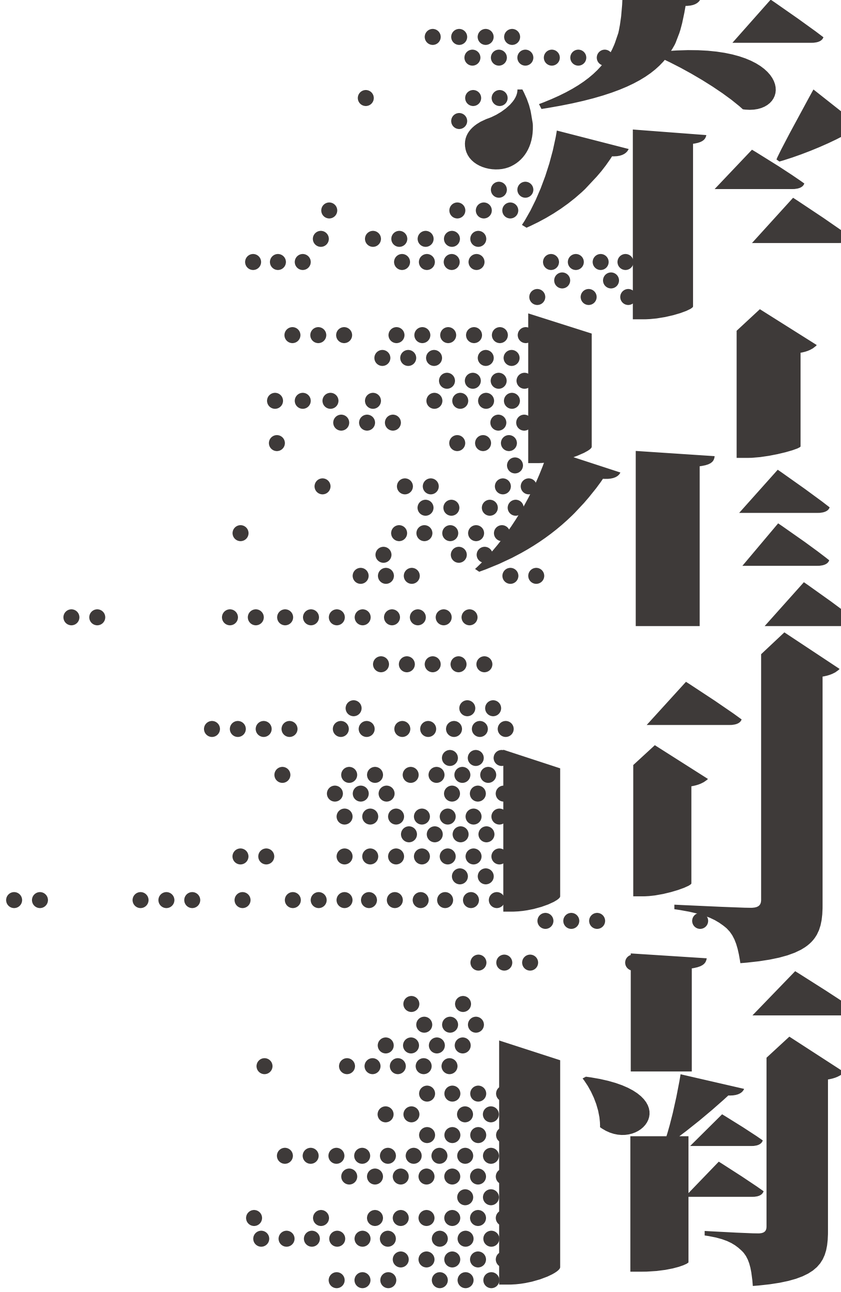

编者序

Editor's Foreword

联合国全球卫星导航系统国际委员会第 13 届大会（ICG-13）于 2018 年 11 月在西安举办，中国科学院国家授时中心有幸承担了大会的筹备工作。为展现中华文化，弘扬丝路精神，增添大会亮点，筹备组策划了“中国古代导航技术展”。为办好该展览，筹备组查阅了大量文献资料，走访了多位科技史专家，经过多次研讨，确定了展览方案。展览分为 4 个板块，分别是：“授时篇——钦若昊天，敬授人时”“导航篇——慈石司南，牵星过洋”“测绘篇——计里画方，甄度四海”“交流篇——一带一路，民心相通”。

该展览获得与会各国代表的高度赞扬。联合国外空司卢克先生盛赞：“这是一个令人惊叹的展览，我非常喜欢！几千年来，导航技术对经济发展做出了巨大贡献，没有这几千年的历史沉淀，卫星导航不可能经过几十年的发展走到今天。”2019 年 6 月，应联合国外太空司邀请，“中国古代导航展——从指南针到北斗”赴维也纳联合国总部，在联合国和平利用外层空间委员会第 62 届会议期间展出，获得与会代表高度评价，联合国外空司司长迪皮蓬用了 3 个“great”来形容此次展览——“a great exhibition，a great idea，a great history”。《人民日报》和新华社对此进行了专题报道。

本书即是作者在这两次“中国古代导航技术展”的主要内容基础上，做了一些拓展，重新编辑整理而成。多位同志参与了书稿编撰，主要有窦忠、陈琳、刘永鑫、李辉哲、宋静、徐玲玲、王沛、蔡宏兵、马莉萍等；英文翻译部分主要由陈琳完成；校对工作主要由窦忠、陈琳、刘永鑫等完成。感谢刘次沅、漆贯荣、郭际、鲁大龙、钮卫星、张箭、李孝辉等老师提出的宝贵意见；感谢潘炼德、宋炜琳、卢晓春、董绍武等老师给予的重要指导。

希望这本书能够向读者展现中华民族五千多年来在授时、导航和测绘技术方面取得的辉煌成就，以及以导航技术为纽带开辟的陆上和海上“丝绸之路”为中西方科技文化交流融合做出的重要贡献。书中所述观象授时、观星辨向、慈石司南、匠人建国、计里画方、牵星过洋等技术在指导中国古代劳动人民生产生活和探索未知世界过程中起到了不可估量的作用，也给我们留下了弥足珍贵的科技文化遗产。本书出版得到了中国科学院 2019 年科普图书出版项目支持。本书绘图主要由李毅凡（尚书传播）提供，谨致感谢！

2020 年 8 月于西安

National Time Service Center, Chinese Academy of Sciences was honored to undertake the preparatory work for the 13th Conference of the United Nations International Committee on Global Navigation Satellite Systems (ICG-13) which was held in Xi'an in November 2018. In order to showcase the Chinese culture, promote the spirit of the Silk Road and add highlight to the conference, the preparatory team had planned "Ancient Chinese Navigation Technology Exhibition". In order to better organize this exhibition, the preparatory team consulted a large number of documents and multiple historians of science and technology. After many discussions, the exhibition plan was finalized with four sections: "Time Service section — time comes heavenly, served sincerely" "Navigation section — lodestone governing south, star-guided ocean crossing" "Geodesy section — grid mapping, land surveying" "Exchange section — one belt one road, people to people bond" respectively.

The representatives of the participating countries applauded "Ancient Chinese Navigation Technology Exhibition" with Luc ST-Pierre, chief of Space Applications section at the United Nations Office for Outer Space Affairs (UNOOSA) praising it highly as "It's an amazing exhibition... Look at this exhibition on the series of navigation in China, it is fantastic. It was China's geography, so I enjoyed it tremendously. But it does show what navigation over the last millennium has done for economy. There will be no safe navigation now without that. There will be no international markets existing without that." At the invitation of United Nations Office for Outer Space Affairs (UNOOSA), "Ancient Chinese Navigation Exhibition— from Compass to BeiDou" was held at the United Nations Office at Vienna during the 62nd session of United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) in June 2019, which received special coverages in People's Daily and Xinhua News Agency and great acclaim from the participants, with Simonetta Di Pippo, director of the UNOOSA using three "great" to describe it — "a great exhibition, a great idea, a great history!".

This book was compiled based on the main contents of the two exhibitions with some extensions. Many professionals had participated in writing the manuscripts, mainly including: Dou Zhong, Chen Lin, Liu Yongxin, Li Huizhe, Song Jing, Xu Lingling, Wang Pei, Cai Hongbing, Ma Liping, etc.; English translation was mainly completed by Chen Lin; proofreading was mainly done by Dou Zhong, Chen Lin, Liu Yongxin, etc. We would like to thank Liu Ciyuan, Qi Guanrong, Guo Ji, Lu Dalong, Niu Weixing, Zhang Jian, Li Xiaohui and so on for their valuable advice and Pan Liande, Song Weilin, Lu Xiaochun, Dong Shaowu, etc. for their important guidance.

We hope to show readers that the Chinese have made brilliant achievements in timing, navigation and geodesy over the past five thousand years. In addition, they have also made important contributions to the integration and communication between the eastern and the western civilizations via the Silk Roads on land and sea opened up by navigation technology. Technologies in this book such as serving the time by observing celestial phenomena, telling directions by observing stars, governing south by lodestone, constructing the capital with craftsmanship, squared map with grid system and scale, crossing the ocean by Chinese latitude hook played an immeasurable role in guiding ancient Chinese people to produce, live and explore the unknown world, and also left us a precious cultural heritage of science and technology. We sincerely appreciate the support from the 2019 Science Popularization Publication Programme of Chinese Academy of Sciences in the publication of this book. Deep appreciation to Li Yifan from Xi'an Shangshu Media for the illustrations.

August 2020, Xi'an

前言

Preface

勤劳智慧的中国人民创造了灿烂的华夏文明。五千年来，中国人在授时、测绘、制图和导航技术方面取得了辉煌的成就。“迷乎云梦者，必须指南以知道，并乎沧海者，必仰辰极以得反。”观象授时、观星辨向、慈石司南、匠人建国、计里画方、牵星过洋，这些技术在指导中国古代劳动人民生产生活和探索未知世界过程中起到了不可估量的作用。同时，以导航技术为纽带，联系中国与世界各国的陆上和海上丝绸之路从未间断。张骞通西域、玄奘西行、鉴真东渡、马可·波罗中国之行、郑和下西洋等，这些丝绸之路的交流大大促进了东西方文明的融合沟通，推动了人类社会的进步与发展。

The industrious and intelligent Chinese people have created a splendid Chinese civilization. Over the past five thousand years, the Chinese have made brilliant achievements in timing, surveying, mapping and navigation technology. "Those who travel to Lake Yunmeng must rely on a compass to get the direction. Those who are lost at a vast sea must resort to stars to return." Technologies such as serving the time by observing celestial phenomena, telling directions by observing stars, governing south by lodestone, constructing the capital with craftsmanship, squared map with grid system and scale, crossing the ocean by Chinese latitude hook played an immeasurable role in guiding ancient Chinese people to produce, live and explore the unknown world. At the same time, with navigation technology as a link, the Silk Roads on land and sea between China and the rest of the world have never been interrupted. These Silk Road exchanges, like Zhang Qian's mission and exploration to central Asia, Monk Xuan Zang's journey to the west, Monk Jian Zhen's travel to Japan, Marco Polo's travel to China, Zheng He's expeditionary voyages and so on greatly promoted the integration and communication between the eastern and the western civilizations, as well as the progress and development of human society.

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——西晋·葛洪

01

授时篇

TIME SERVICE SECTION

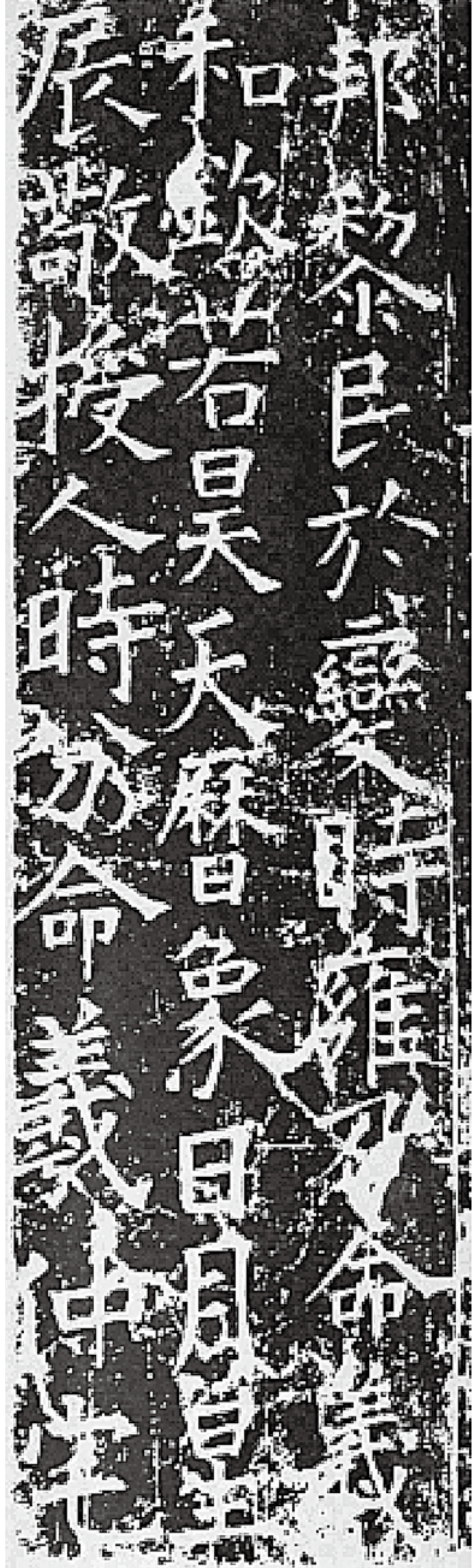
钦若昊天 敬授人时

TIME COMES HEAVENLY, SERVED SINCERELY

“上下四方曰宇，古往今来曰宙”，时间和空间密不可分，构成了人类赖以生存的宇宙。《尚书·尧典》中记载：“乃命羲和，钦若昊天，历象日月星辰，敬授人时。”在中国古代，人们很早就意识到了时间的重要性，并逐步掌握了测时、计时和授时技术。从“立表见影、视影知时”的圭表，到“烧香知夜，刻烛验更”的香钟，再到“孔壶为漏，浮箭为刻”的漏刻，一直到“弦轮密运，机巧精妙”的水运仪象台，测时、计时技术逐步发展，同时又以“打更报时，晨钟暮鼓”等方式授时，并通过“立表验气”“揆日测向”“窥测七政”“制定历法”等，指导农事活动，规范社会治理，方便百姓生活。

"The concept of the universe refers not only to the vast space from heaven to earth, but also to the time from the past to the present". Therefore, time and space are inseparable and constitute the universe on which human beings live. *Book of Documents. Canon of Yao* recorded that "Xi and He were ordered to respect for heaven and observe the sun, the moon and stars to serve people the time". In ancient China, the importance of time was recognized very early. Time determination, timekeeping and time broadcasting techniques had been gradually mastered. The first two had been gradually developed from gnomon to incense clock to clepsydra up to the water-driven astronomical clock-tower. At the same time, the third one was conducted by the method of "sounding the night watches" "morning bell and evening drum" and so on. In addition, "raising the pole to test the solar terms", "measuring the sun shadow to know the direction", "observing the sun, the moon and five planets" and "making the calendar" were used to guide agricultural production, standardize social governance, and facilitate people's life.

