

# **CARTOGRAPHIC METHODOLOGY FOR GEO-INFORMATION SCIENCE**

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## **Abstract**

### **1. Culture gene and knowledge innovation of Chinese cartography**

In China, cartographic cultural inheritance conserved to now can be traced back to inscriptions on bones or tortoise shells of the Shang Dynasty, which was about 3,500 years ago. Its information medium was bones, copper, gold, silk, papers or stone inscriptions, all of which were made of the most advanced materials and craftworks at that time. Its content included hunting, gardening, graveburying, city and geography, all of these also showed advancement of science and technology, comprehensive social requirement of military administration, traffic and roads, urban planing et al. They supplied a multi-cartography-gene base for world and resource of knowledge innovation for progress of science and technology.

### **2. Historical enlightenment of grid mapping evolution and transformation**

Farmland irrigation and “Jing Tian Zhi” (The Square-Fields System) of B.C.6-4 century gestated grid rudiment, mapping principal in 《Ji LI Hua Fang》 (Counting-in-miles and Drawing-in-grids) brought forward A.D. 3 century affected about 1,000 years from carved-stone map of 11 century to chorography and countrywide map of Yuan, Ming, Qing dynasty. Biorbit system overlayed by latitude-longitude and grid system appeared after biexchangment of oriental and occidental mapping science and technology about 16 century. In 20<sup>th</sup> century of remote sensing and computer aided mapping widespread, grid map bobbed up like a cork, it is exerted particular function and created resplendence for solving matching of pixel and statistical cells.

### **2. Drifting of map function**

With the flying development of science and technology on aerial photograph, Remote Sensing and Global Position System et al in 20<sup>th</sup> century, social function of maps has changed distinctly---it is being drifted step by step to client information server. That is: firstly it is reverse with traditional mapping craftwork program, small scale map go ahead, after large-scale map come to heel. Thus it accelerated and simplified enormously mapping craftworks, improved efficiency, advanced adjustment of mapping industry structure, gained valuable time for science prediction and forecast. Secondly it widely applied in new fields of geo-science, space science, bioscience, and maps were used as graph-thinking method of spatial-temporal analysis, data mining and knowledge discovering. These made delightful progress for discovering new geographical distribution law or situation.

### **4. New thinking of Chinese geo-information spatial-temporal methods**

Chinese science-technology progress in 20<sup>th</sup> century, for example, full digital surveying map, digital mechanical test, Chinese characters edition composition and map making system, science prediction theory and ways of prototype-model method, all of which directly made roads even for knowledge innovation and technology revolution of cartography.

One of thought-- 《cartographic methodology for geo-information science》 with Chinese characteristic is being explored and researched. Traditional spatial-temporal method has made golden experience and social economical benefit in geo-science fields. Based on remote sensing image analysis, satellites positioning technology and network technology, depending on integrating of geographical information system, including status, diagnose, model and

virtual reality during the course of information flow, 《cartographic methodology for geo-information science》 will be applied in historical inversion and future prediction, it has been made primary research in solving spatial situation and advantage appraise of eco-environment evaluation, urban growth, resource collocation, it's prospect will be very broad.

**key words:** cartography-culture gene, grid mapping, drifting of map function, cartographic methodology for geo-information science

### **1. Cultural gene and knowledge innovation of Chinese map**

Culture is multi-origin and bi-directional exchange. Historical cultural heritage of Chinese Cartography is centuries-old and abundant<sup>[1]</sup>, for example, 《Hunting in the fields》<sup>[2]</sup> has 3,500-year before by now which was portrayed on bones and germination of decimal number was appeared in pottery culture of Xia Dynasty Ashes. There were more numbers and groupnumbers in inscriptions on bones or shells of Yin Dynasty Ruins<sup>[3]</sup>. “In general, decimal system of Shang Dynasty was more advanced and scientific than that of Ancient Babylon and Ancient Egypt.”

《Zhao Yu Tu》 of B.C. 310, a plane figure of grave which was enchased by gold threads on copperplate, was unearthed at Pingshan County of Hebei Province; “Fang Ma Tan Tu” of B.C. 239 contained water system, mountain pass, road and boundary et al, cartographic features which was suitable for geographical knowledge of the Spring and Autumn Period and the Warring States Period. On the topographical map of B.C. 168 unearthed in Mawangdui of Changsha, eighty six cities were represented by circles or square frames, mountains were represented by black closed hachure, rivers and lakes were drew by blue color, and roads were red dash or solid lines. It was the earliest military geographic map embroidered on silk, which reflected the strong social demand for war and boundary and the progress of astronomy and mapping technology<sup>[4]</sup>. Up to the present, ancient carved-stone map preserved perfectly can be traced back to Song Dynasty (12 to 13 century), besides two monuments of 《Geographic Map》 edited and drew by Huang Shang in 1189 and “Pingjiang Tu” (the plane map of Suzhou city, scale 1:2000) in 1229, there are 《Yu Zong Tu》 and 《Hua Yi Tu》<sup>[5]</sup> used for lithograph. They has craved on both sides and their top and bottom were inverted to suit for lithograph—not erect monuments. Now they are preserved in Xi'an and Zhenjiang respectively<sup>[6]</sup>.

