word, how can readers quickly and effectively obtain the necessary information and knowledge from the map? This requires study from the user's perspective on the problems, such as the visual perception characteristics of user groups, the map usage, the personalized and professional map features, the human's cognitive ability and so on. These problems involve the purpose of the map, the level of knowledge, thinking and judgment, aesthetic quality of map designers and map users, and other factors. Therefore, map design is a process of creative thinking and abstraction; not only are scientific theories (map spatial cognition theory, map information transmission theory, visual perception theory, semiotics, map aesthetics, psychology, physiology, artificial intelligence and other fields of knowledge) required for guidance, but advanced technologies, such as computer-aided mapping technology, map database technology, virtual reality technology, graphics and image processing technology, visualization technology and so on, are also required. Only with rich experience, broad geographical knowledge, considerable cultural and artistic accomplishment, proficiency in the basic theory and process of cartography, and a high spatial cognition ability can a map designer be qualified for map design, map production, and map innovation. Undoubtedly, these requirements create higher standards for map designers.

4.3 Main Research Achievements

4.3.1 The Study of the Topographic Map System

Since the founding of the People's Republic of China, a large number of general maps have been compiled. Among them, the national series of scale topographic maps formed the standard and systematic results. The national maps maintain scientific unity and connection in map projection, sheet numbering, coordinate system, and elevation system; additionally, there is a symbol system with relatively fixed content and basically similar symbols. A large-scale topographic map was compiled and published in 1952 and revised in 1953 and 1958; then, the compilation specifications and schema for large-scale topographic maps was formed. In addition, China's topographic map system, including 1:50,000, 1:100,000, 1:200,000, 1:500,000, and 1:1,000,000 topographic maps, was put forward.

With the increase in map applications and the development of mapping technology, on the basis of the full study of the requirements of various kinds of maps, the original 1:200,000 topographic map was withdrawn in 1980, while a new series of scale topographic maps were formed, including 1:10,000, 1:25,000, 1:50,000, 1:100,000, 1:250,000, 1:500,000, and 1:1,000,000 topographic maps. These maps are divided into three levels of large, medium and small according to the scale, i.e., 1:10,000, 1:25,000, 1:50,000, and 1:100,000 are large scale topographic maps, 1:250,000 and 1:500,000 are medium scale maps, and 1:200,000, 1:500,000, and 1:1,000,000 are small scale topographic maps. Currently the most commonly used maps are 1:10,000, 1:50,000 and 1:250,000.

In the past 60 years, studies and practices on the classification and grading of topographic map content, the expression method of all elements and the symbols and colors have been carried out by cartographers. The compilation of different scale of topographic maps nationwide was completed. Among them, the representative work is the millionth scale topographic map (also known as the new 1:1,000,000 map), which was compiled and published in 1959, a total of 64 sheets. The characteristics of the millionth scale topographic map were analyzed and studied by Liu et al. (1958) and Gao (1963). In addition, the expression method and its comprehensive characteristics of the water system on the topographic map was discussed in detail by Wu (1959). Based on the practical and theoretical summary of map compilation, many scholars put forward many amendments to the map schema and symbols at that time. For example, Qian (1985) conducted a preliminary test on the military value of China's series scale topographic map symbols and pointed out that these maps were appropriate for both military and civilian use; the maps also changed frequently and had more supplementary provisions, so that the mapping products based on these maps were not uniform enough; finally, improvements were suggested. Huang (1964) discussed the symbol representation of topographic maps in the desert region and proposed amendments. These study results provided technical and methodological guidance for the production of topographic maps and enabled the topographic map system and schema symbols to be gradually standardized and made more scientific.

Since the 1990s, to meet the needs of digital production and information construction, China has established the corresponding basic map database for 1:10,000, 1:50,000 and 1:250,000 scale maps, which were regularly updated; China also formed a geographic information encoding standard for the digital environment and map symbol storage regulations. In addition, a series of studies on the standardization, normalization and serialization of topographic map symbols and design have been carried out. Yang (1993) proposed a three bit digital code that was arranged in layers, classes and categories for large scale topographic map (1:500 to 1:2,000) scheme symbols, which not only covers all the symbols but also includes marginal decoration, map surface lettering, and even symbols of cadastral surveys; Dingguo also suggested the improvement of some topographic symbols to adapt to the needs of computer graphics. These factors are conducive to the standardization and normalization of digital terrain surveying and digital cadastral surveying. Yin (1997) discussed the factors affecting the quality of the national basic topographic map and suggested improvements to the design of the national basic topographic map in China based on the investigation and analysis of China's national basic topographic map and its corresponding compilation specification and schema; these suggestions were in reference to the design experience of foreign topographic maps. The mathematical definition of scale symbol, non-scale symbol and semi-scale symbol in the map was improved by Huang et al. (2006), and the conditions for the transformation of these three kinds of map symbols were discussed. These results have important reference values to the further standardization, normalization and serialization of topographic map design, to improve the fine degree of topographic map symbols and notes, to improve map color design and map decoration design and to increase the layering and expression of a map.

4.3.2 The Research on the Design of Small Scale General Map

On the basis of topographic map compilation, since the 1960s, a variety of small scale general maps have been compiled and published, such as 1:1,500,000 *National Situation Map*, 1:4,000,000 *China Relief Map*, 1:2,000,000 *General Map,* 1:4,000,000 *Southeastern Asia Situation Map*, 1:2,500,000 *Whole Chinese Territory Map*, 1:3,000,000 *The People's Republic of China Map* and 1:5,000,000 *World Geographic Map.* In addition, the design principles of the small scale general map, the expressive content and the expression method were deeply studied, and some research results have been obtained. Among them, the China Relief Map is worth mentioning as an important tool for scientific research, especially for geographical research, and has been highly valued by cartographic scholars for the theoretical and practical results in the geomorphology representation method. As a representative figure of the relief shading method, Shi (1964) performed an experiment and summarized the expression method of the 1:4,000,000 *China Hypsometric Shading Map*,

and he discussed the shading representation and color decoration of the geomorphic features on the small scale relief map. Wu (1965) studied the design features of the terrain height meter and put forward some principles and methods for the selection of a terrain height table. These research results provide the basis and technical method for the following 3D terrain representations. With the improvement in map printing technology and the widespread use of the halftone original decoration method, Liu (1965) put forward the principle and method for improving the production and replication technology of the shading original. Zhang (1966) summarized five methods of making a hypsometric map, where the proposed "iterative duplication method" not only can solve the problem of producing flat color edition but also solve the absolute transparency of each hypsometric negative; thus, the quality of plate making was significantly improved. At the same time, he proposed that the strip masking method should be used for making a hypsometric edition whenever possible to save time during retouching and allow layer and layer and layer and water be more closely matched. This study showed a new prospect for the improvement of the making hypsometric map method. These results provide a wealth of practical references for the scientific expression of small scale maps, especially terrain maps, and provide guidance for the design of a series of small scale maps (atlases). According to the theoretical research and experience, the following conclusions are obtained. Shading can enhance and improve the expressiveness of the landform morphology and regional landforms; it is feasible to represent a landform with hill shading as a primary method, and the contouring and hypsometric methods are secondary. Finally, the scheme of height grading and color table for the landform expression of small scale terrain maps in China was preliminarily designed and established.

With the application of computer technology, new achievements in the design, compilation and representation methods of small scale general maps have been made. Wu (1988) provided the formula for calculating the gray level of the terrain surface in the projection plane and the shading algorithm for the natural landscape. Xu et al. (2002) introduced the background of the establishment of the 1:4,000,000 *Administrative Map of the People's Republic of China* and emphatically explained the use of compiling the data and characteristics of the map content, technical route design and map products. Li et al. (2002) researched the relief representation method for the 1:3,000,000 *Geographic Map of the People's Republic of China*; he described the selection of the relief representation method and obtained results with the help of a computer; finally, he summarized the technology and method of computer-based relief shading for a small scale geographical wall map.

These studies have shown that using the digital mapping technical route and process with computer mapping as the main body, supplemented by local manual transition plotting, is feasible. In the whole process of map design and compilation, the procedures, including map content design, computer production, binding design, step-by-step transition transfer and so on, were implemented synchronously and alternately according to the program flowchart and were finally unified and combined. This is the main technical method for the design of small scale general map during this period.