钦若昊天 敬授人时
TIME COMES HEAVENLY
SERVED SINCERELY



唐《开成石经》中《尚书·尧典》篇碑刻拓本局部

Part of the ink rubbing of *Book of Documents. Canon of Yao* inscribed on *Kaicheng Stone Classics* of the Tang Dynasty

该碑石现保存于西安碑林博物馆，其中《尚书·尧典》篇记载“乃命羲和，钦若昊天，历象日月星辰，敬授人时”。

帝尧命官授时图，摹自清代《钦定书经图说》

Picture of Emperor Yao ordering the officials to serve the time, a copy from the *Qing Imperial Edition of the Illustrated Book of Documents*

Picture of ordering the officials to serve the time

立竿见影

Raise a Pole to Cast a Shadow

《尚书·尧典》中记述，约在公元前 22 世纪的尧帝时期就有了土圭。将一根竿子直立于地面，通过观察竿影移动规律和长短，来测定节气和年长。《尚书·尧典》称：“期三百有六旬有六日，以闰月定四时成岁”，这是我国古代关于回归年长度的最早的明确记载，它可能就是由粗略的圭表测量而得的结果（引自陈美东《古历新探》）。成书于公元前 1 世纪前后的《周髀算经》记载，“周髀长八尺，夏至之日晷一尺六寸。髀者，股也。正晷者，句也。”可见《周髀算经》用的即是“土圭测景”之法。《周礼·考工记》中记述，先秦时代，人们已经知道通过悬挂准绳来校正表的垂直度，用水平面来校正圭的水平度。

把每天圭表日影最短，且恰好投射在正北方向的圭面上的时刻定为正午时刻。一年中正午时刻日影的长度并不一样，夏至最短，冬至最长，可以定二至日。根据正午时表影的长度，也可以推定四时节气。从正午时表影长度的周期性变化，还可以确定出一个回归年的日数。此为“立竿见影”之法。

As recorded in *Book of Documents. Canon of Yao*, the gnomon appeared in the period of Emperor Yao as early as the 22nd century B.C. A pole was erected on the ground. The solar terms and length of the year could be determined by observing the change of the shadow length of this pole. *Book of Documents. Canon of Yao* stated that "A year has three hundred and sixty-six days, which is constructed by the intercalary month and the four seasons". This was the earliest explicit record on the length of the tropical year in ancient China, which was perhaps a result of rough measurement with the gnomon (quotation from Chen Meidong's *A New Exploration of Ancient Calendars*) . "Arithmetical Classic of the Gnomon and the Circular Paths of Heaven" ("*Zhoubi Suanjing*") written around the 1st century B.C. recorded that "Zhoubi stands 8 chi high and its shadow at noon in the Summer Solstice is 1 chi and 6 cun long. The word 'bi', in other words, means gnomon. The shadow is measured by the ruler placed on the ground in the direction of due north and south." It can be seen that "*Zhoubi Suanjing*" adopted the method of measuring the shadow with the gnomon. From *Rites of Zhou. Artificers' Record*, it can be known that people in the Pre-Qin Period had learned to calibrate the verticality of the gnomon by hanging a plumb line and calibrate the horizontality of the ruler by using a level.

The shadow for the gnomon cast by the sun is not only the shortest at noon every day, but also on the ruler extending to the north, so the solar noon can be determined. The length of the shadow at noon varies from day to day through the year. It is the shortest in the Summer Solstice and the longest in the Winter Solstice, so the two solstices can be deduced. According to the length of the shadow at noon, the solar terms can also be deduced. The length of the tropical year can be derived from the periodic change of the shadow length at noon. This is the method of "raising a pole to cast a shadow".

摹自清代《钦定书经图说》

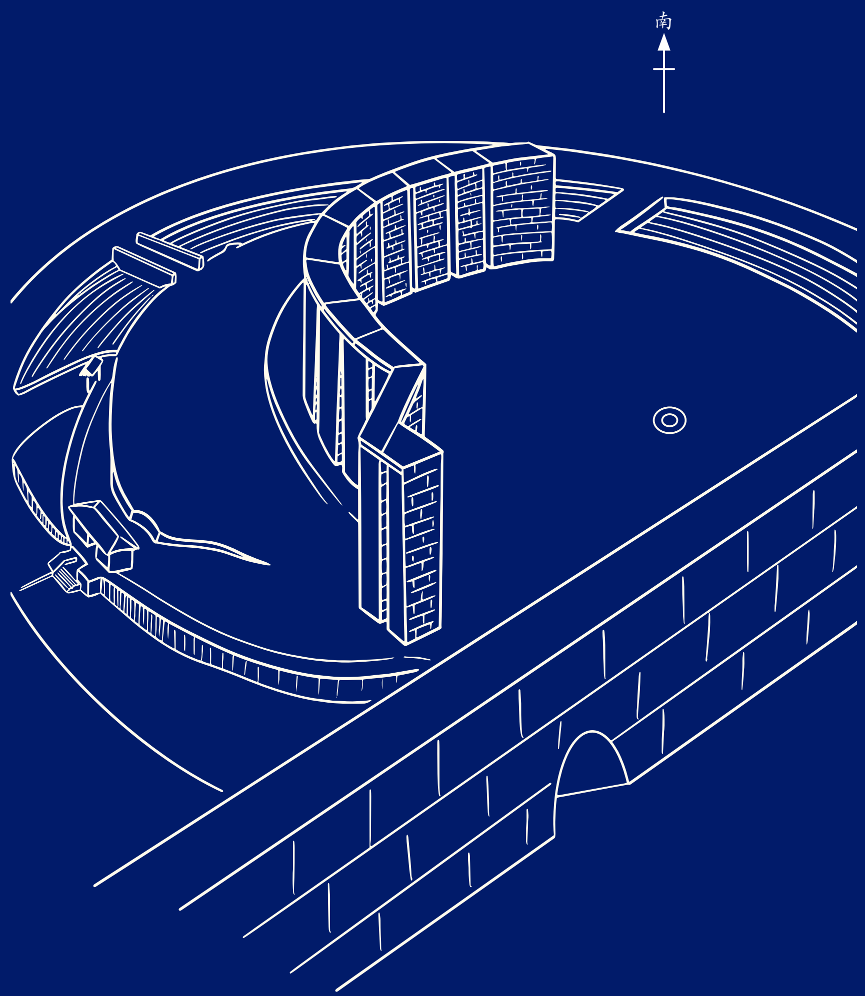
A copy from the *Qing Imperial Edition of the Illustrated Book of Documents*

Picture of "Examining The Sun Shadow at The Summer Solstice"

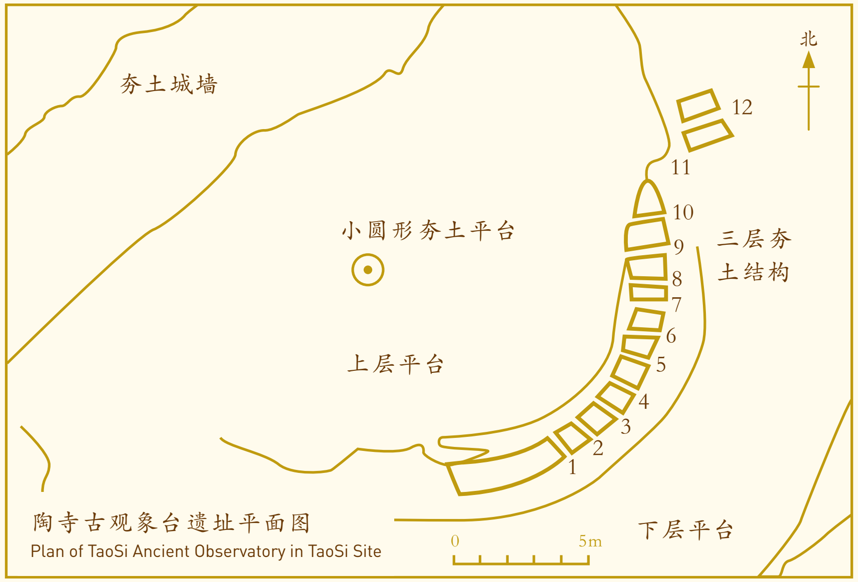
陶寺古观象台
Taosi Ancient Observatory

陶寺遗址是新石器时代晚期我国中原龙山文化的一处重要遗址，位于今山西省襄汾县陶寺村南，距今约为 4 100 年。遗址东西长约 2 000 米，南北宽约 1 500 米，总面积约 300 万平方米。2003 年，我国考古工作者发现，遗址南部有一座三层夯土结构，形状为一座直径约 50 米的半圆形平台。在平台中央部位，有一个直径为 0.86 米的夯土结构观测台，以观测台为圆心，由西向东方向，存有呈扇形辐射状分布的 13 个土坑，据推测这里以前可能矗立有 13 根夯土柱，古代人利用两柱之间的间隙来观测正东方向的塔儿山日出。经实地模拟观测，以观测台为中心，向东望去，从南数第 2 个缝隙看到日出时为冬至日，从第 12 个缝隙看到日出时为夏至日，从中间的 9 个缝隙会看到不同季节的日出。由此推测，该平台遗址很可能是帝尧时期的古观象台，人们通过观测日出方向确定节气时令，安排农耕。经实地模拟观测后确认，其测得的节气时令精确度较高。

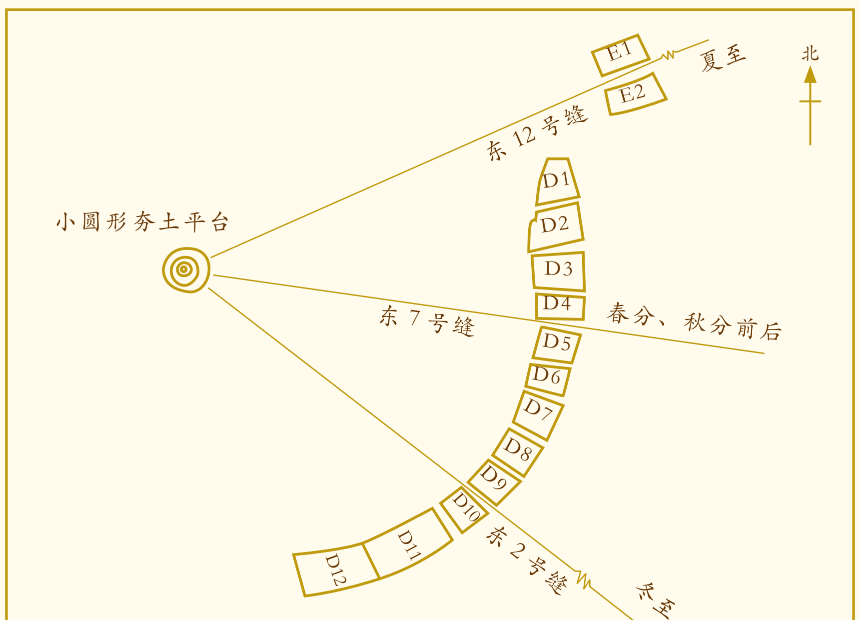
Taosi Site is an important site of Longshan Culture in Central Plains of China in the Late Neolithic Age. Located in the south of Taosi Village, Xiangfen County, Shanxi Province, it was about 4,100 years ago. It is about 2,000 meters long from east to west and 1,500 meters wide from north to south, with a total area of 3 million square meters. In 2003, Chinese archaeologists discovered that in the southern part of the site, there is a three-layer rammed earth structure, with a shape of a semicircular platform about 50 meters in diameter. In the middle of the platform, there is a rammed earth observatory with a diameter of 0.86 meters. Centered on the observatory, there are 13 pits in a fan-shaped radiation from west to east. There may be 13 rammed earth columns, and the ancient people used the gap between the two columns to observe the sunrise from Ta'er Mountain in the east direction. When watching the sunrise in the east through the second gap from the south with the observatory as the center, it is the winter solstice. While it is the summer solstice when watching the sunrise through the twelfth gap and they are other solar terms when watching the sunrise through other nine gaps in the middle through analogue field observation. It can be speculated Taosi Site was probably an ancient observatory during the reign of Emperor Yao to decide on the solar terms and arrange farming by observing the direction of sunrise. Confirmed by analogue field observation, the accuracy of the solar terms is very high.



陶寺遗址中的陶寺古观象台
Taosi Ancient Observatory in Taosi Site



陶寺古观象台遗址平面图
Plan of TaoSi Ancient Observatory in TaoSi Site



陶寺古观象台实地模拟观测日出示意图
Schematic diagram of analogue field sunrise observation of Taosi Ancient Observatory
注：E1、E2、D1 ～ D11 为夯土柱基础。

陶寺古观象台复原效果图
Restoration effect of TaoSi Ancient Observatory

通过柱间狭缝观测日出判断节气，证实了《尚书·尧典》上所说的“历象日月星辰，敬授人时”“分命羲仲，宅嵎夷，曰旸谷。寅宾出日，平秩东作。日中，星鸟，以殷仲春”的记载。

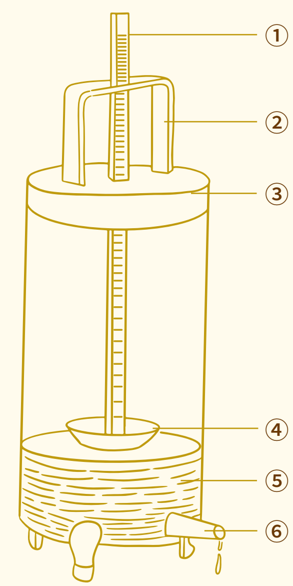
西汉铜漏
Western Han Copper Clepsydra

漏壶是中国古代最主要的计时仪器，也称“漏刻”，历史非常悠久。梁代《漏刻经》记载：“漏刻之作，盖肇于轩辕之日，宣乎夏商之代。”早期漏刻多为泄水型漏刻，水从漏壶孔流出，漏壶中的箭尺随水面下降，箭尺上的刻度指示时刻。受水型漏刻的箭尺在受水壶中，随水面上升指示时刻，为了得到均匀水流可置多级供水壶。直到北宋燕肃创制了莲花漏，莲花漏首次采用漫流系统，使得只需两级供水壶，即可保证受水壶水位均匀增加。已出土的最古漏壶为西汉遗物。这里展示的是内蒙古出土的西汉“千章铜漏”和陕西省兴平县（今兴平市）出土的西汉“兴平铜漏”，均属于泄水型（沉箭式）漏壶。

Water clocks or clepsydras are the most important timing instruments in ancient China. This kind of clocks is rich in history. *The Classics on Clepsydra* of the Liang Dynasty recorded that "The clepsydra was originated during the reign of Emperor Huang and popularized in the Xia and Shang Dynasties." Most of the early ones are outflow water clocks. When water flows out of the water clock hole, the sinking arrow in the water clock will fall down with the water surface and the markings on the sinking arrow indicate the passage of time. The floating arrow in the inflow vessel of an inflow water clock indicates time with the rise of water surface. In order to get the constant flow, the multiple reservoirs can be placed. It was not until Yan Su invented the lotus clepsydra in the Northern Song Dynasty adopting the flooding system for the first time that the water clock with only two vessels was able to ensure the even increase of the water in the inflow vessel. The earliest water clocks unearthed are from the Western Han Dynasty. Here are "Qianzhang copper water clock" and "Xingping copper water clock" of the Western Han Dynasty, which are unearthed in Inner Mongolia and Xingping County (today's Xingping City), Shaanxi Province respectively. Both of them belong to the outflow type (sinking arrow) water clock.