The brief introduction above shows that the media of ancient maps keeping good condition up to the present are bones and shells, Copper, gold, silk, paper or craved stone; and that the contents of ancient maps are mainly about hunting, grave, city and geography...the making of ancient Chinese map always use the most advanced materials and technologies of the time and the maps can perfectly reflect the progress of astronomy and technology and the increase of geographic knowledge of the time. Above all, they are closely related to the social demands of military activities, administrative management, exploration and investigation, and city planning<sup>[7]</sup>. The broad and deep cultural connotation of Chinese cartography will provide a multi-gene base of historical culture for cartological scientists all over the world.

### **2 Historical enlightenment of grid map evolution and transformation**

Histories not only gestate today but also enlighten future. Four Inventions of ancient China made directly or indirectly contribution to progress of the world cartography<sup>[8]</sup>. C.W.F.Von Leibniz (1646-1716) discovered binary system arithmetic, he also got inspiration and encourage of 《Zhou Yi》 (the book of changes), being as forerunner of cybernetics and computer science, he direct tasted benefit of oriental and occidental culture exchange<sup>[9]</sup>. Chinese map is one of resources of the world cartography. During the course of long-term

culture exchange, it always interweaves altogether, more gestates and rich modern cartography.

For example, 《The Map With Grid System》, it's historical social background should derive to “The Square-Fields System” of B.C.6-4century, it showed then construction farm irrigation and scientific thought of using Pythagorean Theory as Triangle measurement. These large-scale irrigation projects, such as Li Bing's Dujiang Weries (Chengdu), Shilu's Xinanling trench in Kwalin, now still live on, in historical documents, such as 《Guanzi》 (Book of a Philosopher)、《Shi Ji》 (Historical Records) et al, records was more detailed.

Pai Xiou (224 – 271 A.D.) proposed “Zhi Tu Liu Ti”(Principle of Cartography), summarized forerunner's achievement of surveying and mathematics. When he mapped, he adopted the principal in “Ji LI Hua Fang”(Counting-in-miles and Drawing-in-grids) and affected Chinese ancient mapping about 1,000 years. Curved-stone in 11<sup>th</sup> century could be seen clearly on the geographical maps, and it were also recorded in Shen Kuo's (1031 A.D.-1095A.D.) “Meng Xi Bi Tan” (Recording by writing near the dreaming river). And Zhu Si-ben's “Yu Di Tu” (Geographical Atlas) in the 16<sup>th</sup> century, which made direction by the “Counting-in-miles and Drawing-in-grids”, had continued its influence until the Ming and the Qing dynasty<sup>[10]</sup>.

Especially in the maps of Yuan dynasty, the grid maps of “Counting-in-miles and Drawing-in-grids” were predominant because of dire need of compiling regional maps and records and conquering Eurasia. The grid maps were very convenient to use for the zoom of map scale and for gross positioning, direction, and estimating area. In modern term, the interface of the mapping method is friendly in the period of handmade maps.

Until the Shen-Zong Period of the Ming dynasty (the 16<sup>th</sup> century A.D.), Xu Guangqi (1562 A.D.-1633 A.D.) translated “Ji He Yuan Ben” (the Principle of Geometry), and the mapping instruments and technology were imported into China. The longitudes and latitudes were measured in four cities (including Beijing, Nanjing, Nanchang, and Guangzhou) and eleven provincial capitals with the proceeding precision, specially the precision of measuring longitudes<sup>[11]</sup>. After Matteo Ricci (1552 A.D.-1610 A.D.) came to Macao, he compiled “Hua Guo Tu Zhi”(Atlas of China) according to Luo Hongxian's “Yu Tu” (Geographical Atlas) and published the French version in Paris to fill up the “blankness” about far east on the European maps. At the same time, he introduced the main points on the five continents and the climatic zones in world map and the projection of longitude-latitude map to China<sup>[12]</sup>. This began a new phase that the East and the West communicated the mapping science and technology each other. In China, the Qing government proceeded in large-scale mapping by the rule of overlapping the longitude-latitude network<sup>[13]</sup> and the grid system among the 17<sup>th</sup> and 18<sup>th</sup> century. This method of overlapping grid was adopted firstly in the map of 1:80000 which French mapped in 1818 A.D.-1882 A.D.. The grid system on the relief maps was convenient for the artillery measuring on maps and used for computing the intervisibility condition and the relative topography as well<sup>[14]</sup>.