4.3.3 The Study on the Overall Map Design

(1) Map symbol study

Since there is a map, there is a map symbol. Along with the progress of society and the development of map production, the application scope of the map expands day by day, and the contents need to be expressed more and more. People are constantly exploring the methods of content representation and the design of map symbols.

Map symbol design is an important part of map design. Research results in this area are outlined as follows: the system theory and method of map symbol design considering 8 factors (Wang 1993); the relationship between map symbols and characters; the significance of text symbols in the map; the evolution of nature and function of the character symbol after transplanting to map; the three types of symbols and texts on the map, such as original text symbols, text annotation symbols and text graphic symbol, and their different functions and characteristics (Yu 1996); the study on the constitution and rule of map symbols (Ling 1997a, b); the characteristics of map annotation, including the subordination of position, the dispersion of arrangement, and the hierarchy and classification of contents, as well as the map notation font, font size, text arrangement, and text color (Ling et al. 2007); and so on.

With the application of computer technology in mapping, the construction of the map symbol library and the composition rule of the electronic map symbol become an important issue in the study of map symbols, and relevant results have been achieved. Based on the theory of map transmission, Ma (1995) put forward the concept and the design pattern of symbol composition elements. This concept provides a new vision for the design of the graphic output module based on a map database, which can be used as the basis and operation mode of symbol design. Ai (1998) believed that the design principle of the traditional map symbol is based on Bertin‘s visual parameter system and to meet the requirement of map symbol design under the new technology conditions, dynamic visual variables of symbols need to be extended based on the original visual variable system to adapt to the function and application of a dynamic map in the fields of course response, real-time tracking and process monitoring. According to the definition of topology and graph theory and the visual threshold of symbol configuration, Zhong et al. (2001) proposed the concept of a lower limit (limit circle) for the clear depiction and representation of symbols. By comparing the surface area of an object on the projected plane with a limit circle, the mathematical definitions of scale symbols, non-scale symbols and semi-scale symbols were derived. Thus, the basic concepts of the three kinds of map symbols can be quantitatively described with precise mathematical expressions. Zhu (2006) put the time dimension into the dynamic map so that the electronic map experienced a new development in the form of visual expression. At the same time, this change also presented a new challenge to the problem of dynamic map visualization. The advent of the information age means that the traditional two dimensional information cannot meet the new requirements. However, the development of the computer makes it possible to display and describe the three dimensional geometric features

and attributes of objects. Fu (2007) discussed the application characteristics of the traditional two-dimensional (electronic) map symbols in a three-dimensional visualization environment and the dialectical relationship between the two, and he explored some principles of the geographic information expression and map symbol design in the three-dimensional visualization environment.

With the development of geographic information technology and digital technology, making an electronic map has become increasingly simple and convenient. The applications are growing in popularity, and digital network communication is increasingly widespread. It is imperative to promote the guidelines or standards of the electronic topographic map symbol to guarantee the uniformity and accuracy of cognized geographic information. Wang et al. (2003) suggested that the electronic map symbol system and the symbol entity should adapt to the change in digital technology and the visual environment; through his studies, a draft standard symbol library of the basic map for universal use in geographic information system software was created, and much effective testing, supplementation, modification and perfecting was done for relevant maps. The result has been published on the website of the China spatial information network.

Through these studies, the composition rules of map symbols are explained in theory. These rules provide mathematical tools for the scientific and rational design of symbols and the quantitative calculation of information loads. Thus, the experience and behavior of map symbol design is more scientific, and the theory and technology of symbol standardization and normalization has been promoted.

(2) Study on map color design

As a kind of information carrier to describe and study the living environment of humans, maps combine science and art as an organic whole. With the extensive use of maps and the continuous improvement of peoples' aesthetic abilities in mapping, an increasing amount of attention has been paid to map aesthetics. Map color design is an important part of map aesthetics and plays an important role in the beautification of the map, guiding readers to appreciate and study the map. The task of map color design is to use color to express the quantity and quality characteristics of geographical phenomena, that is, to establish a one-to-one mapping relationship between color and geographic feature data. Since a map is a scientific expression of geographical phenomena, the establishment of this kind of mapping is different from the creation of pure artistic works in which the artist has more freedom; mapping is subject to a series of mapping principles and color habits. However, map color design has never had a complete system of standards, and the practice of using color is also different from charts, which created great difficulties in map design work.

For a long time, people have carried on with research and practice for the map color characteristics, the constitutive law of the color-coded standard, the color design features of map symbols, and the characteristics and rules of the whole color design of map layout. At the same time, the characteristics and rules of color design for the electronic map, map design expert system and so on, were discussed, and a series of research results were obtained. Zhong (1989) studied the constitutive law of the map

color standard and analyzed the basic elements of color; he showed that the total number of colors in a map color standard depends on three factors and pointed out that certain regularity of coloration exists in various color standards and ink chromatography; thus, we can use these rules to create the color design according to a plant's own equipment or specific mapping task. Jiang (1991) preliminarily explored the map design expert system and clarified that a map design expert system should be composed of five parts, namely, the knowledge base, database, reasoning machine, explained part, and knowledge acquisition. This study result provides a reference for research on the map color design expert system. Taking the map design, especially the color design, as the research object, You et al. (1996) considered that color design as a specific research process is very suitable for the implementation of visualization methods; at the same time, he analyzed the advantages and strategies of the visualization method to solve this problem; finally, through examples, he discussed three problems, including the mapping of color space, the interaction between user and color space, the mapping between data and color space, and so on. Ling et al. (2000) studied color using the map boundary and pointed out that the bounding lines on a map comprise a smaller portion compared with the color block, so its role is often neglected; however, color use greatly influences the entire color effects of a map and should be considered as one of the most important aspects of map color design. Wang (2003) discussed the powerful images of color combination and considered that as a visual symbol, color is not a kind of isolated ornament once it is assembled on the map; different color combinations will result in different psychological effects, as the audiences' feeling of map work chiefly depends on mastery and use of tones. Hou (2004) described the different forms of map aesthetics, such as the appearance, drawing materials, composition of a picture, symbols, annotations and colors, and he discussed the principles and methods for the color design of a map in terms of point, line and surface symbols. Zhou (2006) suggested that like all works of art, a map requires giving prominence to the subject and having a clear hierarchy, as well as obtaining natural harmony and being rich and vivid; to achieve this effect, it is important to deal with the problems regarding color selection and color matching.

Due to the restrictions of the display device, in the process of the symbol design of an electronic map, the use of three visual variables, such as shape, size and pattern, is limited. Thus, the use of a color scheme is more important. Chen (2000) designed a color perception experiment for the electronic map - A Color Matching Experiment on Electronic Maps, and a method and idea was provided for the color matching experiment of the electronic map. Guo et al. (2004) automatically configured the colors in the national administrative region map according to the contrast harmonic theory of color design and realized the automatic implementation of color design in an administrative map. The results show that in the visual environment, the color effect of a map designed by automatic color implementation is better than that by a human with no or only little cartographic knowledge. They also explored the color design of the color hill-shading map based on visual imagery and designed a set of feasible color schemes for the color hill-shading map according to the characteristics of China's terrain, as well as laying the foundation for the establishment of hill-shading map knowledge engineering in the digital environment.

(3) Study on map aesthetics and art design

The aim of map aesthetics design is to beautify the map in the form of aesthetics that are suitable for map application to improve the information content of the map and increase the reader's interest; this enhances the transmission efficiency of information and gives the map the beauty of the present time. It is necessary to study map aesthetics and the art of map style design to develop the map design, especially large map works, thematic maps and atlas designs, to a higher level.