千章铜漏
（现藏于内蒙古博物院）
Qianzhang copper water clock
(now housed in Inner Mongolia Museum)

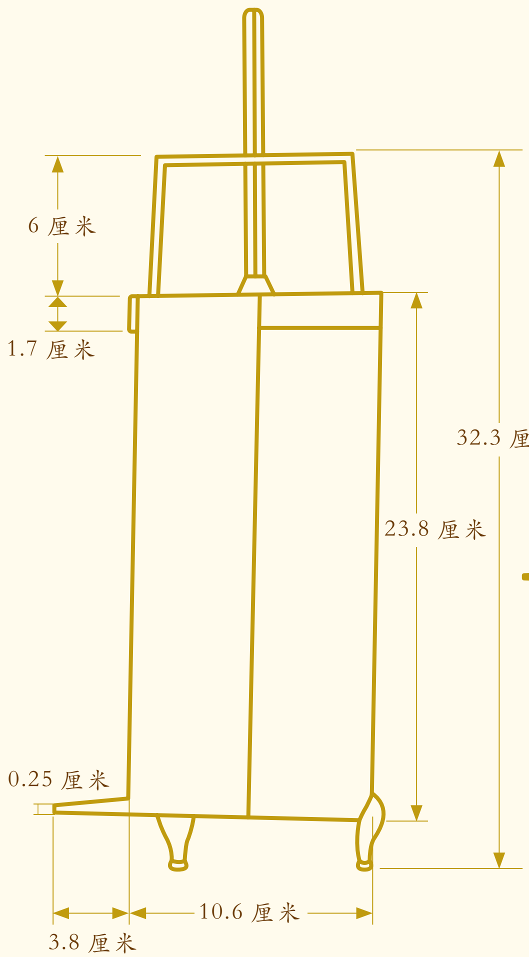
兴平铜漏
（现藏于陕西茂陵博物馆）
Xingping copper water clock
(now housed in Shaanxi Maoling Museum)



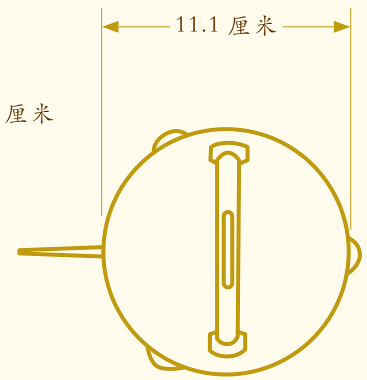
① 箭尺 Arrow
② 提梁 Handle
③ 壶盖 Lid
④ 浮舟 Float
⑤ 水 Water
⑥ 流管 Water clock hole

沉箭漏结构图
Structure of a sinking arrow clepsydra

沉箭漏古老且简单，只有单壶，壶的下部有流管，壶中有一直立浮于水面的箭杆，上有刻度，此即箭尺。使用时，壶中水通过流管不断泄到壶外，箭尺便逐渐下沉，以指示时刻。由于是单壶，壶中水位在滴泄过程中会逐渐下降，从而导致流速不匀，故应不等距地划分箭尺的刻度：越接近下端，刻度越疏；越接近上端，刻度越密，这样才能够表示相等的时间间隔。

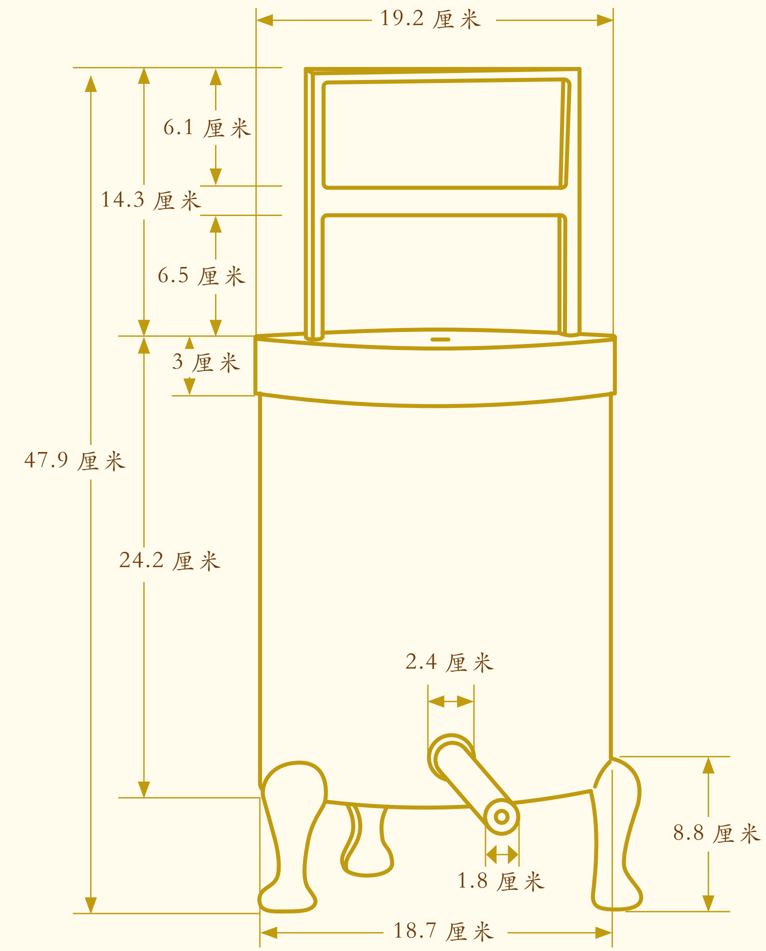


兴平铜漏侧视图
Side view of Xingping copper water clock



兴平铜漏俯视图
Top view of Xingping copper water clock

兴平铜漏，1958年出土于陕西省兴平县（今兴平市）茂陵附近的西汉墓。壶通高32.3厘米，口径10.6厘米，提梁梁高6厘米。盖和梁的中央有正相对应的长方形插尺孔各一个，孔长1.73厘米，宽0.5厘米，用以穿插有时辰的标尺。其容水量为2 082立方厘米，年代属西汉中期。壶身亦较完整，流管长3.8厘米，管口径0.25厘米。现藏于陕西茂陵博物馆。



千章铜漏
Qianzhang copper water clock

千章铜漏，1976年出土于内蒙古伊克昭盟（今鄂尔多斯市）杭锦旗。壶通高47.9厘米，口径18.7厘米，容水量为6 384立方厘米。下部流管长8.2厘米，近管端处有一圈凹槽，管口径0.31厘米。此壶为迄今容量最大、保存最完整的西汉铜漏壶，制于汉成帝河平二年（前27）。壶身刻有一行铭文“千章铜漏一，重卅二斤，河平二年四月造”。现藏于内蒙古博物院。

仪征东汉铜圭

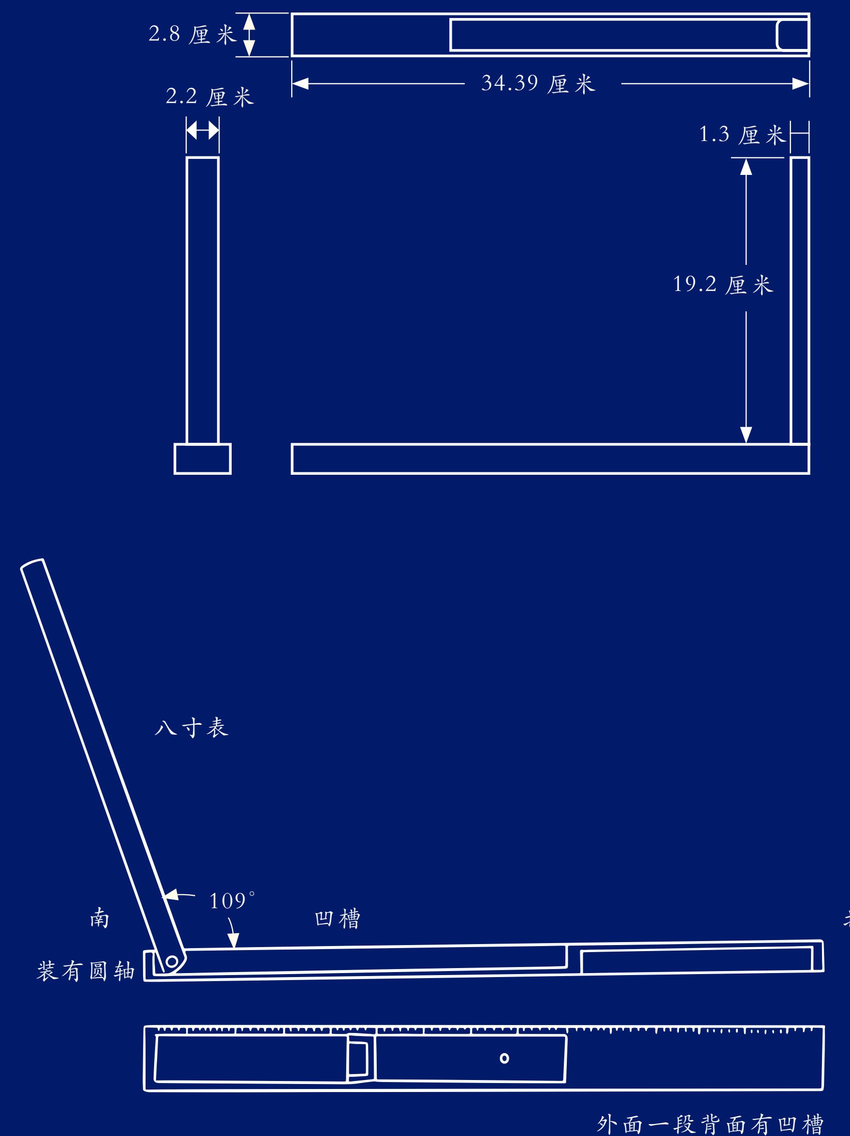
Yizheng Eastern Han Sundial

圭表是一种古老的测量日影长度的天文仪器，它由直立的表和一个南北方向水平放置的圭组成，用以观察太阳光投射的表影影长，以定午时和四时节气等。

1965 年在江苏省仪征市一座东汉中期的木椁墓中出土了一件小型折叠式铜圭表。这圭表高仅汉尺八寸（通常表高八尺），即 19.2 厘米，宽 2.2 厘米，厚 1.3 厘米。表底部有轴与下面的圭身相连接，犹如铰链，可以启合。圭身长汉尺一尺五寸，即 34.39 厘米，宽 2.8 厘米，厚 1.4 厘米。此圭表不用时可放倒表身，再将其置放在长扁形圭体匣内，能随身携带。此圭表圭身边上刻有尺寸，共 15 寸，寸以下还有分，每寸 10 分，以圆点作标志。刻度略有参差，有修改的痕迹。自零点至 5 寸处为 11.49 厘米，至 10 寸处为 23.33 厘米，至终端 15 寸，总长 34.39 厘米。仪征东汉铜圭现保存于南京博物院。

A sundial is an ancient astronomical instrument for measuring the length of the sun shadow. It consists of an upright gnomon and a ruler placed horizontally in the north-south direction. It is used to observe the shadow length for the gnomon cast by the sun in order to determine the noon and solar terms.

In 1965, a small folding copper sundial was unearthed from a wooden coffin tomb of the middle Eastern Han Dynasty in Yizheng, Jiangsu Province. The sundial is only eight cun (Generally they are eight chi tall. Cun and Chi are Han Dynasty's units of length. 10 cun=1 chi) tall, that is, 19.2 cm tall with 2.2 cm in width and 1.3 cm in thickness. There is an axle at the bottom of the gnomon to join the ruler below, just like a hinge, so it can be close and open. The ruler is one chi and five cun long, that is, 34.39 cm long with 2.8 cm in width and 1.4 cm in thickness. When not in use, it can be folded into a long flat ruler-shaped box so that it can be carried on. The graduations are marked on the ruler. There are 15 markings in cun. Smaller than cun, there is fen (10 fen=1 cun) marked with dot. The graduated markings are slightly uneven with traces of modification. It is 11.49 cm long from zero to 5 cun and 23.33 cm long from zero to 10 cun with a total of 34.39 cm in length ending in 15 cun. Yizheng Eastern Han Sundial is now preserved in Nanjing Museum.