The grid system map gets revived after the computer-aided mapping popularizes, it is exerting more and more functions in map analysis. Specially, grid map is an indispensable technology to match and compare the statistic data between the natural unit and the administrative unit. All data of three censuses in China have been transformed in the grid. This transformation gets the success and profoundly embodies the rule of regional difference in researching the relationship between human and the Earth and the question about resource and environmental capacity. All these effectively provide the argumentation for the strategic decision on developing in west, China.

Remote sensing, specially the digital scanning data of spatial remote sensing, provides the multi-scale pixels of remote sensing in the global scope. The resolution has been improved from some kilometers to several centimeters. So the grid maps are much more refined. The

global database's unit of World Meteorology Organization (WMO) is in 1km\*1km. And the grid of earth surface has been of meter-level in some practical information systems such as precision agriculture and urban management<sup>[15]</sup>.

The utilization of human culture treasure and the exchange of science and technology were often intermitted for the preoccupation, the shortsightedness, or other historic reasons. Too many opportunities have been missed, we should endeavor in this work which links future with past.

### **3. The drifting of map's function**

It is a long road that Human beings know where we can live in this planet, but this progress has a high acceleration. Respectively, European and Chinese geographical explorers independently knew the occident and the oriental world. Spent about 2,000 years, until the 16<sup>th</sup> century, the shoreline of the continents and oceans was shown approximately clear in the maps. After about 300 year, topographic map was begun to survey, only covered the 30% of the land. In the first part of 20<sup>th</sup> century, it took 50 years for the aerial photogrammetry to cover 70% of the land. Since the end of the 20<sup>th</sup> century, depending on satellite remote sensing, it need only 220 hours to collect the data of the sea and the land in middle and low latitude, which is about 80% of the whole world area, came up the 3-D terrain map and thematic maps in 2 years<sup>[16]</sup>.

With the progress in surveying and mapping techniques, the social function of the map has clearly changed. In the era of whole-field surveying and mapping, map is the major media for geographic information and knowledge. All the procedures from the data acquiring to data storing were done on the plate in the field. The measurement of latitude and longitude, terrain interpolation and map projection were the key techniques in this era. Since the aerial photogrammetry has been wildly used, the data acquiring and storage was all in the aerial photos, and the cartographer only need to extract the basic features of the map from the aerial photos. With the geometric correction by TIN both on the ground and in space, most of the works were done by indoor instruments. In the era when the whole day, high resolution, hyperspectral satellite remote sensing data are abundant, the precise positioning is done by GPS, the social and economic data are supported by GIS, the social function of the map should not only, or not mainly, to acquire and store data, but focus more and more on the data mining and knowledge discovery.

In the time when information is abundant, digitization has become the foundation for the realization of informalization and modernization. The topographic map was imported to GIS in the form of DEM, and act as the information infrastructure. Using the data acquired from the satellite and airborne remote sensing, and the GPS, together with GIS, all the procedures of mapping can be done in fully digital way by the interaction between the operator and the computer aided mapping. This brand new map surveying procedure is completely different from the traditional one which generalize the features from point to area, and from the local to the regional and global scale. In the new procedure, it starts from small-scale mapping, even from global mapping, and makes it in more detail when necessary. This logic conforms more to the depth mankind investigation to the science, and conforms to the law of the development of the earth system science.

Map is not just a kind of art for quantitatively describing the earth in space. The map has become the indispensable scientific tool for spatial-temporal analysis and graph thinking. It has been welcomed more and more by the geoscientist, biologist and space scientist, and attracted more and more scientists to work on it. In recent years, China was very successful not only in geochemistry<sup>[17]</sup>, pedology, earth therm, earthquake mapping, but also use the map in the fields of cancer, schistosome and plague spot, found new rules.

In the 21<sup>st</sup> century, information and space-time, cartography will not shrink with the

development of satellite remote sensing, GIS and other advanced information technology. It will absorb new nutritious from multi-disciplines in the course of interdisciplines. The most important for the cartography is to meet the social need and conform to the development rules of science, change the functions and industrial structure in time. The cartography will develop successfully.

#### **4 New thought of Chinese Geo-information Tupu**

How should cartography change its functions and bring its potentials into play? It should be able to find rules from the present status, and use these rules to inverse the past and predict the future, just like the statistics. But it should not as the same as the statistics. It should brings the unique potentials in spatial pattern and image thinking, to extend the living space of cartography temporally, to enlarge new science field by interpenetrating, to exploit international market by deep-processed elaborate works, and to materialize or condense technique sublimation by science laws.