The artistic beauty of the map is mainly reflected in the appearance, content and color. Research results in this area are mainly listed as follows: Yu (1989, 1990) emphasized the aesthetic problems in cartographic research and discussed the necessity of research and education in map technology aesthetics from three aspects of the period request for map aesthetics, the aesthetic value and practical value, and the expression form. His papers summarized the map aesthetics rules that can guide map design work, and he discussed the relationship between the activity of mapping science and technology and the aesthetic concept and creation of beauty. He also studied the relationship between the characteristics of map aesthetics and the map visual perception effect, as well as the way to achieve complete reunification of formal beauty and functional beauty, including the characteristics and methods of external map decoration. The aesthetics of map design and map production were discussed from the perspective of technology aesthetics by You (1990). He pointed out that designers should be concerned about the fashion trends of color and product style, and it is feasible to use the technology aesthetics as the core theory to realize the art of the map, because it can guide the map design and production and meet the aesthetic requirement of the current society. Guo (1991) believed that the aesthetic characteristics of the map are the adaptability of the map to readers. Readers create the feeling of map beauty. It is only when readers adapt to the various representations of a map that they can find a sense of beauty in the map. Map contents must be determined according to the subject to be expressed by a map and to convey the correct information to readers at the same time. The adaptability of map style mainly refers to the appearance, the basic material, the composition, the symbol and so on. Wang (2004) believes that, in addition to a specific theme and rich contents, a successful map should also have beauty in form; many map designers do everything possible in the pursuit of exquisite beauty in form and a remarkable creative idea, and the purpose is to enable readers to easily obtain all kinds of information in the form of beauty, as well as produce visual aesthetic pleasure in the reading process. Yang (2007) studied the specific principles and methods of map symbol and area color design; he considered that although the design of graphics, text and numbers is important, the color design is the most effective way to reflect the inner scale and law of the artistic beauty of a map.

The results of these studies indicate that designers should grasp and apply the principle of formal beauty in long term practice, having owned the perfect knowledge structure and keeping their vision widened and their knowledge will broaden. They must also care for the development of modern science and technology, culture, art and other related fields; only then can they understand and use the formal beauty at a

higher level. Lu (1988a) stressed that the thinking mode of a map designer should have acute, random and jumping characteristics, as well as the ability to think horizontally, comprehensively and philosophically. In addition to professionals, the development of contemporary cartography needs more well-rounded designers. Map designers having a wide range of hobbies and understanding other area, such as literature, painting, music, calligraphy, photography and so on, may plays an important role in map design.

(4) Study on the applications of the map visual variable and overall design

The information transfer of the visual map is the embodiment of a map author's design idea in the visual perception of map readers. Therefore, in the process of information transfer for a whole map, the visual perception effect of the reader is the key to the success or failure of information transmission, and it should be an important basis for evaluating the quality of map design and production.

For example, in the applications of multilayer planar map design, map color design, layered landscape design, map symbol design, map title design, map frame design, and so on, reasonable use of visual illusion can not only reduce the noise in the process of map information transmission and improve the map information transmission effect but can also improve the expressiveness of the map and enhance the loading function of map information. He et al. (1991) introduced the rules and principles of common visual illusion in mapping and preliminarily discussed their applications in mapping. Chen (1995) discussed the method of establishing the mental map and its characteristics from the viewpoint of cartography. Song (2002) studied the human's visual perception and main factors affecting the perception effect, and to a certain extent, he analyzed the determination of map content selection and generalization index and the relationships among map symbol design, color design, layout, decoration design and visual perception. Some of problems that require attention in map design were proposed as a result.

4.3.4 The Study on Atlas Design

Here, we mainly introduce the studies on the overall design of the comprehensive atlas, urban atlas and electronic atlas.

(1) Study on the overall design of the comprehensive atlas

Since the 1960s, China began the compilation of a national atlas, and five large national comprehensive atlases were successively published until the 1990s. Through practice, a series of studies were carried out on the overall structure of the comprehensive atlas, including the representation methods of various elements, symbol system, color design, process scheme design, and so on. The regularity of summary results regarding the design idea, map contents, map representation method, layout design, color design and so on, effectively promoted the study of the design theory

and method of the map, as well as the compilation of provincial atlases (Liu 1963). These studies provided theoretical and technical guidance for the preparation of a regional atlas.

The upsurge of making an integrative provincial atlas appeared in the promotion of the national atlas compilation. These atlases are called the first generation of provincial atlases. After the reform and opening up, China had set off the second wave of provincial atlas compilation. Most of these atlases were general and thematic atlases, and integrative atlases were compiled less often and are called the second generation of provincial atlases. Since the end of twentieth century, the content, form and preparation methods of provincial atlases have constantly improved; the comprehensive atlas of provinces, municipalities and autonomous regions, which have been published or are being compiled, are known as the third generation of provincial atlases (hereinafter referred to as the third generation of provincial atlases).

Through the compilation practice of the comprehensive atlas, a series of research results, such as the basic principle, overall design, expression method and preparation process in the design of the comprehensive atlas and regional atlas, were summarized. For example, Zhou (1965) discussed the characteristics of compiling a regional atlas and the principles of the compilation process design; at the same time, several commonly-used regional atlas compilation process schemes were analyzed and evaluated according to the clipping, content standard compilation quality, printing effect and drawing time, and the best scheme for the production of the general geographic map in a regional atlas was given. Mao et al. (1982) discussed the structure design, use of materials, content representation, relationship between elements and map decoration of the *Atlas of the People's Republic of China*, and the characteristic of combining science and art provided a reference for the preparation of other atlases. Li (1987) discussed the principles and methods for the preparation of a river basin atlas. He stressed that the compilation of a river basin atlas can be used to summarize the scientific results of the investigation and study of Chinese rivers from various aspects, and they have important significance in the study of rivers, resource exploration, development, utilization, cities along rivers, and construction of ports, shipping, tourism and even natural ecological protection. Lu (1988b) summarized the characteristics of the atlas and put forward constructive suggestions for some problems in the compilation process of the China Atlas. She thought that for an atlas with short timeliness and little range, the use of computer mapping technology and loose-leaf binding should be considered; for a highly specialized or small drawing area atlas, that is, a small circulation atlas or an atlas that is not publicly issued, dual color printing and loose leaf binding should be adopted. Meanwhile, she pointed out that cartographers must fully understand readers and make full use of the characteristics of the atlas. These are the key factors to improving the quality of China's atlases.

Fu (1991) discussed the characteristics of atlas design, development and compilation in the information age according to the understanding of concept, process technology, application efficiency, and so on. He proposed that when using the remote sensing analysis system, geographic information systems, and other advanced technologies and methods to compile an atlas, especially the thematic analysis atlas, we must organically combine remote sensing, geographical information system,

computer assisted cartography and map color printing technology into an automatic assembly line to reform atlas printing technology and develop modern atlas compilation technology. Combined with the design of *Officer Atlas*, Wang (1991) expanded upon the design features of the atlas from six aspects of the overall design idea, architecture pattern, selection of contents, expression method, cooperation system and printing process. The study results provide an important theoretical basis and technical methods for the compilation of a comprehensive atlas. Lu (1997) discussed the editorial and design characteristics of the national general atlas, i.e., the presentation content, the explicit guiding ideology of introductory map design, the scientific definition solution and the orientation problems of an introductory map. Looking at the national atlases of the world, there is no fixed pattern in the editing and design of introductory maps, and there is a large difference in the number of map sheets and contents. Also, some focus on one aspect of the content. Combined with the compilation of the *Naval Officer Atlas*, Jia et al. (2002) summarized the atlas's basic design ideas including the basic content and principle of the overall design; he also presented the structure model of the atlas, as well as the projection selection, scale design, map subdivision method, and so on; further, he proposed that the architectural organization and design of the atlas should follow the principle of structural integrity, macro to micro principles and the principle of internal logicality. The structural integrity of the atlas mainly refers to the integrity of the main content and auxiliary content. The auxiliary content of a comprehensive atlas shall include a table of contents, index, legend, explanation, and appendix; and the main contents must include a natural map, social economic map, human map, and so on. Pang (2007) believed that an atlas is different from ordinary books because it is a visual map to show the reader, with more use of symbols, colors and lines to show the content of things and the relationships among various things. Thus, for the expression technique to be recognized by readers, it should be reasonable and scientific and directly affect people's understanding of the contents of the map, as well as have a direct impact on the use value of the atlas. He also studied the overall design content, the basic principle and the evaluation methods of the atlas. Bai (2007) and Wang (2008) summarized the design ideas and methods of the provincial and regional atlas according to the compilation of the Uyghur version of the *Atlas of Xinjiang Uyghur Autonomous Region* and the *Atlas of the Status of Fujian Province*; They also studied the nature of the third generation of provincial atlases, the compiling principle, selection of contents, data compilation, contents and expressions, compiling characteristics, and so on and put forward the corresponding design ideas. These findings offered guidance for the theory and a method of preparation for a general regional atlas. Wang (2008) put forward three issues regarding the overall design of a regional comprehensive atlas, that is, the content system design based on the concept of regional scientific development, the map information representation design based on cartographic theory, and the compilation process design based on databases and GIS. Additionally, the relevant design thoughts were discussed, which provided a reference for the preparation of the general regional atlas.