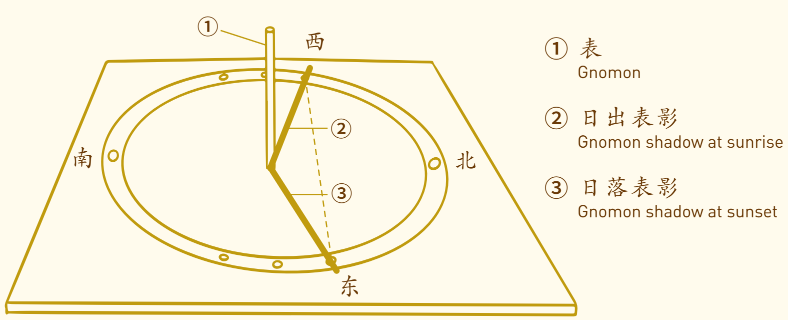
南京博物院展示的东汉铜圭表构造图
The configuration of the Eastern Han sundial in Nanjing Museum

仪征东汉墓出土的铜圭实物图
The copper sundial unearthed from the Eastern Han tomb in Yizheng

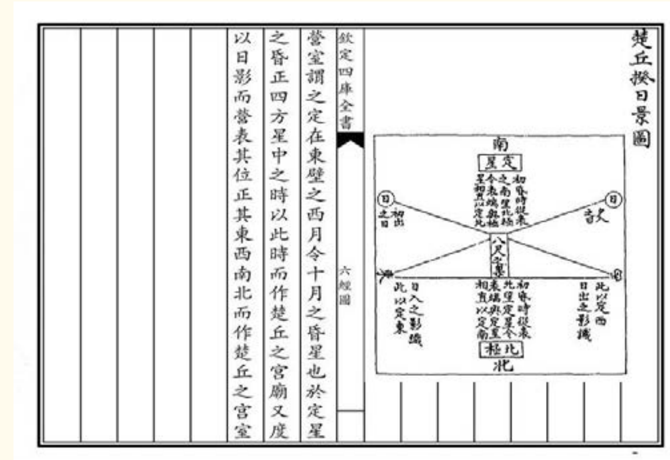
圭表早期的主要功能应该包括定方向、定节气、定午时等。

定方向

以表为圆心画一个圆周，观测同一天日出、日落时的表影与圆周的交点。连接两个交点的直线，就代表正东、正西的方向。正午时的表影方向和夜间北极星的方向，可作为验证依据。南宋杨甲编撰的《六经图》中的“楚丘揆日景图”给出了利用初昏观表以定南北，利用日出、日入表影以定东西的方法。



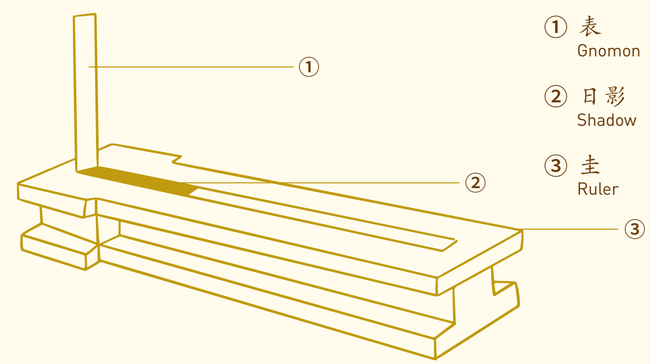
土圭定方向示意图
Schematic diagram of a sundial determining the direction


楚丘揆日景圖
欽定四庫全書 六經圖
營室謂之定在東壁之西月令十月之昏星也於定星
之昏正四方星中之時以此時而作楚丘之宮廟又度
以日影而營表其位正其東西南北而作楚丘之宮室

《钦定四库全书》记载的《六经图》中的“楚丘揆日景图”
Illustration of Six Classics paraphrasing the measurement of the sun shadow recorded by *Complete Books of the Four Imperial Repositories*

定节气

冬至、春分、夏至、秋分是一年中的关键性时间标记点，对农业耕作有极为重要的指导作用。一年中，冬至正午时表影最长，夏至正午时表影最短。



圭表定节气示意图
Schematic diagram of a sundial determining the solar terms

定午时

每天日影最短的时刻，就是太阳上中天的时刻，也就是午时。

李兰秤漏

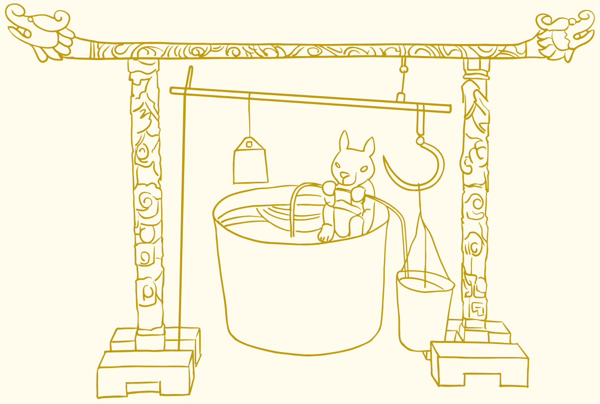
Li Lan Steelyard Clepsydra

秤漏是一种与滴漏原理不同的漏刻，是用中国秤称量通过虹吸流入受水桶中水的重量来进行计时的仪器。秤漏是公元 450 年左右由北魏道士李兰发明的，故也称李兰秤漏。秤漏有一只较大的供水桶，用一根细管（古称“渴乌”）通过虹吸原理将水引入另一只受水桶中。受水桶悬挂在秤钩上，通过秤即可称量受水桶的重量。唐代徐坚等编撰的《初学记·卷二十五》中记载了李兰漏刻法：“以铜为渴乌，状如钩曲，以引器中水于银龙口中，吐入权器。漏水一升，称重一斤，时经一刻。”当流入受水桶中的水增加一升时，重量增加一斤，时间间隔一刻。秤漏的计时精度高于普通滴漏，因此，隋朝以后秤漏基本成为官方的主要计时器，直到北宋人们才正式采纳燕肃莲花漏。

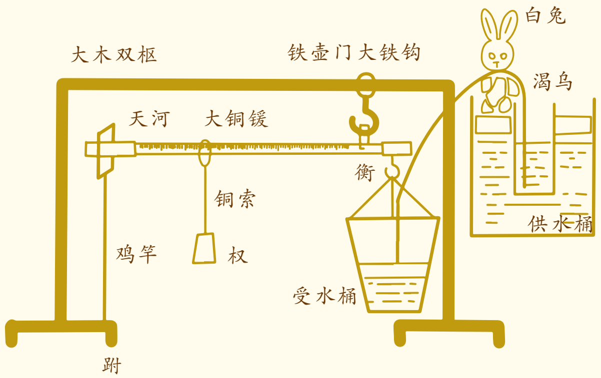
英国李约瑟博士最先指出其特点，从设计思想上看，秤漏与传统漏刻是有所不同的。传统漏刻是利用在单位时间内漏水体积相等的原理来进行时间的量度，而秤漏利用的则是在单位时间内漏水重量相等的原理。

A steelyard clepsydra is a type of water clock which is completely different from other forms of water clock in terms of the principle. It is a timepiece by which time is measured by the flow of water into a bucket, and where the amount is then weighed by a Chinese steelyard scale. It was invented by Li Lan, a Taoist of the northern Wei Dynasty around 450 A.D., so it is also called Li Lan steelyard clepsydra. Water is siphoned through a thin tube (formerly known as "kewu") from one bigger reservoir bucket to the other inflow bucket which is suspended via a hook, and the weight of the inflow bucket can be indicated by the scale. *A Primer for Beginners. Volume 25* compiled by Xu Jian et al. recorded the usage of Li Lan steelyard clepsydra, "The kewu is made of brass and bent like a hook to lead water from the reservoir bucket to the inflow bucket. When water in the inflow bucket reaches one sheng (Chinese unit of volume), the weight is one catty and the time interval is a quarter." Tests have shown that the steelyard clepsydra has the daily error of no more than 1 minute, more accurate than other clepsydras. For this reason, steelyard clepsydras were the main official timing devices after the Sui Dynasty and had been used into the Northern Song Dynasty when Yan Su lotus clepsydra was formally adopted.

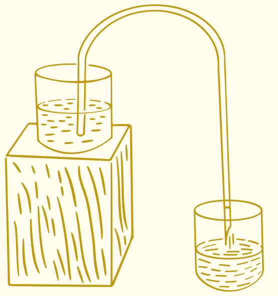
British scholar Dr. Joseph Needham first pointed out its importance. From the perspective of design, the difference between the steelyard clepsydra and the traditional water clock is that the latter measures time by constant volume flowed per unit of time, while the former measures time by constant mass flowed per unit of time.



李兰秤漏
Li Lan Steelyard Clepsydra



秤漏原理图
Schematic diagram of a steelyard clepsydra



虹吸原理示意图
Schematic diagram of siphon principle

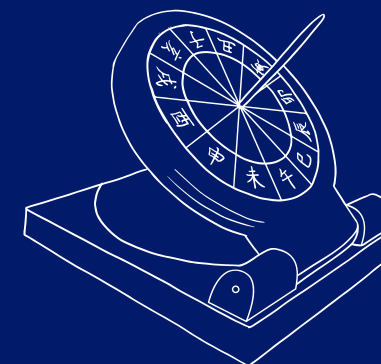
虹吸是利用液面高度差的作用力现象，将液体充满一根倒 U 形的管状结构内后，将开口高的一端置于装满液体的容器中，容器内的液体会持续通过虹吸管向较低的位置流出。虹吸实质是因为液体压强和大气压强而产生的。

西安小雁塔日晷

Xi'an Small Wild Goose Pagoda Sundial

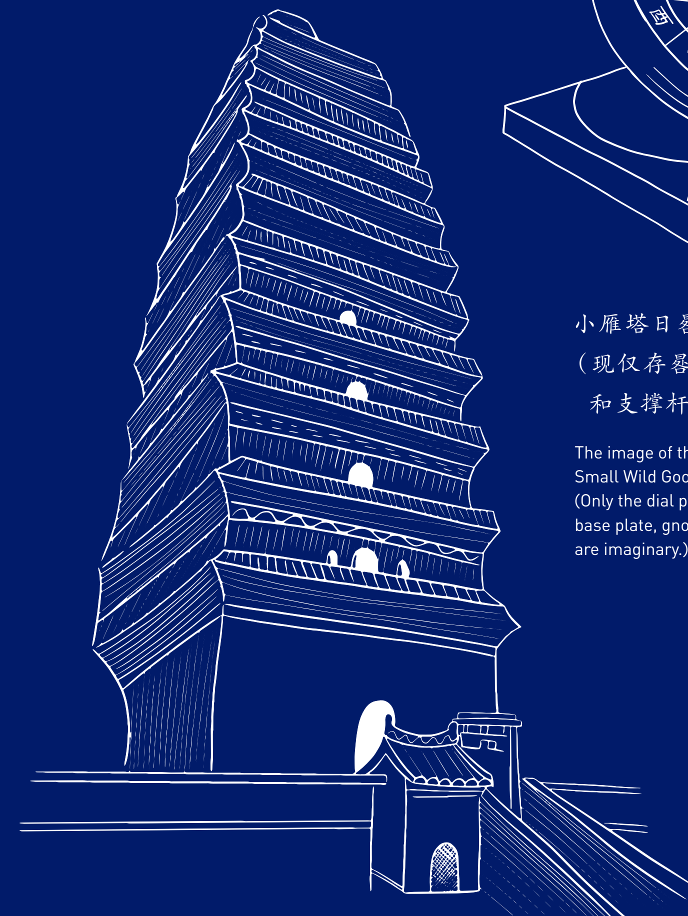
西安小雁塔日晷是在 1976 年 7 月出土于西安市新城广场。此日晷晷面直径 33 厘米，厚 4.5 厘米，晷面下侧有一长耳，耳中有一横向圆孔，孔径 1.5 厘米。若孔中有一横轴与基座连接，则晷面角度可调。据此可推测这是一种可调角度的类赤道式日晷（见刘次沅、张铭洽《陕西关中古代天文遗存》）。在春分至秋分的半年里，保持其晷面与地球赤道面平行；在秋分至下年春分的半年里，随季节变化逐渐调整晷面角度，使阳光始终能照射在正面。小雁塔日晷与其他日晷最大的不同就在于此日晷盘面与基座处通过轴连接，可以调整盘面的倾斜角度，这使得它有两个特点，其一，使冬季阳光亦能照在正面，其二，可适应放置在不同纬度的地点。该日晷收藏于西安小雁塔博物馆（现西安博物院）中，故称之为小雁塔日晷。从形制及文字判断其制作年代应为隋代（581—618）或唐代（618—907）初期。

Unearthed in Xi'an Xincheng Square in July 1976, Xi'an Small Wild Goose Pagoda Sundial is 33 cm in diameter and 4.5 cm in thickness. There is a long knuckle with a diameter of 1.5 cm at the bottom of the dial, through which a pin can be inserted in laterally to join the base, thus allowing the dial to rotate a limited angle. It can be inferred that this is a quasi-equatorial sundial whose dial plate can be moved in altitude (*Ancient Astronomical Relics in the Central Shaanxi Plain* by Liu Ciyuan, Zhang Mingqia). During the half-year period from the vernal equinox to the autumnal equinox, keep the dial plate parallel to the equator, while during another half-year period from the autumnal equinox to the next vernal equinox, gradually rotate the dial plate by the appropriate angle with the seasons, so the sun shadow can be cast from above. The biggest difference between the Small Wild Goose Pagoda Sundial and other sundials is that its dial plate and base are coupled together by an axle so that the dial plate can be rotated so as to allow the sun to shine on the front in winter too and to match the local latitude. The sundial is housed in Xi'an Wild Goose Pagoda Museum (present-day Xi'an Museum), hence the name. Based on its style and characters, it was made in the Sui Dynasty (581 A.D.–618 A.D.) or the early Tang Dynasty (618 A.D.–907 A.D.).



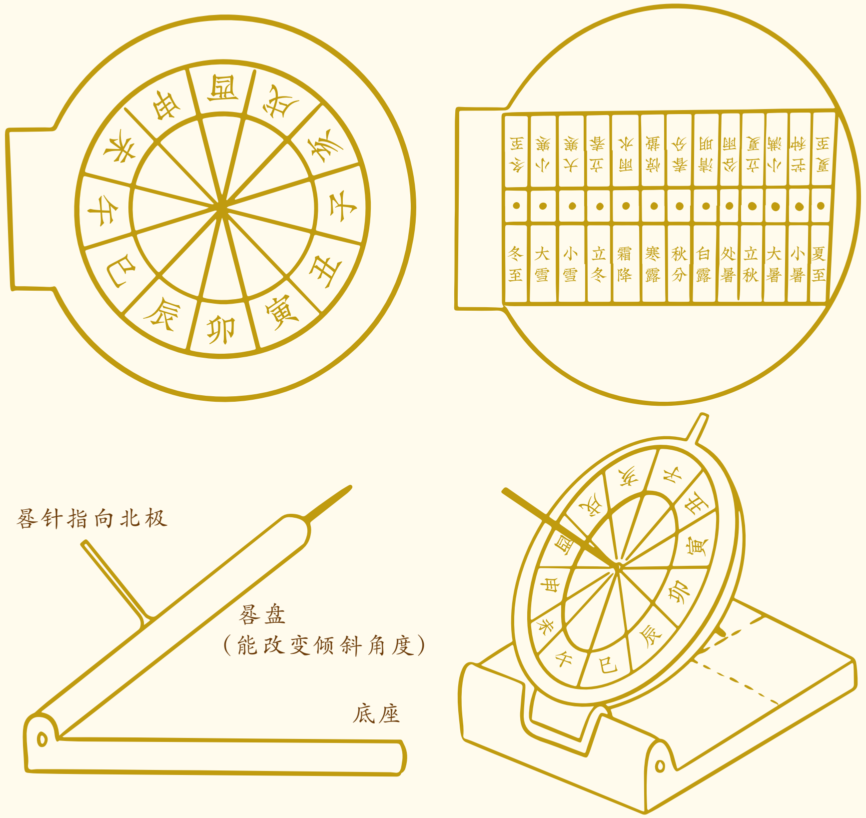
小雁塔日晷复原图
（现仅存晷盘；晷座、晷针和支撑杆是想象的）

The image of the restored Xi'an Small Wild Goose Pagoda Sundial (Only the dial plate remains. The base plate, gnomon and support bar are imaginary.)