Chinese cartographers pay great attention to the international progress in cartography. We actively take part in ISO<sup>[18]</sup> and Global Mapping<sup>[19]</sup>, et al. We greatly push the Digital Earth forward<sup>[20]</sup> and take on the duty in international plans such as EOS and IGBP<sup>[21]</sup>. At the same time, we attach great importance to the treasure of Chinese culture to get historical inspiration and to explore the way of original innovation. We have great achievements such as digital photogrammetric survey of Wang Zhizhuo<sup>[22]</sup>, Chinese character editing system of Wang Xuan<sup>[23]</sup>, digital proving for machine of Wu Wenjun<sup>[24]</sup> and prototype-model science prediction theory of Weng Wenbo<sup>[25]</sup>. They not only devote greatly to theoretical innovation and technical development of cartography in China, but also set great examples for national independent innovation to encourage the new cartographers to make great effort.

A new cartographic method called 《Geographic Information Tupu》<sup>[26]</sup> is being explored. Graphs(Tu) are commonly used to represent spatial distribution or spatial analysis, while diagrams(Pu) are commonly used to represent temporal course. It is possible to systematically describe spatial structures or to deduce bypast course and future situation using multi-dimension combination, transform and display of Tupu. Thus, traditional static cartography method evolves to dynamic and visual science thought and foretells. It is a kind of supplement and extension to mathematical statistic spatial analysis method that is widely used. It may be “an invisible hand” newly discovered in cartography field.

Tupu method appeared in geo-science field very early. It is successive used sometimes. The syncretic spatial-temporal graph-style thought lying in Weigena’s famous continent drift hypothesis, Kuppen’s climate types and Н. Т.Тцкцаев’s natural belt diagrams had greatly pushed geo-science forward. The tectonic structure model of Li Siguang and climate change research in recent 5,000 years in China of Zhu Kezhen are more well-known examples of Traditional Geographic Tupu in China<sup>[27]</sup>.

In 20<sup>th</sup> century, syncretic spatial-temporal Tupu method is widely used by geologists both here and abroad to study spatial structure change, such as the drift of polar; displacement of regional population barycenter and scientific center (Japan). Migration of river bed and bank<sup>[28]</sup>, shifted rhythm of transportation route, seasonal change of landscape vertical and horizontal zonality et al. Both natural and economic problems could be deeply refined, transformed and multi-dimensionally displayed through abstract, generalization and integrated graph-style thoughts. Thus, more simple and obvious rules could be found.

Geographic Information Tupu in 21<sup>st</sup> century will inherit from traditional Geo-science graph and diagram thoughts and methods. Baed on Remote Sensing and Geo-Information System, it will realize digital quantitative analysis and improve data mining and knowledge discovery by digital dynamical imitation in order to provide a new cartographic method for earth system science in this spatial d information society. It could also contribute to new

well-processed map production to satisfy the social need for information highway and network globalization. In information flow, geographic information Tupu could take advantage of information compress, spatial-temporal scale conversion and data mining, and provide maps of system analysis, assessment, imitation and prediction for water resource planning in drainage areas, city system and urbanization<sup>[29]</sup>.

According to grand strategic disposition of economy development in the new century, Chinese scientists begin to do research and experiment on geo-information Tupu. For example, migration of the central line of the Yellow River Bed, growth of delta, the evolution of bank of the Yangtse River and the meandering of Jinjiang River et al, this study of geo-information Tupu is very important to site the place of the port and control flood instrument. Research about fractal--dimensional and tide simulation of coastal zone is useful to dynamic monitoring on fishing season and red tide. It makes progress of quantitative forecasting on crop estimation and ecological environment evaluation to improve the models of land capacity and net primary productivity estimation. It helps us avoid misleading urbanization through analyzing and understanding urban growth and city system. The cartography of biogeochemical element abundance ratio affords the strategic rule to find mineral resources and survey environment background.

## 5. Conclusion

(1). China has made a rapid progress in NSDI, the white book titled “Aerospace in China” points: China will plan to launch about 30 satellites again before 2010, include land satellites, meteorological satellites and oceanographic satellites. So database updating based on Remote Sensing data is ensured, moreover, it makes a good chance to knowledge innovation of cartography and industry flourishing.

(2). Chinese cartographers will cooperate with scientists of other countries in studying and researching. They will encourage intersection of multifield, develop the theory and method of geo-information Tupu. China will endeavor to mutually build and share “Digital Earth”, global cartography and IGBP, and fulfil the “1km×1km grid” data exchange of WMO. We hope the system research and technology development in the cartography. We expect to make great contribution for cartography information and innovation.

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# Spatial and Temporal Geographical Analysis Methodology (TU-PU)