Under the guidance of atlas design theories, beginning from 1990, the compilations of the *Great National Atlas of China* and many high level comprehensive

regional atlases were completed and published one after another. Representative works are listed as follows: *The National Agricultural Atlas of the People's Republic of China*, *The National Economic Atlas of the People's Republic of China*, *Atlas of the Jiangsu Province, Atlas of the Zhejiang Province*, *Atlas of the Jiangxi Province*, *Atlas of Chongqing City*, *Atlas of the Xinjiang Uyghur Autonomous Region*, *Atlas of the Jilin Province*, *Atlas of the Status of Fujian Province*, and so on. Compared with the original atlases, these atlases have been greatly improved in terms of content, representation method, color use, and symbol design. The general maps have fine symbol design, harmonious use of color, and a strong sense of three-dimensional terrain; the representation method of the thematic map is novel, the thematic information is prominent, the symbol design is vivid and intuitive, the color is highlighted, the level is distinct, and the status and development characteristics of the thematic phenomena in different regions are well expressed. These changes demonstrated the characteristics of the atlas as a product of scientific research, economic planning, and scientific tools for external propaganda.

(2) Study on the overall design of the city atlas.

The city is the center of politics, economy, culture and transportation, and cities have an important status in social development and human activities. With the rise of the information revolution, the combination of map science, spatial aerial remote sensing, computer technology, and so on has led to the renewal of the traditional concept of urban mapping. Some city atlases and city image atlases have since appeared.

The main study results on city atlases in China are outlined as follows. According to the compilation of the *Atlas of Shanghai City*, Zou (1990) studied the function of a comprehensive city atlas and the basic principles of map compilation; he emphasized that the topic and content of an atlas are based on the urban geographical science system, which aims to reflect the nature of a city, and the focus was on practical application. Qi et al. (1991) analyzed the compilation and printing characteristics of the *Atlas of Xi'an City* in terms of content selection, internal structure, pattern design, decoration, printing, and so on. Yang et al. (1992) discussed the overall design idea and design characteristics of *Atlas of Xi'an City*, as well as the mathematical foundation, format, expression form, content structure, arrangement principle, geographical base map and compilation process. Ma et al. (1994) discussed the design principles and characteristics of the city atlas, illustrating the important guidance and promotional role of the city atlas in city modernization, scientific management and planning. He et al. (1999) described in detail the characteristics of *Atlas of Shenzhen City*, such as overall design, content arrangement, basic geographic base map compilation, color design, layout design, general map series compilation, thematic map series compilation, production technology of electronic versions, and so on.

The main study results on city image atlases in China are outlined as follows. Huang (2002) described the design idea and compilation of *Image Atlas of Shanghai City*, and the process of making an image map using a computer; he showed the advantages of computer aided mapping technology in improving the quality of map works and production efficiency, as well as reducing production costs, etc.; Yuming

described the difference between an image map and traditional line map in the expression of spatial information. Based on the design and compilation of the *Image Atlas of Suzhou city*, Wang et al. (2007) focused on several key technical problems, such as the overall design of the atlas, the expressed contents and representation method, data selection and processing, digital proofing, new process of computer direct plate making, and so on. The research has important reference value for the theory, method and technology of image atlas production based on high resolution aerial (remote sensing) images.

On the basis of research and experiments, a large number of urban atlases have been prepared and published, and they are important reference tools for urban construction and planning. At the same time, a variety of electronic atlases and multimedia electronic atlases were also established, which reflect the characteristics of the times in terms of map representation methods. Among them, the *Atlas of Shenzhen City* achieved the Outstanding Cartography Achievement Award awarded by ICA (International Cartographic Association) in 1999. This is the first time that one of China's map works won this award.

(3) Study on the overall design of the electronic atlas

Based on the publishing of a paper version of the atlas, the overall design of the electronic atlas was studied and some achievements were obtained. By comparing the electronic atlas with the traditional atlas, Liu (2003) considered that the design of an automatic map subdivision was more dynamic and interactive and mainly affected by map scale, geographical features of the mapping region and map projection. The core of automatic map subdivision is the calculation of the subdivision; the purpose is to retain the elements within the scope of a separated sheet. Xu et al. (2003) discussed the function of the multimedia electronic atlas of a city and pointed out that the multimedia electronic atlas of a city is no longer just a map product; it can be viewed as an information system-urban information system. Wang et al. (2005) discussed the automatic map subdivision techniques of electronic atlases, the database storage structure, management techniques and the automatic generalization and multi-scale display technologies. Based on the development of an electronic atlas of Wuwei city, Shi et al. (2008) developed and studied the design and integration of urban electronic atlas to serve the government and the national economic construction department, putting forward a hypermedia network information organization structure based on Series-Thematic map-Map sheet to reflect the basic geographical features of the region; they also designed the content framework of the integrated electronic atlas of the city area with the distribution rules of all kinds of natural and social economic factors and their relationships as the main content; finally, they designed the functions of attribute query, dynamic map display, multimedia automatic link, 3D flight and so on, as well as user identification and information interaction interfaces.

4.4 Problems and Prospects

4.4.1 Research on the Theory and Application of Modern Map Design Should Be Strengthened

In traditional cartography, technically, map design mainly solved expression and technical realization problems, such as map content abstract and generalization in the processes of field to map, map projection, map representation, map making process and so on. However, in modern cartography, a significant feature of map design is not only the focus on the process from field to mapping but focusing more on the relationship between reader and map. In other words, it stressed that the user is the judge and consumer of the map, so human and map must be studied as a whole. The theoretical and practical problems in map content design, expression model design, representation method design, map layout configuration and effect design are explored to adapt to changes in new map requirements. These design concept changes in map design place more emphasis on the guiding role of people's cognitive ability and people's map perception effect on map design; additionally, map design will gradually develop from passive design guided by experience to active design guided by theory.

4.4.2 The Intelligence Level of Map Design Should Be Improved

At present, since the spatial cognitive mechanism of the brain remains a "black box", a map designer can design a beautiful map, but the knowledge and thinking process used in this process are not fully understood. Therefore, there are many theoretical and technical problems to be studied and solved in the field of map design. In theory, as the map design involves human vision and visual perception, it has close contact with frontier science, such as some theories and methods in the field of cognitive science and cognitive psychology; also, it must explore how to promote the image thinking ability of the brain by the 'graphic language' of the map, enhancing the spatial cognitive ability, graphics memory, understanding ability and so on. Therefore, the research on map use, map perception and spatial cognition will be the important theoretical issues in the future. It involves not only continuing to study the theoretical problem of the traditional paper map but also the study of the theoretical issues of new types of maps, such as digital maps, electronic maps, multimedia maps and atlases. In terms of techniques and methods, with the application of computer technology, artificial intelligence technology, data mining, knowledge discovery technology and so on in the discipline of cartography and map design mainly studies how to use data mining and knowledge discovery technology to construct a new map expression content system and form a 'knowledge map'. At

present, map works and their service objects are still very limited, and the content of map works contains little information. We must study how to deeply process a large number of resources and environmental information with the viewpoints and methods of system theory to provide users with an intelligent knowledge base, deep processing and practical final products, as well as update the values of map design, with a focus on practicality and science. We must research the data organization and hierarchical display mechanism, interface and map expression for map products, especially electronic maps, multimedia maps and electronic atlases. We must research how to use virtual reality technology and visualization technology to build a real time and realistic virtual geographic environment with the support of a spatial database. Also, we must research how to use life science and technology, as well as artificial intelligence technology to establish an intelligent map design system, and so on.