陕西西安小雁塔

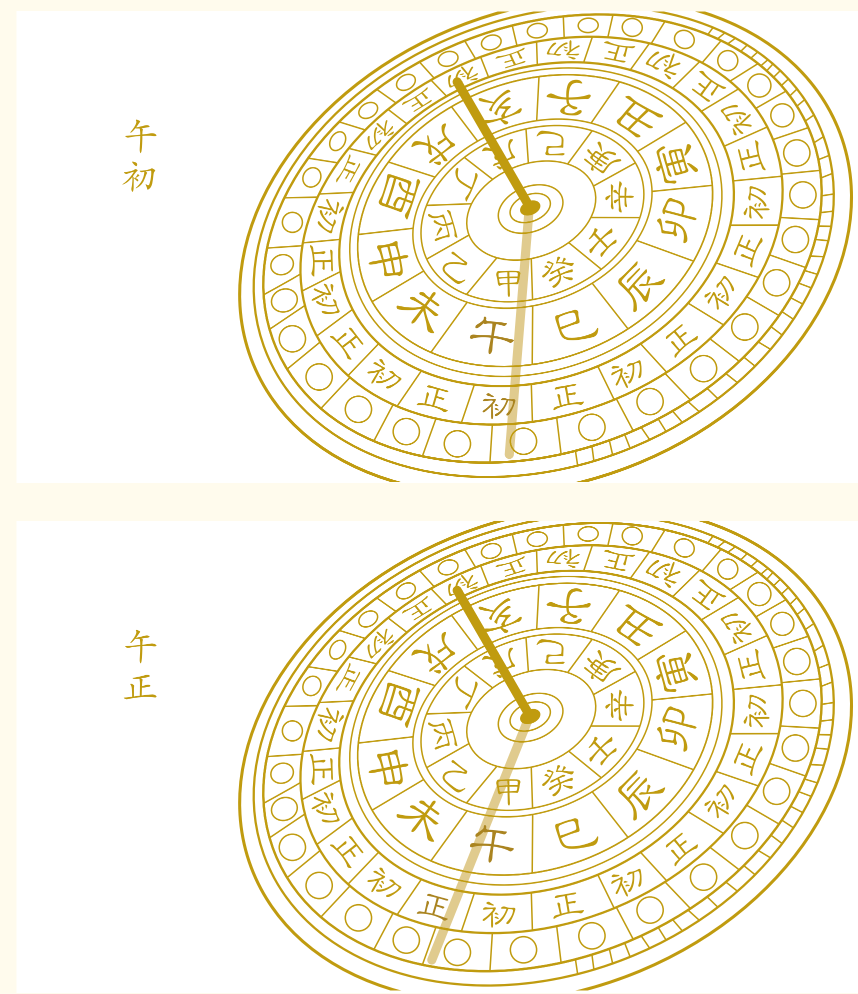
Small Wide Goose Pagoda, Xi'an, Shaanxi



小雁塔日晷的晷面（左上）、背面（右上）
及侧视（左下）、结构复原图（右下）

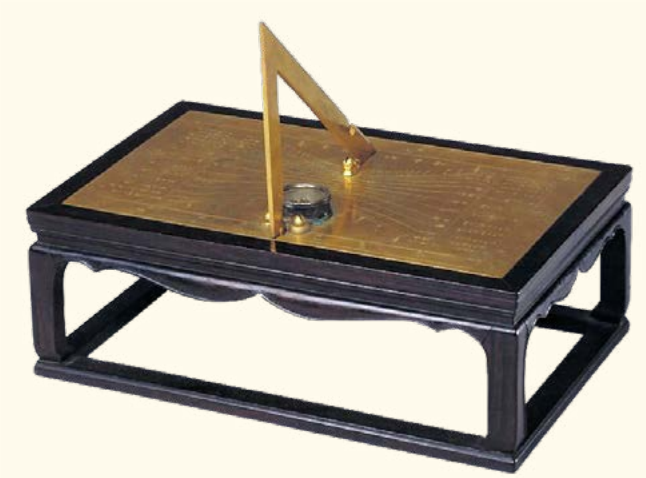
The dial plate of Small Wild Goose Pagoda sundial (upper left), the reverse side (upper right), the side view (bottom left), the image of the restored structure (bottom right)

日晷正面刻有两个同心圆，直径依次为 17.7 厘米和 27.5 厘米。圆心处有小孔，深 2.3 厘米，直径 0.8 厘米。自圆心向外，刻有均匀分布的 12 条辐射线。在外圆内形成的 12 格依次刻有子、丑、寅、卯、辰、巳、午、未、申、酉、戌、亥十二时辰。在晷盘背面，沿中心子、午两字正中方向有 13 个圆孔，其间距为 1.4 厘米，其左右两方，以楷书分别刻有二十四节气名。自上向下，右面为夏至、小暑、大暑、立秋、处暑、白露、秋分、寒露、霜降、立冬、小雪、大雪、冬至；左面为夏至、芒种、小满、立夏、谷雨、清明、春分、惊蛰、雨水、立春、大寒、小寒、冬至。



赤道式日晷指示时刻示意图

Schematic diagram of an equatorial sundial indicating time

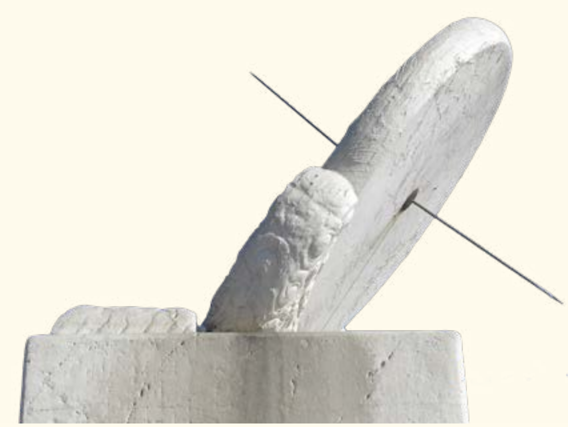


新法地平日晷（上）及晷面图（下），现存于故宫博物院

Horizontal Sundial with the New Mechanism (top) and the dial plate (bottom), currently in the Palace Museum

地平式日晷，即晷盘水平放置，晷表置于正南正北方向的日晷，在北半球，晷针指向北天极，即晷针和晷盘的夹角是当地的地理纬度。

新法地平日晷，明末由德国传教士汤若望制作，它采用了当时欧洲流行的地平日晷制作法，并且结合了中国传统的时间历法制度，被称为“新法”。该日晷以不等分形式标注时刻线，采用一日 96 刻制。汤若望于 1644 年 7 月将此日晷进呈清廷。



北京故宫太和殿丹陛的赤道式日晷

An equatorial sundial on the raised platform of the Hall of Supreme Harmony in the Forbidden City, Beijing

18 世纪英国制造的铜镀金地平赤道公晷仪，现存于故宫博物院

A gilded bronze horizontal-equatorial sundial made in England in the 18th century, currently in the Palace Museum

赤道式日晷的晷面平行于地球赤道面，晷盘倾斜摆放。在北半球，其晷针指向北天极，晷盘和水平面的夹角是当地地理纬度的余角。每年春分之后，人们就可以在倾斜晷盘的上表面看到日影，到了秋分之后，人们又可以在晷盘的下表面看到日影。

龙舟香漏
Dragon Boat Incense Timing

香漏是利用燃烧香料来计时的仪器，至迟出现于北宋（960—1127）时期（见王立兴《民间计时仪器“香漏”考》）。下图所示是龙舟香漏，可以看到一艘龙舟形的盛器上放着一根或几根点燃的香，香上横放着数条两端系上金属球的线，每隔一段时间，香便会烧断一条线，使金属球跌入下面的铜盘，发出响声，报告时间。其也称“火闹钟”。香漏计时虽然精度不高，但简单易行，极适合民间使用，所以曾经十分流行。

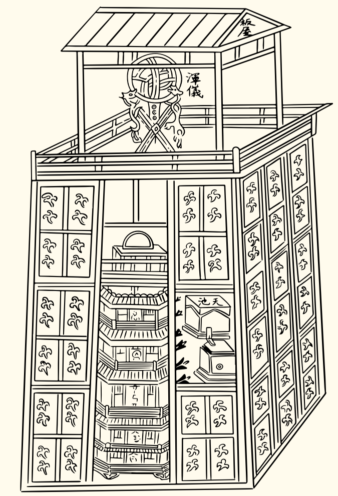
An incense clock which emerged no later than the Northern Song Dynasty (960 A.D.–1127 A.D.), is a timekeeping device that uses the burning incense to measure time (*A Study of the Folk Timepiece "Incense Clock"* by Wang Lixing). The picture below shows "Dragon Boat Incense Timing". One or more lighted incenses are placed on a container shaped like a dragon boat. Several threads with metal beads on both ends are placed across the incenses. At regular intervals, the incense will burn one of these threads, making the metal beads drop onto the brass tray below, giving off a sound and reporting time. Despite its relatively poor timing accuracy, it is still an easy-to-use folk timepiece, and thus it was very popular for a time.

龙舟香漏
Dragon Boat Incense Timing

水运仪象台

Water-driven Astronomical Clock-tower

水运仪象台是以水为动力来运转的集计时、报时、天象演示和天文观测为一体的大型天文计时仪器。由北宋科学家苏颂和韩公廉设计建造，宋哲宗元祐初年 (1086) 开始设计，6 年后建成。整台仪器高约 12 米，宽约 7 米，分为 3 层，构造十分精巧。水运仪象台的最下层是动力系统和计时报时系统，由打水人转动“升水轮”，将水升至最顶部的“天河”中，“天河”中的水流入两级漏壶装置，两级漏壶采用漫流系统保证了“平水壶”水位恒定，从而保证了泄水的均匀性，平水壶中的水通过一根虹吸管注入“枢轮”的水斗，“枢轮”上有 36 个水斗，依次盛水，在重力作用下驱动“枢轮”转动，这就是整台仪器的原动力；报时装置分为 5 层木阁，分别报告或显示昼夜辰刻、昏旦时刻、夜间更点等，此报时装置由若干小木人通过钟、鼓、铃、钲 4 种乐器报时。中间一层放置了一台浑象，在八重昼夜机轮联动下，按照天体周日视运动转动，可以演示实时天象。水运仪象台最上层的平台上放置一台浑天仪，实际上就是一台没有镜片的望远镜，它在昼夜机轮和天柱系统联动下实时转动，与天体运动保持同步。浑天仪外有一个“脱摘板屋”，可防风挡雨，屋顶拆卸后即可观测。



苏颂《新仪象法要》中的水运仪象台台体图

Illustration of the Water-driven Astronomical Clock-tower in *Essentials of a New Method for Mechanizing the Rotation of an Armillary Sphere and Celestial Sphere* written by Su Song

水运仪象台的机械传动装置中，由“天关”“天衡”和“天锁”等部件组成一组杠杆装置，这组杠杆装置把连续稳定的水流运动转化为均匀的间歇式机械运动，这类似于现代钟表的锚状擒纵器，比欧洲出现锚状擒纵器早了约 6 个世纪。英国科技史学家李约瑟认为“水运仪象台可能是欧洲中世纪天文钟的鼻祖”。

公元 1127 年金兵攻陷北宋都城汴梁（今开封）时，水运仪象台遭到严重破坏，其被运送到金中都（今北京）后，未能恢复。南宋曾试图依据苏颂编写的《新仪象法要》恢复这台旷世奇作，但始终没有成功。从此，水运仪象台只能成为史书上的记载，证明中国古代天文计时仪器和机械制造曾经达到的一个高峰。

水运仪象台的三大创新性贡献：一是设计了与水斗联动的天衡关锁系统，类似于现代钟表的擒纵系统；二是建立了自动天文跟踪观测装置，昼夜机轮和天柱系统带动浑象和浑仪实时转动，类似现代望远镜的转仪钟；三是其可拆卸式屋顶，是现代天文圆顶的雏形。

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水运仪象台

Water-driven Astronomical Clock-tower

The water-driven astronomical clock-tower is a hydraulic-powered large astronomical instrument that integrates timekeeping, time broadcasting, astronomical demonstration and observation. The design and construction by Su Song and Han Gonglian started in the first year of the Yuanyou period (1086 A.D.) of Emperor Zhezong of Song and were completed six years later. Divided into three levels, it is about 12 meters high and 7 meters wide with very delicate structures. The bottom level is the power and timing system. A man raises water to the top "celestial flume" tank by rotating the waterwheel, from where the water flows to the two-level clepsydra. The two-level clepsydra employs flooding system to ensure the constant water level of the constant-level tank, thereby the evenness of the water jet can be achieved. A siphon leads the water from the constant-level tank to one of the 36 scoops mounted on the driving wheel which moves forward in turn under the effect of gravity. This is the power system of the entire instrument. The timing system is a five-storey wooden pavilion which announces or displays the dusk, dawn, and midnight, etc. with four musical instruments, namely ring, drum, bell and gong played by wooden minions. A celestial sphere is placed on the middle level. By the performance of the linkwork called "eight superimposed wheels", it is rotating following the diurnal motion of the celestial bodies to demonstrate the celestial phenomena in real time. The top level is equipped with an armillary sphere which is actually a telescope but with no lens. Whenever the linkwork devices of "eight superimposed wheels" and "celestial pillar" moves, it rotates the armillary sphere in real time, keeping pace with the movement of the celestial body. The armillary sphere is placed in a chamber with a removable roof which is advantageous for observing the sky as well as preventing rain and wind.