4.5 Representative Publications

(1) ***The Compilation and Design of the Map*** (GAO Jun. Zhengzhou Institute of Surveying and Mapping, Zhengzhou, Henan, China, Sept., 1977)

The whole book consists of 12 chapters. Chapter one, an overview, describes the role of map compilation and design in map production, and the general contents of map compilation and design. In the second and third chapters, the general map is summarized; the key is the type and use of the topographic map. The fourth chapter, the overall design of the map, describes the process of overall design and the specific content of each process. From chapters five through seven, the research contents and methods of map compilation data, regional research and geographic name translation are described, respectively. The eighth and ninth chapters describe the representation method of the various content elements in general maps, focusing on the terrain representation. In the tenth chapter, the principles and methods of map symbol design and font selection are introduced. In the eleventh chapter, the principle and method of programming for the map production process are introduced, and the typical map making process is given. Chapter 12 introduces the final results of the map design, that is, the types of map compilations and design documents, as well as their content and writing methods.

(2) ***Principles of Map Design*** (CHEN Yufen, JIANG Nan. The People's Liberation Army Press, Beijing, China, Aug., 2001)

The book comprehensively and systematically introduces the basic theories and technical methods involved in map design, focusing on the new theories and core technologies in map design, while considering the traditional map design theories and methods.

The whole book consists of nine chapters. Chapter one covers the map and map design. Chapter two covers the basic theories of map design. Chapter three discusses

the overall design of the map. Chapter four discusses determining the map content. Chapter five is the design of the content representation method for the general map. Chapter six covers the design of the content representation method for the thematic map. Chapter seven covers map annotation and translations of geographic names. Chapter eight discusses the design of the map production process. Chapter nine is the design of electronic maps.

(3) ***Map design and compilation*** (ZHU Guorui. Wuhan University Press, Wuhan, China, Oct., 2001)

The book is divided into 4 parts and has a total of 15 chapters. The first part consists of four chapters. Chapter one covers the map and cartography; chapter two discusses the map symbol and map representation; chapter three is the mathematical foundation of the map; and chapter four describes the map making process. The second part of the book consists of two chapters, where chapter five covers the geographical variables and graphical representation, and chapter six discusses map generalization. The third part of the book consists of five chapters, where chapter seven covers the map design documents; chapter eight is the map layout design; chapter nine is the cartographic region and mapping data; chapter ten discusses map compilation manuscripts and publishing preparation; and chapter eleven covers the design and production of an atlas. The fourth part of the book consists of four chapters; chapter twelve is the general map; chapter thirteen is the natural map; chapter fourteen is the social and economy maps; and chapter fifteen is the special map.

(4) ***Map design and compilation*** (WANG Guangxia et al. Surveying and Mapping Press, Beijing, China, Jun., 2011)

This book comprehensively introduces the theories, technologies, methods and applications of map design and compilation. The whole book consists of 11 chapters and an appendix. The first chapter is the introduction, which introduces the concepts of the map, map design and compilation, as well as the research content and development; the second chapter introduces the theoretical basis of map compilation design; the third chapter describes the content of map editing and design and the preparation work; the fourth through seventh chapters describe the theories and methods of the overall design, map symbol design, color design and map representation design; the eighth through tenth chapters expound upon the basic concepts and characteristics of map graph generalization and geographic information generalization, as well as the methods of cartographic generalization and the concepts and methods of electronic map multi-scale representation; chapter eleven analyses the characteristics of typical map product design and compilation; and the appendix lists the contents and requirements in the map design and compilation practices.

(5) ***Atlas of the Yellow River Basin*** (Chief Editor: ZHANG Zhengming, LI Hongjie; preparation unit: Yangtze River Water Conservancy Committee of Water Resources Department; publishing units: China Map Publishing House; time of publication: December 1989)

This atlas is a large comprehensive atlas for the river basins in China. The objective form of the atlas is to reflect the history of the Yellow River, the natural geographical environment of river basins, the characteristics of water and sediment resources of the Yellow River, as well as harnessing these resources and the development achievements and scientific research results; this atlas provides a scientific basis for understanding and studying of the Yellow River, as well as controlling and developing the Yellow River and developing the basin economy.

As a standard 8 folio atlas, the content includes six groups, such as general maps, historical, social and economic maps, natural conditions and resources maps, control and exploitation maps, and tributaries of the river; there is a total of 92 pictures, 260 thousand commentary texts, and more than 100 color photos. The atlas gives priority to the map, which is combined with text, color photos and statistical charts; additionally, this atlas is published in two kinds of forms: bound book and loose leaf.

The atlas uses the data from fixed stations (sites), the latest research results and a great deal of maps to reflect the distribution of water resources in the Yellow River from different aspects (different series, measured and natural runoff, surface water, groundwater, and so on). As a representation method, according to the characteristics of the water and sediment in the Yellow River, in addition to displaying the water quantity increment with the width, the atlas also vividly displays the variance in sediment concentration using different colors. The DC figure is an important part of the atlas, and the selection principle is according to the size of the catchment area with consideration for the amount of incoming water and sediment; there is a total of 14 pictures of 25 tributaries. To reflect the evolution law of the deposited silt at the estuary mouth, in addition to the estuary regional map, modern change charts in the Yellow River estuary and sediment diffusion charts in the coastal area were compiled. The geographical base map of the atlas takes the national topographic map as the basic data and takes the Standard Map of Province-level Administrative Boundary, as well as the relevant provinces (autonomous regions) map data, and so on as supplementary reference materials. The data of the Yellow River estuary and its nearby coastline were updated according to the satellite image at that time.

(6) ***Atlas of Qinghai-Tibet Plateau*** (Chief Editor: LIAO Ke; deputy editor: LV Renwei, LIN Kangtai; preparation unit: Institute of Geography, Chinese Academy of Sciences; publishing units: Science Press; publishing time: December 1990)

The atlas is a summary of the scientific expedition and research results in the Qinghai-Tibet Plateau and has high scientific value and application value; the design concept and scientific content have reached an advanced international level. As an excellent piece of scientific literature, from the viewpoint of art, this atlas shows the dynamic evolution of a unique geographical region, which vividly depicts the historical and geographical relations between humans and nature. The atlas scientifically utilizes the various representation methods of a thematic map and is creatively combined with examples. By making full use of the map, aerial photos, satellite images, topographic surveying, mapping information, picture examples, this atlas completely and visually

reflects the complicated natural conditions and rich natural resources, as well as the development and utilization prospects of the Qinghai-Tibet Plateau. The atlas not only shows the characteristics of the natural environment on the Qinghai-Tibet Plateau but also reveals the formation and evolution of the plateau and its impact on the environment and human activities. The atlas includes the introduction, geology, topography, climate, hydrology, soil, vegetation, animals, resource utilization, and partition general map for a total of 10 map groups and 233 color maps. There are also some charts, satellite remote sensing images and ground photographs, and 100,000 words of explanatory text, as well as a gazetteer with 7,000 geographical names. It is a standard 8 folio atlas, and all maps, charts, explanatory text, and place names in this atlas were published for the first time. In addition, the 1/4 maps are the research achievements from the process of atlas compilation.

(7) ***The officer Atlas*** (Chief Editor: GAO Jun; deputy editor: WANG Jiayao; preparation unit: Headquarters of the General Staff; publishing units: The People's Liberation Army Press; publishing time: December 1992)

This atlas is a comprehensive atlas for use by military cadres, and it mainly provide the political, economic, military, and other comprehensive geographic environmental information of the world, continents, oceans, and China, as well as neighboring countries, large districts, key regions and choke points at strategic and campaign levels.

The atlas is composed of seven parts: an introductory map, world map, continental and oceanic map, China map, map of neighboring countries, map of the history of the Chinese people's Revolutionary War and an appendix. The introductory map plays a guiding role for the atlas, including the universe and outer space, the human understanding and exploration of the universe, the earth, the human understanding and mapping of the earth and its military function and significance. The world map comprehensively presents global political, military, and economic situations and the natural environment. The continental and oceanic map comprehensively shows the politics, nature, resources and economic situations of the continents and oceans, highlighting key areas and strategic routes, and selected example battles are also shown. The China map is the focus of the atlas; it includes the whole China map, which shows China's politics, nature, resources, economy, transportation, humanities and other conditions from an overall standpoint; the sea area chart shows China's vast sea area; the group of maps with large districts show the units reflecting the regional geographical environmental characteristics, terrain, natural conditions, economic strength, human resources and transportation maps and provincial maps. The map of China's neighboring countries, including China's land and sea neighbors, reflects the basic geographical environment. The map of the history of the Chinese people's Revolutionary War shows typical battles that reflect the relationship between combat operations and the regional geographical environment.

The content of the atlas is abundant with an innovative design, bright colors, vivid symbols and pictures, and the accompanying words are also excellent; so this atlas has strong practicability and high artistic quality. In the layout of the contents,

it highlights the military characteristics, focusing on the military significance of the "typical contents", "typical events" and "typical regions"; in the design of the representation method, it focuses on the unity of art and coordination to allow people to enjoy its beauty. The compilation and publishing of the Officer Atlas represents the science and technology level of military surveying and mapping in China since the 1980s.

The atlas won the Excellent Military Scientific Research Product Award in 1992 and the Military Science and Technology Progress Award in 1999.

(8) ***China's City Atlas*** (Chief Editor: Ministry of Construction; preparation unit: Science and Technology Development Promotion Center, Ministry of Construction; publishing units: China Map Publishing House; publishing time: June 1994)

Compiled by the China Ministry of Construction, this atlas was the first large-scale comprehensive city atlas created in China. It incorporates all the planned cities of China from the founding of new China until the end of 1989, with a total of 445 cities (Taiwan, Hongkong and Macao were not yet included). This atlas comprehensively and systematically reflected the natural environment, the cultural and geographical characteristics, the urban development evolution and the long-range plan for Chinese cities; this atlas propagates the great achievements of city construction in the forty years of new China; the atlas is an all-around, multi-level atlas to show the style of the Chinese city. The compilation of the atlas began at the end of 1989, and after four years of efforts, it was published in 1994. It uses fair drawing and scribing, as well as the copy process method, with spot color printing and a wireless adhesive hardcover process. In addition, it will play an important guiding and promoting role in the modern construction and the scientific management and planning of cities.

(9) ***The National General Atlas of the People's Republic of China*** (Chief Editor: YU Cang; preparation unit: China Map Publishing House, Shanxi Provincial Bureau of Surveying and Mapping, Chinese Academy of Surveying and Mapping; publishing units: China Map Publishing House; publishing time: January 1995)

The National General Atlas is the first volume of the series of the National Atlas of the People's Republic of China and is the basis for the preparation of other sub volumes. The atlas includes four parts, such as introductory maps, regional maps, provincial maps, and the index of place names. The introductory maps consists of 18 nationwide thematic maps and 20 statistical charts, reflecting the macro distribution the regional mapping factors in the whole country. There are 20 maps in the regional map group, highlighting the natural and geographical landscapes in four regions of Northeast China, Southeast China, Southwest China and Northwest China, as well as the major residential areas, the traffic line distribution and the terrain of both sea and land, especially the topographic features of the sea bottom. The provincial map group is the main body of the atlas, the nation and provinces (autonomous regions and municipalities directly under the Central Government) each have a map,

the 9 typical areas under the jurisdiction of provinces (autonomous regions) each have an enlarged map, and 108 major cities each have a map; the distribution and relationship of the six elements and related contents of the general geographic map are expressed in detail. They can be used as the important basis to understand the actual situation of one province and the natural geography and social economic ties of the surrounding provinces. The index of place names contains a total of more than 40000 place names of provinces and autonomous regions; each of them lists the names of Chinese characters, Roman alphabet spelling and the coordinates on the map for convenience of quick retrieval on provincial (autonomous regions) maps (the place name index is compiled according to the place name database established by the census data of the national geographic name).

The atlas is compiled using the latest measured data and new research results of geosciences surveys, and parts of them are updated using satellite images to ensure the novelty of the maps. There is innovation in the representation method. For example, the terrestrial maps of the regional map group use the new expression method of landscape tinting for the general map, changing the traditional concept of paying more attention to the land than the sea; it uses a light purple color system to express the Qinghai-Tibet Plateau, breaking through the usual practice of China's hypsometric contour. The altitude scale is divided into three kinds of colors according to three major ladders of China to better shows the terrain features of all regions.

(10) ***Atlas of Shenzhen City*** (Editor: LIU Jiasheng; deputy editor: HUANG Rentao, GUO Renzhong, HUANG Fulai; preparation units: Shenzhen Municipal Planning and Land Source Bureau, Wuhan Technical University of Surveying and Mapping; publishing units: Shenzhen Municipal Planning and Land Source Bureau (For internal use only); time of publication: April 1997)

This atlas is the representative work of the China urban atlas and is the first large-scale comprehensive atlas of China released simultaneously in both printed and electronic editions. It integrates the map language, pictures, video, graphics, text and other multimedia tools, and comprehensively and systematically reflects the resources, environment, population, social economy, and developmental planning of Shenzhen city, and this atlas is innovative in content structure and expression mode.

The atlas uses the latest map of Shenzhen city, 1:10,000 aero photogrammetric topographic maps, and the latest professional data provided by various departments as basic data; additionally, computer mapping and electronic publishing technology were used to compile this atlas. It is the earliest successful attempt to create a large engineered atlas by using computer mapping.

The atlas consists of five groups, such as introductory maps, regional detailed maps, social and economy maps, natural and environment maps, and development and planning maps. It is a standard 8 folio atlas, with 177 maps, 154 charts, 162 photos and 6 aero photos.

The representation method of the atlas is novel, the thematic information is prominent, the symbol design is scientific and reasonable, and the drawing is delicate. In terms of the map color design, the color is very exquisite, scientific and reasonable.

The design of the main tone focuses on the map content and makes full use of the contrast color to enhance the level of content expression and to enhance the clarity and beauty of the graphics expression.

The atlas won the Outstanding Cartography Achievement Award in the nineteenth general assembly of ICA (International Cartographic Association) in 1999. This is the first time that China won this award, which is the highest honor in International Cartography.

(11) ***Atlas of the Yangtze River Basin*** (Editor: WEN Fubo; deputy editor: YAO Chuguang, CAO Shengzhong, CHEN Bingquan; preparation unit: Yangtze River Water Conservancy Commission, Ministry of Water Resources; publishing units: China Map Publishing House; time of publication: August 1999)

This atlas is a large comprehensive river basin atlas that provides a comprehensive description of the trunk stream and branch of the Yangtze River. It focuses on water conservancy construction and also considers the natural resources, social and economic development, and the historical and cultural environment. It is also a large mapping project. From content to form, the atlas tightly encircles the theme of water resources and water conservancy construction, which is a highlighted subject. It takes the comprehensive utilization plan report of the Yangtze River Basin approved by the State Council (revised in 1990) as the basis, while absorbing and summarizing the achievements of various disciplines in the development of the Yangtze River. This atlas is based on maps and supplemented by text descriptions, photographs and tables to facilitate the readers understanding and knowledge of the Yangtze River intuitively, vividly and profoundly. The atlas is divided into 7 groups. The introductory group mainly includes the introduction and overview. The historical map group describes the historical evolution of the Yangtze River and its general situation, aiming to provide historical data for the development of the Yangtze River. The map group of natural conditions reflects the geology, topography, climate, soil, vegetation, mineral resources, hydrology, water quality and other natural geographic factors of the Yangtze River Basin; this river has a longer length, which is the most important part in the atlas. The social and economic map group mainly reflects the land use, industrial and agricultural, urban, transportation, tourism, economic development and other contents of the Yangtze River Basin. The map group of environmental protection mainly represents water quality evaluation, water quality pollution, water source protection, distribution and protection of rare animals and plants, fish resources and protection, distribution and control of schistosomiasis and endemic diseases, and other contents in the Yangtze River Basin. The map group of water resources development and use mainly reflects the comprehensive utilization plan of water resources, water conservancy and hydropower engineering, flood control, power generation, irrigation, water and soil conservation, river regulation of the middle and lower streams, urban water supply, the South-to-North Water Diversion Project, and so on in the Yangtze River Basin; this group highlights the social and economic benefits of the Three Gorges water conservancy project, which is the

focus map group of the atlas. The map group of dry tributaries mainly reflects the relative position of the main tributaries of the Yangtze River, the basic situation of each river section of the mainstream, the general situation and development plan of the main tributaries and is also the focus map group of the atlas. The 7 groups are interrelated and complement each other, which basically reflects the whole picture of the Yangtze River Basin.