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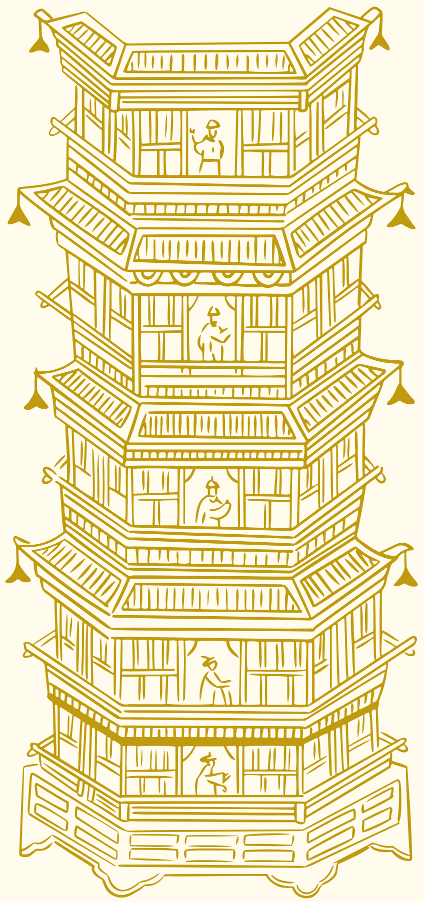
水运仪象台

Water-driven Astronomical Clock-tower

The mechanical power transmitting device of the water-driven astronomical clock-tower consists of a set of lever components such as "celestial stopping device" , "celestial counterweight" and "celestial lock" which can turn the continuous and stable motion of water flow into the uniform intermittent mechanical motion, similar to the anchor escapement of modern clocks. Earlier than Europe by six centuries, it is believed by British historian of science Joseph Needham that "The water-driven astronomical clock-tower may be the originator of the European medieval astronomical clock."

The astronomical clock-tower was seriously damaged in 1127 A.D. when the invading Jurchen army of Jin captured Bianliang (now Kaifeng), the capital city of the Northern Song Dynasty. After the components of the clock-tower were carted back to the central capital (now Beijing) of Jin, they were unable to piece it back together. The Southern Song Dynasty tried to restore this elaborate masterpiece according to Su Song's treatise "Xinyi Xiangfayao" (lit. *Essentials of a New Method for Mechanizing the Rotation of an Armillary Sphere and Celestial Sphere*), but they never succeeded. Since then, the astronomical clock-tower can only be seen in the historical records, witnessing a peak of ancient Chinese astronomical instruments and machinery manufacturing.

The three innovative contributions of the water-driven astronomical clock-tower are: The first is the design of the system of "celestial counterweight" "celestial stopping device" and "celestial lock" which moves with the scoops, similar to the modern clock escapement. The second is the establishment of the astronomical tracking system—"celestial pillar" and "eight superimposed wheels"— to operate the rotation of the armillary sphere and celestial sphere, similar to modern clock drive of an equatorial mounted telescope. The third is the removable roof which is the prototype of the dome of modern astronomical observatories.



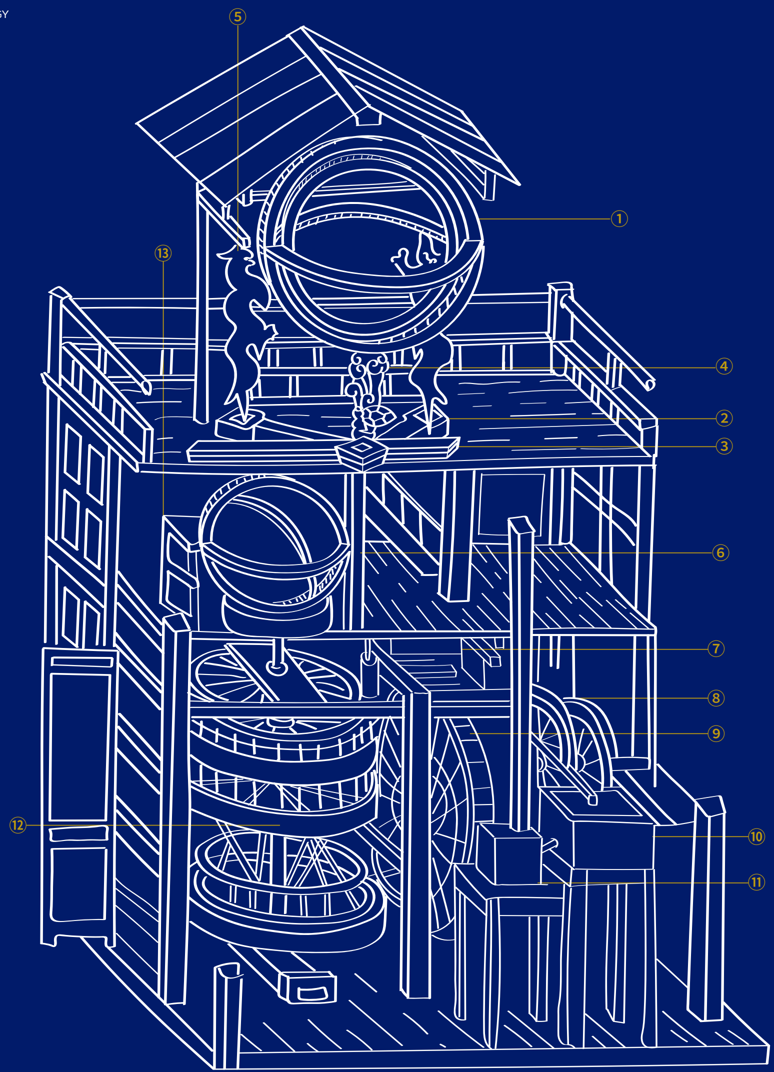
苏颂《新仪象法要》中的木阁图

Illustration of a wooden pavilion in *Essentials of a New Method for Mechanizing the Rotation of an Armillary Sphere and Celestial Sphere* written by Su Song

《新仪象法要》对水运仪象台的整体进行了描述，并画有一图，包括全部机构。从仪器的功能来看，水运仪象台包括报时和传动两大系统。报时系统就是“木阁”，文字说明是：“右木阁五层，在机轮前：第一层，时初木人左摇铃，刻至中击鼓，时正右扣钟；第二层，木偶人出报时初及时正；第三层，木人出报十二时中百刻；第四层，夜漏击金钲；第五层，分布木人出报夜漏箭。”

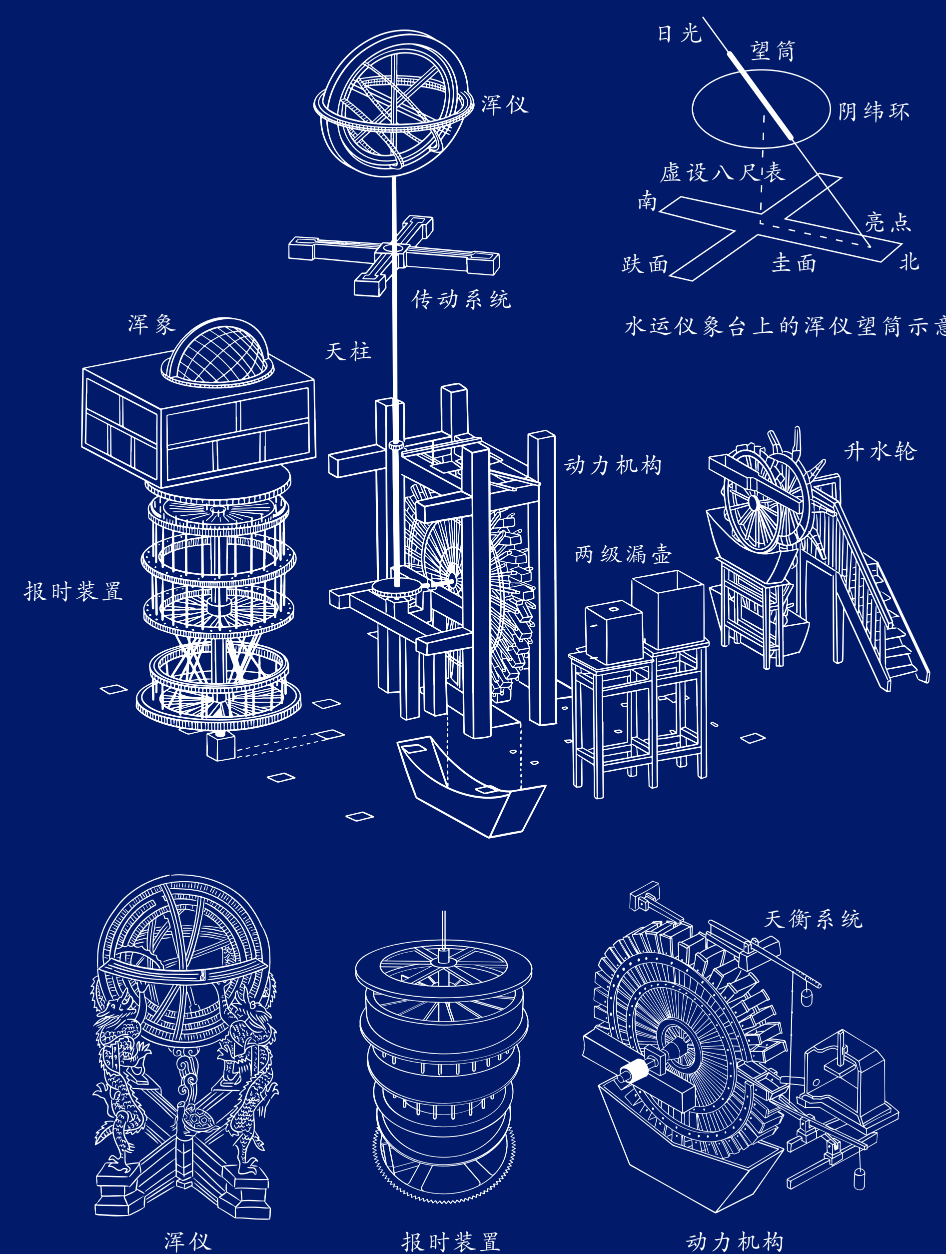
国家授时中心时间科学馆中按 1:5 比例缩仿的水运仪象台模型

1:5 scale model of Water-driven Astronomical Clock-tower in Time Science Museum of National Time Service Center



① 浑仪 Armillary sphere
② 水趺 Water level
③ 圭面 Ruler
④ 鳌云 Legendary turtle cloud
⑤ 龙柱 Dragon column
⑥ 天柱 Celestial pillar
⑦ 天锁 Celestial lock
⑧ 河车 Steering wheel
⑨ 枢轮 Pivot wheel
⑩ 天池 Celestial reservoir
⑪ 平水壶 Constant-level tank
⑫ 昼夜机轮 Eight superimposed wheels (lit. Day and night wheel)
⑬ 浑象地柜 Terrestial cabinet

水运仪象台结构图
Structure of Water-driven Astronomical Clock-tower



水运仪象台各部分结构图
Structure of the parts of Water-driven Astronomical Clock-tower

登封观象台

Dengfeng Observatory

登封观象台位于河南省登封市市中心东南 15 千米的告成镇，由元代郭守敬主持建造，公元 1279 年前后落成。“表高八尺，圭长一丈三尺有余”，是自周代开始中国古代圭表的主要形制。登封观象台“表高四十尺，圭长一百二十八尺”，相当于一台放大的圭表。近 10 米高的城楼相当于一根直立的竿（表），城楼下正北方有一条 31 米长的石圭，则相当于测量日影的尺（圭）。城楼上有两间小屋，一间放着计时用的漏刻，一间放着观天用的浑仪或者简仪，两屋之间有一横梁。每天正午时，阳光将城楼两屋之间横梁的影子投射在石圭上，可以测量正午时刻的影长。夏至日正午的投影最短，冬至日正午的投影最长。从一个夏至（或冬至）到下一个夏至（或冬至），就是一个回归年的长度。中国古代就是采用这种方法测定一年的时间长度和“夏至、冬至、春分、秋分”的时间，从而为制定历法奠定了基础。郭守敬还发明了在石圭上移动的“景符”，利用针孔成像的原理，使得影长的测量精度大大提高。郭守敬编修的《授时历》成为中国历史上最为精密的历法之一，正是得益于观象台的观测数据。

Dengfeng Observatory, located in Gaocheng town, 15 kilometers southeast of Dengfeng County, Henan Province, was built by Guo Shoujing in the Yuan Dynasty. "A pole with eight chi in height and a ruler with one zhang and three chi or more in length" had been the main style of ancient Chinese gnomons since the Zhou Dynasty. Used like an enlarged gnomon whose pole is forty chi high and ruler is one hundred and twenty-eight chi long, Dengfeng Observatory was completed around 1279 A.D. Its tower-like structure which is nearly 10 meters high is equivalent to an upright pole, while the 31-meter-long causeway-like stone lying due north is equivalent to a measuring ruler for the sun shadow. There are two cabins connected by a beam on the tower. A water clock for timing is inside one of them and an armillary sphere or abridged armilla for observing is in the other. At noon every day, the sun casts the shadow of the middle beam on the measuring ruler and the length of the shadow at noon can be measured. The noon shadow on the winter solstice is the longest, while that on the summer solstice is the shortest. From one winter (summer) solstice to the next winter (summer) solstice, it is the length of a tropical year. In ancient China, this method was used to determine the length of a year and the time of the "summer/winter solstice, spring/autumn equinox", which laid the foundation for the formulation of the calendar. Guo Shoujing also invented the "shadow device" that can be moved on the measuring ruler. It used the principle of pinhole imaging to improve the accuracy of the shadow length measurement greatly. The *Season-granting Calendar* (*Shou Shi Calendar*) made by Guo Shoujing had become one of the most precise calendars in the Chinese history because of the observational data from the observatory.