(12) ***Atlas and Gazetteer of Standard Geographical Names in the People's Republic of China by Administrative Division*** (Editor: LI Baoku, LI Zhiguang; preparation of units: Ministry of Civil Affairs of the People's Republic of China and the Bureau of Surveying and Mapping of the General Staff of the People's Liberation Army; publishing units: the Planet Map Publishing House; time of publication: September 1999)

This atlas is a thematic atlas that is based on the achievements of administrative divisions, geographical name management and mapping in the 50 years since the founding of the People's Republic of China. This atlas comprehensively and accurately reflects the standard name of China's administrative region and the distribution of the administrative areas, government residential locations and the historical evolution. It has more than fifty-three thousand administrative region standard names. The atlas was compiled by using digital mapping technology and is in standard 8 folio format. Then, after more than 1 year, the atlas was revised with updated data, and it was compiled and published in 16 folio format in January 2001.

The atlas consists of three major parts, including introductory maps, provincial administrative area maps and an appendix. The introductory maps include the China administrative division, relief, urban distribution, distribution of nationality autonomous districts, and evolution of territory and contemporary administrative regions; this atlas reflects the evolution of China's territory and the first-level administrative division since the Qin Dynasty, and it emphasizes the development situation of the provincial administrative regions of contemporary China. The provincial administrative area maps include sketch maps and detailed maps of administrative divisions, city maps and text descriptions. The appendices include the contrast between new and old names of some cities and counties, a table of the names and the setting time of Ethnic Autonomous Regions, a name list of city municipal districts and street offices, the national administrative region name index, and a list of the uncommon words in the administrative district names and their local pronunciations.

This is the first atlas with an administrative division standard name as the theme after the founding of the People's Republic of China. The administrative division names of the 4 levels of province, region, county and township in China are the standard names approved by the government at all levels. All of them are represented in the atlas, and the full names are given to reflect their categories and levels and to reveal the rich connotation of the administrative division standard name. This is one of the main features of the atlas. This atlas includes the map, table, text description and other means to illustrate the theme from multiple aspects and to show the evolution of the administrative division in each of the main historical periods over the past

2000 years. At the same time, it also highlights the main contents of the contemporary administrative divisions. The information is rich and clear with a prominent theme that is easy to read. The atlas has the characteristics of rich information, distinct levels, prominent theme and readability. It won the First Excellent Map Award issued by Chinese Society of Geodesy, Photogrammetry and Cartography (CSGPC) in 2004.

(13) ***Atlas of the Xinjiang Uygur Autonomous Region*** (Editor: LIU Geqing; deputy editor: LI Quanzhan, CHANG Gejun; preparation unit: Bureau of Surveying and mapping of Xinjiang Uygur Autonomous Region; publishing units: China Map Publishing House; publishing time: August 2004).

This is a general atlas that reflects the natural geographical features and main social economic phenomena in the autonomous region. There is also cartography and geographic information system engineering involved in multiple disciplines and multiple domains.

The atlas contains information according to the principles of accuracy and completeness, which includes scientific, unified, up-to-date data, as well as and safety data. The new technologies of an integrated GIS and a digital computer desktop mapping system are used to establish a database and compile the atlas, reflecting the use of an advanced level of modern mapping and GIS technology.

The atlas is composed of two parts: introductory maps and regional maps. The former part generally reflects the natural, economic and social development profile of the autonomous region (29 pages); the latter part reflects in detail the basic situation of each prefecture, county and city (278 pages). The atlas contains 169 maps, 13 charts and 20 photos, including approximately 100,000 words of text to comprehensively, systematically, intuitively and vividly show the basic situation in Xinjiang. The introductory map group has 14 mapping units, including administrative regions, geographical location, satellite image, terrain, climate, water system, vegetation, land use, mineral resources, transportation, tourism, Production and Construction Corps and others. The regional map group consists of 140 mapping units of three map types, including prefecture, county and city maps. In the aspects of layout arrangement, map decoration, symbol design, representation method, color scheme and so on, the atlas is fresh and natural, novel and unique, with a distinctive theme and clear level; it also contains supplements from before and after the echo, which are harmonious and united.

(14) ***Atlas of the Jiangsu Province*** (Editor: SHI Zhaoliang; preparation of units: Basic Geographic Information Center of the Jiangsu Province; publishing units: China Map Publishing House; time of publication: September 2004).

The atlas consists of five parts, including introductory maps, population, resource and environment maps, economic and societal maps, sustainable development maps and city, district and county maps. The atlas is in standard 8 folio format. There are 48 thematic maps, 150 general maps, 80 color photos, and approximately 200,000 words of text in a brief introduction. Therefore, it has the largest format and is the most fundamental masterpiece in the Jiangsu Province atlas (copies) series. The atlas

is compiled based on the latest geospatial data of various-scale digital line maps and satellite remote sensing image data provided by the Basic Geographic Information Center of the Jiangsu Province, as well as the latest statistics from the *Statistical Yearbook of the Jiangsu Province* and various departments.

An advanced integrated computer mapping and publishing system was used to complete the atlas design, data processing, map drawing, prepress processing and plate making. The structural arrangement, graphic selection, symbol making and element generalization methods are novel and scientific, meeting the requirements of modern cartographic theory. The decorative layout and the use of color not only contribute to the intuitive and vivid display of contents, but overall, it reflects the distinctive professional characteristics, local characteristics and the characteristics of the times.

In 2006, the atlas won the gold award, "PEI Xiu Award for Excellent Map Works".

(15) ***Atlas of Chongqing City*** (Editor: JIANG Yong; preparation of units: Chongqing Investigation and Surveying Institute; publishing units: Xi'an Map Press; published: April 2007).

This atlas is a comprehensive provincial city atlas and is the first atlas created since Chongqing city as the municipality directly under the central government.

This atlas is in a standard 8 folio format. The content includes introductory maps, population, resource and environment maps, economic and societal maps, district and county maps and development plan maps. There are a total of 248 pages of maps. Among them, there are 51 pages of thematic maps, 84 pages of general maps, 7 pages of aerial pictures, 2 pages of satellite images and 76 pages of photos.

The atlas is designed and compiled by using a combination of multiple elements, such as illustrations, text and pictures and is completed with full digital mapping technology. It brings together many of the latest 1:10,000 topographic maps of Chongqing city, the 1:50,000 place names database of Chongqing city, the administrative maps of Chongqing city, and a variety of the latest yearbooks from Chongqing city and other information; thus, the atlas systematically and thoroughly presents the situation and development of Chongqing city.

The representation method of the thematic map is novel, the thematic information is prominent, and the symbol design is vivid and intuitive, with color that is harmonious and unified. The district and county maps use layered tinting coupled with the hill shading method to represent landforms; the symbol and color of urban areas is prominent and the level is clear. The geographical status and development characteristics of natural and social factors in different regions were well expressed.

In 2008, the atlas won the gold award, "PEI Xiu Award for Excellent Map Works".

(16) ***Atlas of Zhejiang Province*** (editor in chief CHEN Jianguo; preparation of units: The First Surveying and Mapping Institute of the Zhejiang Province; publishing units: China Map Publishing House; publication dates: January 2008)

The atlas is composed of six parts: the introductory map group, population, resource and environment map group, economic and societal map group, development plan map group, regional geographic map group and indexes. The atlas is in standard 8 folio format. There are 52 pages of thematic maps, 79 general maps, 74 urban maps, 350 color photos, and approximately 200,000 words of text in a brief introduction. The atlas mainly shows the Zhejiang Province's natural environment and resources, humanities, social and economic development and planning, the administrative divisions at or above the county level, township boundaries, topography, geomorphology, water systems, infrastructure, transportation and appendages, the distribution of residential areas and other conditions; the atlas provides basic geographic information and a scientific basis for the formulation and implementation of the sustainable development plan for all levels of government.

Based on the latest multi-scale digital line map, satellite remote sensing image data, a digital elevation model and other geographic spatial data provided by the Bureau of Surveying and Mapping of Zhejiang Province, the atlas is compiled and published by using digital mapping technology and with the support of computer technology, database technology, remote sensing technology and geographic information system technology. The thematic map is represented in a novel way; the, thematic information is prominent, and the symbol design is scientific and reasonable, with color that is harmonious and beautiful. The general maps use layered tinting coupled with the hill shading method to represent landforms and overlay various ground feature symbols, the symbols and colors of urban areas are prominent and the level is clear. The characteristics of the regional geographical environment are well expressed. The index contains nearly a thousand geographic names that appear in city and county maps, such as streets, islands, mountains, scenic areas, nature reserves, forest parks, the main tourist attractions and so on.

The atlas won the gold award, "PEI Xiu Award for Excellent Map Works" in 2008.

(17) ***Atlas of the Jiangxi Province*** (Editor: LIU Baohua; preparation unit: Third Surveying and Mapping Institute of the Jiangxi Province, Jiangxi Province Basic Geographic Information Center; publishing units: China Map Publishing House; publication date: May 2008).

The atlas is composed of five parts: the introductory map group, population, resource and environment map group, economic and societal map groups, sustainable development map group, and the map group of districts (cities and counties). The atlas is in standard 8 folio format. There are 166 pages of thematic maps (38 topics), 186 general maps, 167 color photos, and approximately 200,000 words of text in a brief introduction.

By using visual map language and supplementing with text, charts and color photos, the atlas comprehensively and systematically shows the basic geographic information and the economic, societal, resource and environmental and other basic situations of the Jiangxi Province.

Based on the latest multi-scale topographic map and satellite remote sensing image data and with the support of the latest professional data provided by various departments, the atlas is compiled and published using digital mapping technology. In terms of topics and content, the atlas includes a thematic map to highlight Jiangxi's features, such as the red revolutionary cradle (former red capital, the cradle of the People's Republic China), green homes and the Millennium Ceramic Capital. The symbols are of very fine quality; the color is exquisite, and the atlas is scientific and reasonable.

The atlas won the gold award, "PEI Xiu Award for Excellent Map Works" in 2008.

(18) ***Atlas of the New Beijing Great Olympics*** (Editor: ZHANG Hongnian; deputy editor: DENG Nan; compilation units: Beijing Municipal Planning Commission, Beijing Surveying and Mapping, Design and Research Institute; publishing units: China Map Publishing House; time of publication: July 2008).

This is a thematic atlas that introduces Beijing and its service to the Beijing Olympic Games. On the basis of the Beijing urban basic geographic information data platform, with "New Beijing, Great Olympics" as the main line, it uses a bright, innovative design style and intuitive and visual map language to show the long history of Beijing, the harmonious and livable environment, the dramatic development of the central city, and the thriving new towns and suburban counties; the atlas expresses the development course of the Olympic movement and the twenty-ninth Olympic torch relay route; and the atlas demonstrates the beautiful desire for "One world, one dream" and "To ignite passion, to pass the dream". Also, the atlas exhibits the Olympic competition venues, training venues, non-competition venues, contracted hotels, designated hospitals and other thematic information, as well as the cityscapes of the assisting host cities, such as Qingdao, Hongkong, Tianjin, Shanghai, Shenyang and Qinhuangdao.

The atlas includes an introduction to the Olympic Games, an overview of Beijing city, the central city of Beijing, Beijing's new towns, Beijing's suburban counties, an index and an electronic CD-ROM; the atlas is available in both Chinese and English. The data are from December 2007.

(19) ***Atlas Series of China's Provinces*** (Editor: XUE Guijiang, YAO Jie; deputy editor: ZHOU Ruixiang, LIU Hongnian; compilation units: Planet Map Publishing House; publishing units: Planet Map Publishing House; time of publication: June 2009).

This is a large provincial series atlas that was edited and published for the first time in the 60 years after the founding of the People's Republic of China. The atlas uses visual maps that are complemented by graphics and tables, texts and photos to vividly reflect the 60-year construction achievements of China's provinces (autonomous

regions, municipalities directly under the central government) and special administrative regions in the administrative divisions, towns, transportation, tourism and other aspects.

The atlas is rich in content and novel materials, and the map compilation, layout and cover design are expertly planned. The complete set includes 34 volumes in 16 folios. The main color of the cover is gold, which conveys magnificent, elegant and brilliant character, and the artwork is pleasing to the eyes.

Each volume of the atlas is mainly composed of introductory maps, prefecture level maps, county level maps, and city maps, as well as text introductions and scenic pictures. The introductory maps offer an overview, which shows the provincial administrative divisions, topography, transportation, tourism and other comprehensive information. The prefecture level map acts as an administrative map to show the geographical information of all the county level administrative regions under the jurisdiction and plays a connecting role. As the main body of atlas, the county level map is a topographic map to show in detail the administrative division boundaries, residents in townships and parts of the villages, highways and ancillary facilities, as well as county and township roads, railways, railway stations, airports, ports, water conservancy facilities, scenic spots and so on. A single county's map uses the layering method to reflect the relief and topographic features of the county. These are the highlights and features of the atlas. The city map is mainly to show the city's periphery, main street, transit route, public facilities and so on. Through the above four map groups and the photos and texts, the reader can intuitively, systematically and easily understand the situation of a province or county and the regional geographic characteristics of the country, as well as experience the great changes that have occurred in new China in the past 60 years from a multiple perspectives.

The unique compilation method and layout design style gives the atlas a unique position in the current domestic map market.

(20) ***Atlas of the Jilin Province*** (Editor: ZHANG Limin; preparation unit: Geographic Information Engineering Institute of the Jilin Province; publishing units: China Map Publishing House; publication dates: September 2009).

This is the first large-scale comprehensive atlas compiled by the Jilin Province; it comprehensively reflects the natural and human geography and the economic and social development of the Jilin Province.

The atlas is in standard 8 folios and consists of five parts, including the introductory map group, population, resource and environment map group, economic and societal map group, sustainable development map group, and the map group of cities, districts, counties and development zones. The atlas is compiled by using geographic information system technology, remote sensing technology, and database technology. The atlas integrates feelings, science, artistry and practicality in one; it is rich in both pictures and text, with strong practicability. The atlas uses up-to-date thematic information and data, among which the geographical base map of the provincial thematic map contains the 1:500,000 *Jilin Province Map* compiled

in 2007 as basic data. All kinds of thematic information are included based on the latest information provided by the professional departments and the *Jilin Statistical Yearbook* in 2008. The county maps are compiled using the latest versions of the 1:50,000 digital topographic maps from the National Basic Geographic Information Center. The city maps are updated using the 2.5 m resolution SPOT satellite image from the recent two years. The atlas is both current and accurate in its content.

(21) ***Atlas of the Anhui Province*** (Editor in chief: XU Tiejun; preparation unit: Fourth Surveying and Mapping Institute of the Anhui Province; publishing units: China Map Publishing House; publications date: January 2011).

This is the first large-scale comprehensive atlas compiled by the Anhui Province. It consists of five parts: the Anhui overview map group, population, resource and environment map group, economic and societal map group, scientific development map group, and the map group of cities, districts and counties. The atlas begins with an introduction to Anhui's Location in China and contains 49 pages of thematic maps, 113 general maps, 600 color photos, and approximately 200,000 words of text in a brief introduction. The atlas uses visual design language and is supplemented by charts and tables, text descriptions and color images, systematically reflecting the basic situations of the Anhui basic geographic information, economy, society, resources, environment, and so on. To exhibit the regional characteristics of Anhui, four maps, i.e., "Historical celebrities", "Ancient rhyme of Huizhou ", "The war flames in the Yangtze-Huaihe region" and "Beautiful Mount Huangshan" are set up to highlight the rich cultural heritage and beautiful natural scenery of Anhui; meanwhile, the layout design of the four maps is unique, which breaks through the centralized and unified layout style in the traditional map, which is a novel characteristic.

The atlas is in the standard 8 folios. It is compiled and published using an advanced integrated system based on the latest basic survey and mapping data, remote sensing image data, digital elevation models and other geospatial data. The perfect combination of science, cartography, color, aesthetics and printing allow the atlas to not only reflect distinctive professional characteristics but also the local style and features of the times.

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