登封观象台
Dengfeng Observatory
（位于河南省登封市告成镇）

郭守敬
Guo Shoujing
（1231—1316）

登封观象台今貌
Present-day appearance of Dengfeng Observatory

《元史·天文志》中记载了登封观象台的形制："圭表以石为之，长一百二十八尺，广四尺五寸，厚一尺四寸，座高二尺六寸……其端两旁为二龙，半身附表上擎横梁，自梁心至表颠四尺，下属圭面，共为四十尺……"

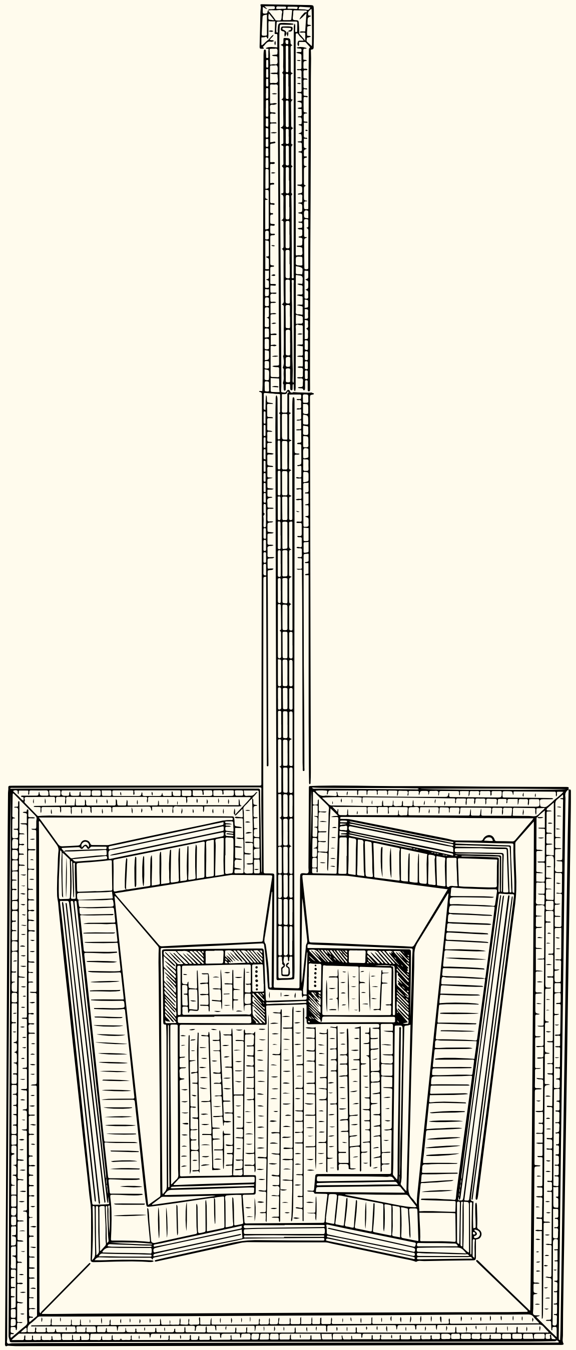
观星台的基本结构：一是由回旋踏道簇拥着的巍峨台身；一是由台身北壁凹槽内向北平铺的石圭。台身颇似覆斗，高 9.46 米，连小室通高 12.62 米。台顶平面呈方形，每边 8 米余，底边 16 米余。壁面有明显的收分，表现出早期砖石建筑的特征。北壁下方设有对称的两个踏道口，可盘旋登临台顶。踏道及顶部边沿筑有 1.05 米高的短栏和短墙，可凭栏遥望长空。台北壁正中的凹槽直壁是测影"高表"的遗迹。槽东西壁对称，自下而上有明显的收分，唯南壁上下垂直。直壁与石圭间留有 36 厘米的间隙，看来是横梁下垂悬球的地方，用以经常校验横梁和石圭间的高差。直壁上方相对两小室的窗口的下沿即置横梁的位置，由此到石圭的高度等于 40 尺，也就是"高表"所要求的高度，这说明此台采用直壁——横梁结构代替大都所用的铜表 。[①]

圭面由 36 方石块组成，长 31.19 米，相当于 128 尺（由此可推知，当时的 1 尺相当于 24.367 厘米）[②]，置于砖砌的基座之上。圭面的北端有水池，中轴两旁有双股平行的水渠，并有尺、寸、分的刻度。

引文出处：

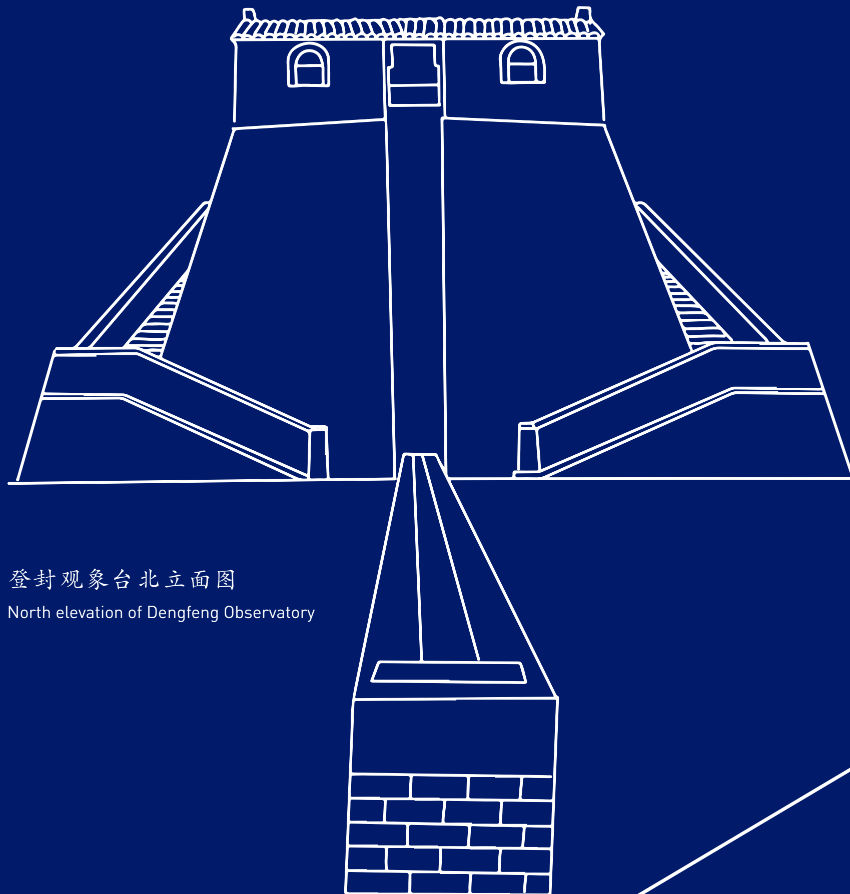
①张家泰：《登封观星台和元初天文观测的成就》，1976 年；邢台市郭守敬纪念馆：《郭守敬及其师友研究论文集》，1996 年。

②元代，1 市尺 =0.3072 米，1 太史院尺 =0.8 市尺 =0.2458 米，登封观象台实测 1 太史院尺为 0.24367 米。

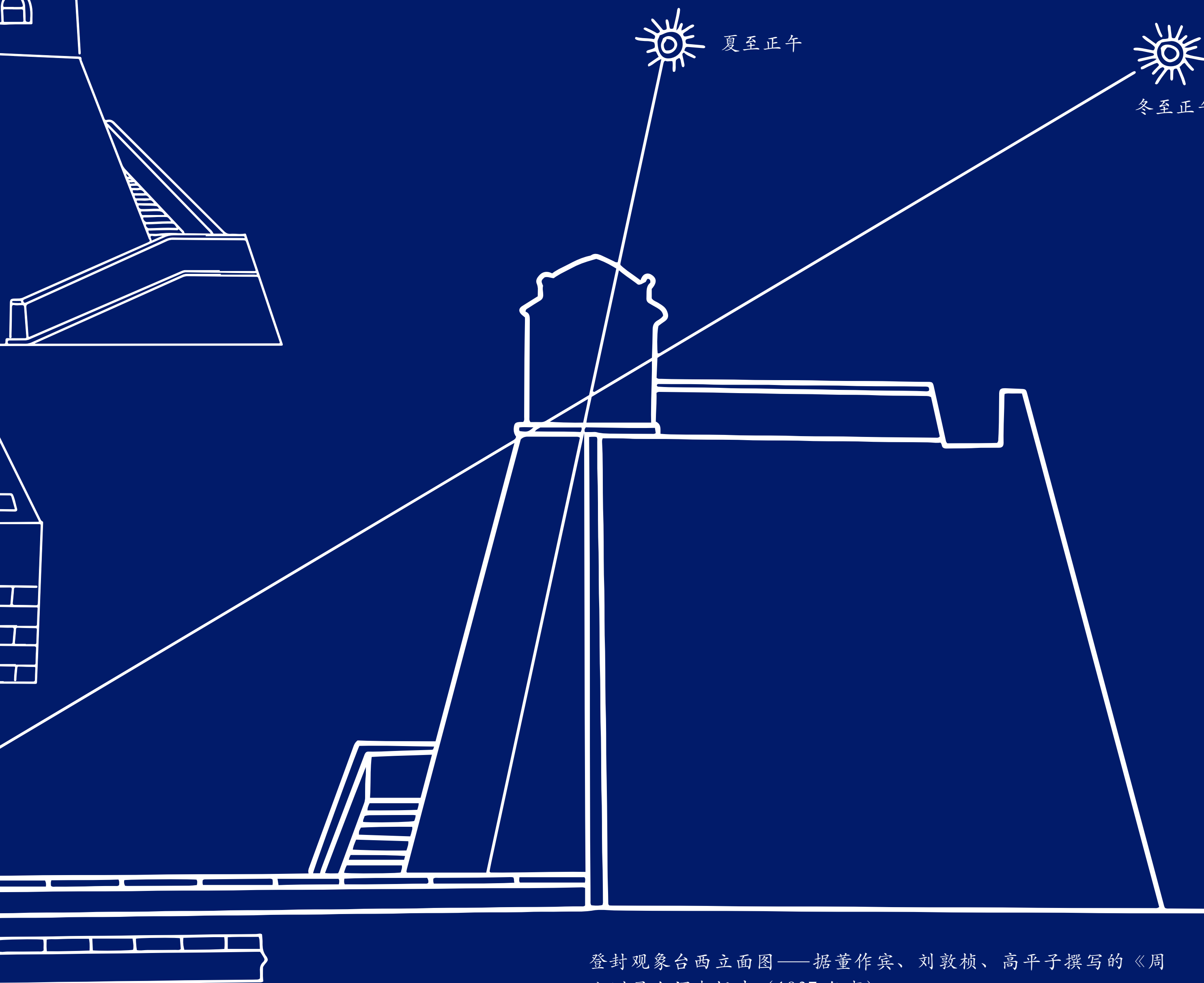


登封观象台今平面图
Present-day plan of
Dengfeng Observatory
——张家泰绘制

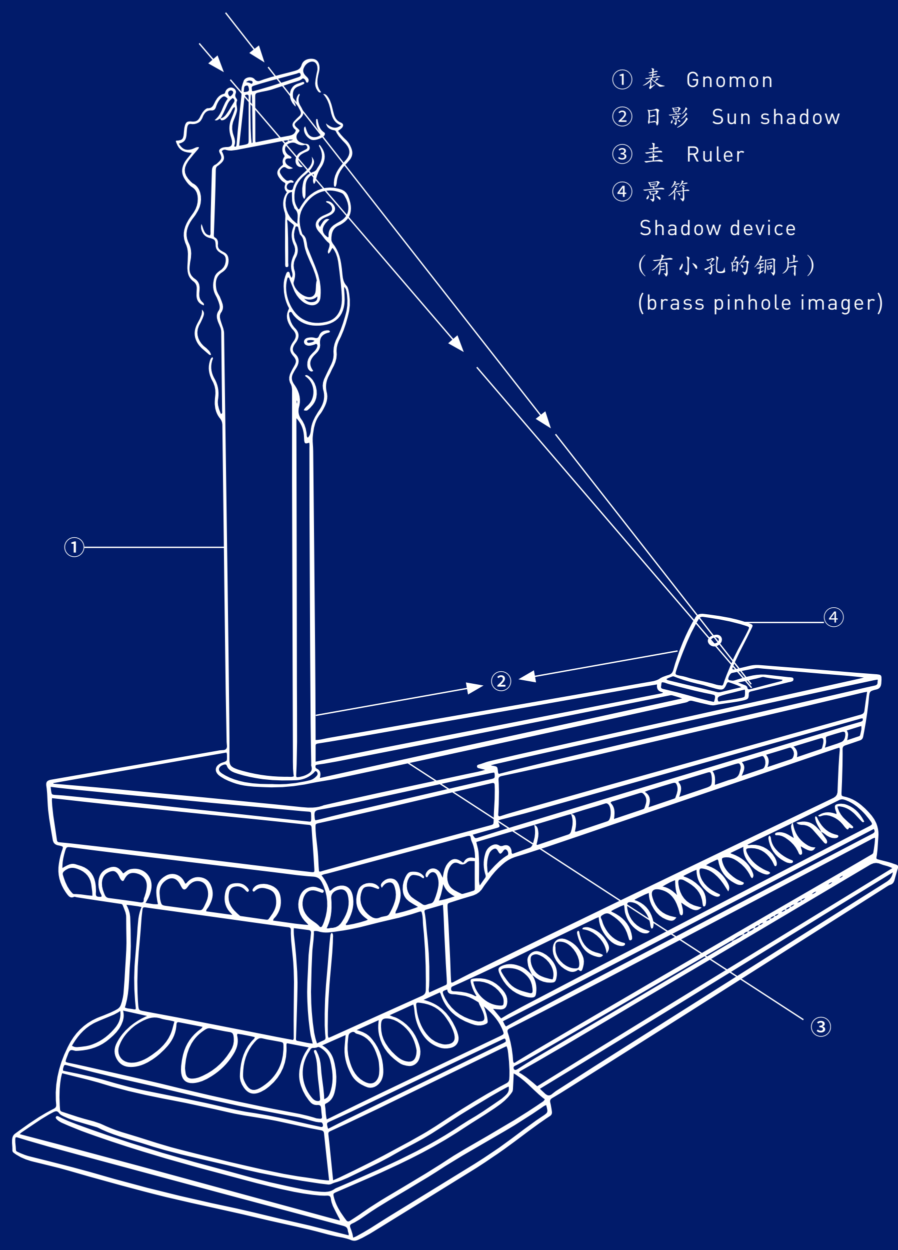
清乾隆九年（1744）《观象台图》
Picture of the Observatory in the 9th year of Emperor Qianlong in the Qing Dynasty (1744)



登封观象台北立面图
North elevation of Dengfeng Observatory

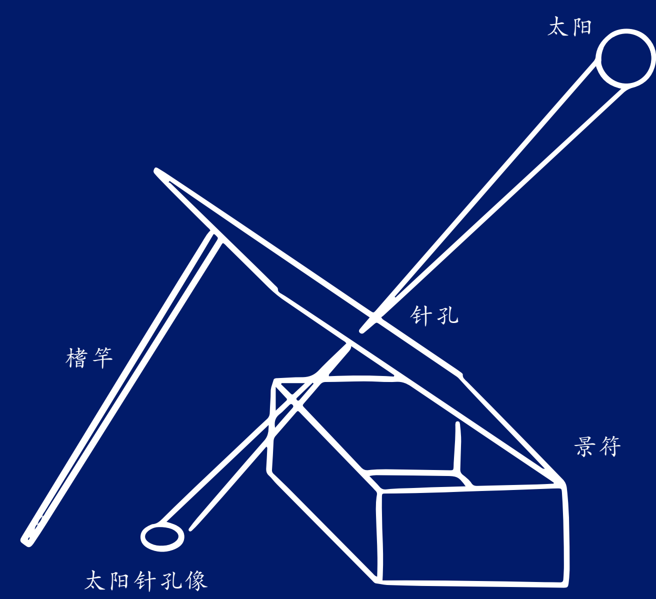


登封观象台西立面图——据董作宾、刘敦桢、高平子撰写的《周公测景台调查报告（1937 年事）》
West elevation of Dengfeng Observatory based on *Investigation Report on Shadow Measuring Platform of the Duke of Zhou* (1937) written by Dong Zuobin, Liu Dunzhen and Gao Pingzi



① 表 Gnomon
② 日影 Sun shadow
③ 圭 Ruler
④ 景符
Shadow device
（有小孔的铜片）
(brass pinhole imager)

圭表和景符示意图
Schematic diagram of the gnomon and the pinhole imager



景符示意图
Schematic diagram of the pinhole imager

景符的发明是为了提高立表测影的精度，它是根据小孔成像的原理制成的，其发明人是元代大科学家郭守敬。

《元史·天文志》详细记载了景符的结构、使用方法，还记录了使用景符所得到的测量数据：

“景符之制，以铜叶，博二寸，长加博之二，中穿一窍，若针芥然。以方跂为趺，一端设为机轴，令可开阖，榰其一端，使其势斜倚，北高南下，往来迁就于虚梁之中。窍达日光，仅如米许，隐然见横梁于其中。旧法一表端测晷，所得者日体上边之景。今以横梁取之，实得中景，不容有毫末之差。至元十六年己卯夏至晷景，四月十九日乙未景一丈二尺三寸六分九厘五毫；至元十六年己卯冬至晷景，十月二十四日戊戌景七丈六尺七寸四分。”

延祐滴漏

Yanyou Clepsydra

中国古代以漏壶为主要计时工具，开始时使用单只漏壶，后来出现多壶组成的复式壶，以提高计时的精度。“延祐滴漏”是一组多级漏壶，元代延祐三年（1316）造，整件仪器由四级漏壶组成，由上而下分别是“日壶、月壶、星壶和受水壶”。日壶的水滴入月壶，月壶的水再滴入星壶，最后星壶的水滴入受水壶。受水壶壶盖正中立一铜表尺，铜表尺上有时辰刻度。铜表尺前放一木制浮箭，木箭下端是一块木板，叫浮舟。受水壶中的水随时间的推移而均匀增加，浮舟便托起木箭均匀上升。木箭与铜表尺上的时辰刻度相对照，便指示当时的时间。其形制如右图所示。

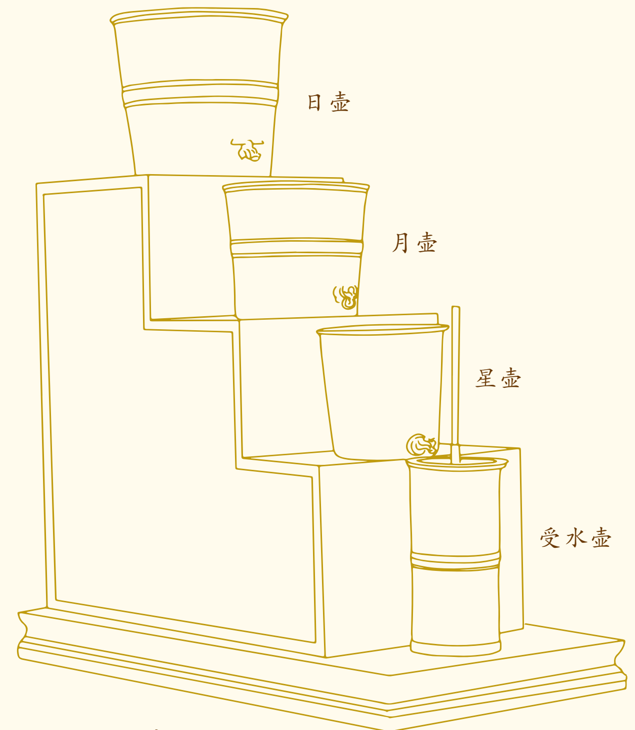
多级漏壶由于采用了逐级水位补偿的办法，使得星壶之中的水位基本保持恒定，这样滴入受水壶中的水的流速也相对均匀，浮舟托起木箭上升的速度也就相对均匀，指示时间的准确性就大大提高了。

唐代吕才（约 600—665）曾制作四级补偿式漏壶，其形制为：有四匮，一夜天池，二日天池，三平壶，四万分壶。又有水海，以水海浮箭。以四匮注水，始自夜天池，以入于日天池，自日天池，以入平壶，以次相注，入于水海，浮箭而上，每以浮箭为刻分也。

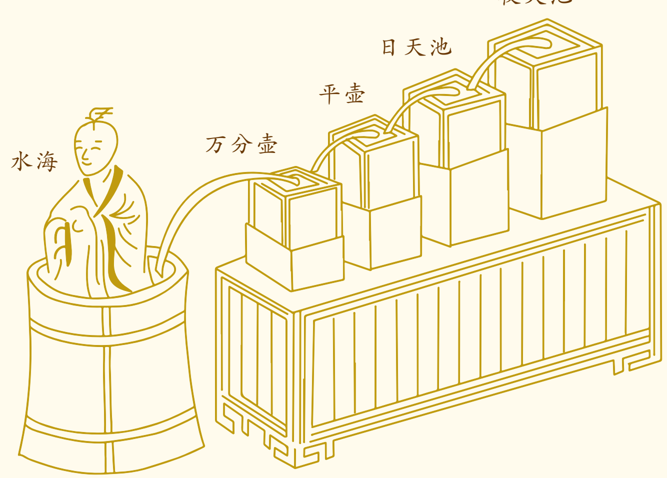
A clepsydra was used as a main timing tool in ancient China where a single-tank water clock was used at the beginning and a compound water clock made of multiple tanks was used later to improve the accuracy of timing. "Yanyou Clepsydra" made in the third year of the Yanyou period of the Yuan Dynasty (1316 A.D.) is a compound clepsydra with four tanks: sun tank, moon tank, star tank and water-receiving tank placed in order from top to bottom, to which the water drips in turn accordingly. There is a copper ruler in the middle of the lid of the water-receiving tank with hour markings on it. A wooden rod in front of the ruler is borne on a float below. The water in the water-receiving tank will increase evenly over time, and the wooden rod borne on the float is thus lifted evenly. By comparing the wooden rod with the hour markings on the copper ruler, the passage of time can be indicated. Its style is shown in the upper illustration on the following page.

Because of the adoption of a phase-by-phase water-level compensation method, the constant water level in the star tank of the compound clepsydra keeps the flow rate into the water-receiving tank uniform, so that the rod is evenly borne up by the float and the accuracy of timing is greatly improved.

In the Tang Dynasty, Lv Cai (approximately 600 A.D.–665 A.D.) made a compound clepsydra with four tanks.



延祐滴漏示意图
Schematic diagram of Yanyou Clepsydra



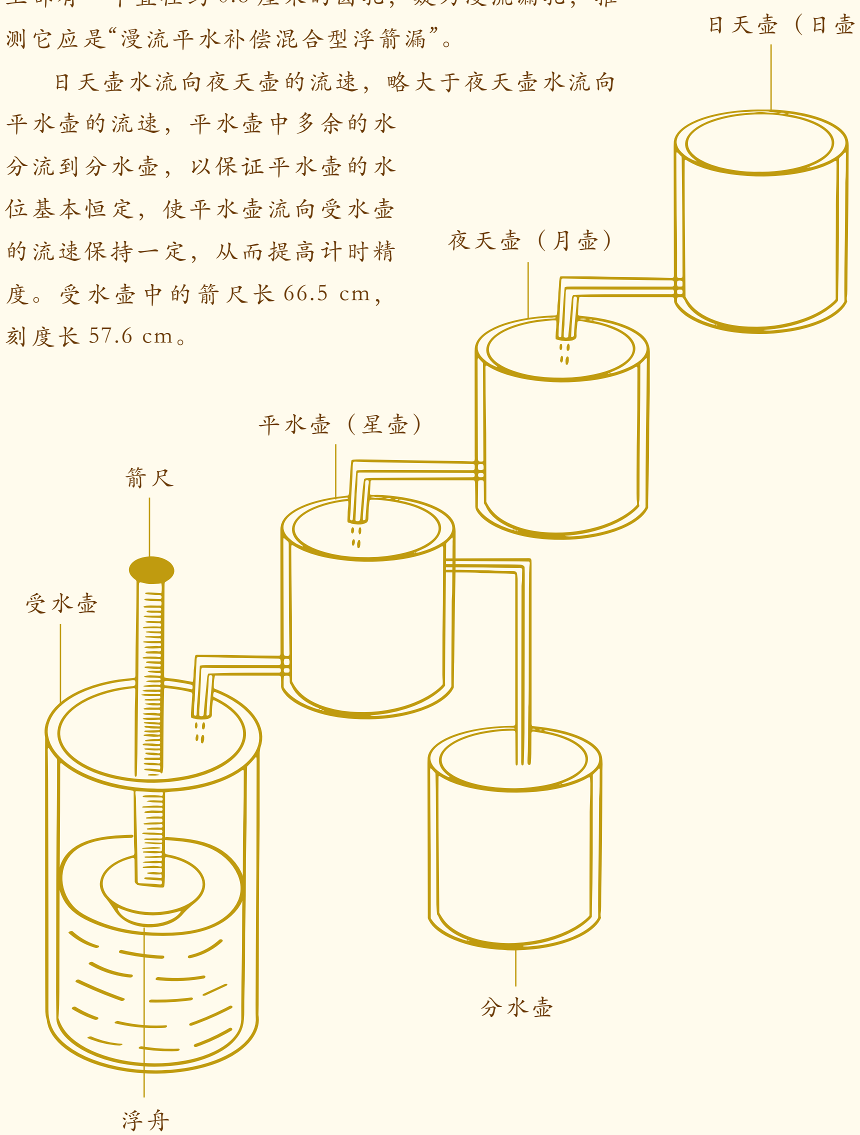
唐吕才四级补偿式漏壶
Lv Cai's compound clepsydra in the Tang Dynasty

延祐滴漏
Yanyou Clepsydra

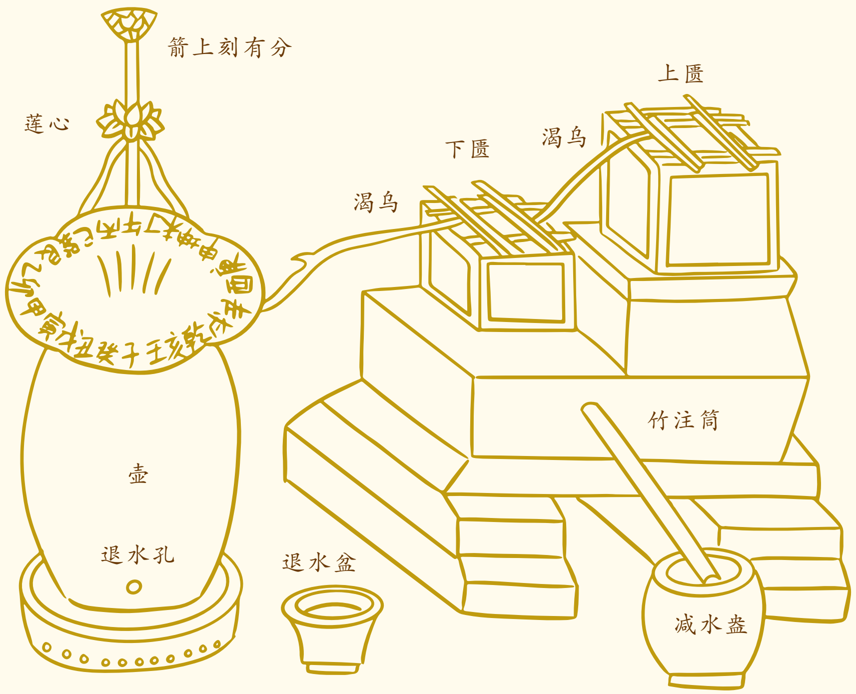
延祐滴漏制于元仁宗延祐三年（1316）十二月十六日。“凡四壶，分四层。第一上水壶，以建初尺度之，口围九尺六寸六分，径二尺六寸，底围七尺八寸，高三尺三寸。第二壶口围七尺五寸九分，径二尺二寸，底围六尺八寸五分，高二尺五寸五分。第三壶口围六尺三寸，径尺九寸一分，底围四尺八寸二分，高二尺四寸五分。第四箭壶，口围四尺四寸五分，径一尺三寸八分，底围同高三尺六分。皆有盖。上三壶底隅皆有孔以滴水，铜笕承之，以次相注滴入箭壶。昼漏卯初一刻上水，夜漏酉初一刻上水。水加一刻则箭浮一刻，水与壶平而昼夜箭尽。”用来供水的三个壶自上而下依次被称为日、月、星壶。日壶之侧铸有铭文一篇，约四百字，记叙了铸造背景、制作工匠和监制官员的姓名等。

延祐滴漏通常被认为是“多级补偿型浮箭漏”，但是，1983 年 9 月，天文学家薄树人与华同旭去中国历史博物馆（现中国国家博物馆）考察此漏，发现星壶左侧上部有一个直径约 0.8 厘米的圆孔，疑为漫流漏孔，推测它应是“漫流平水补偿混合型浮箭漏”。

日天壶水流向夜天壶的流速，略大于夜天壶水流向平水壶的流速，平水壶中多余的水分流到分水壶，以保证平水壶的水位基本恒定，使平水壶流向受水壶的流速保持一定，从而提高计时精度。受水壶中的箭尺长 66.5 cm，刻度长 57.6 cm。



漫流平水补偿混合型浮箭漏示意图
Schematic diagram of a floating arrow hybrid clepsydra, using the flooding system and the compensation system to keep the water level constant

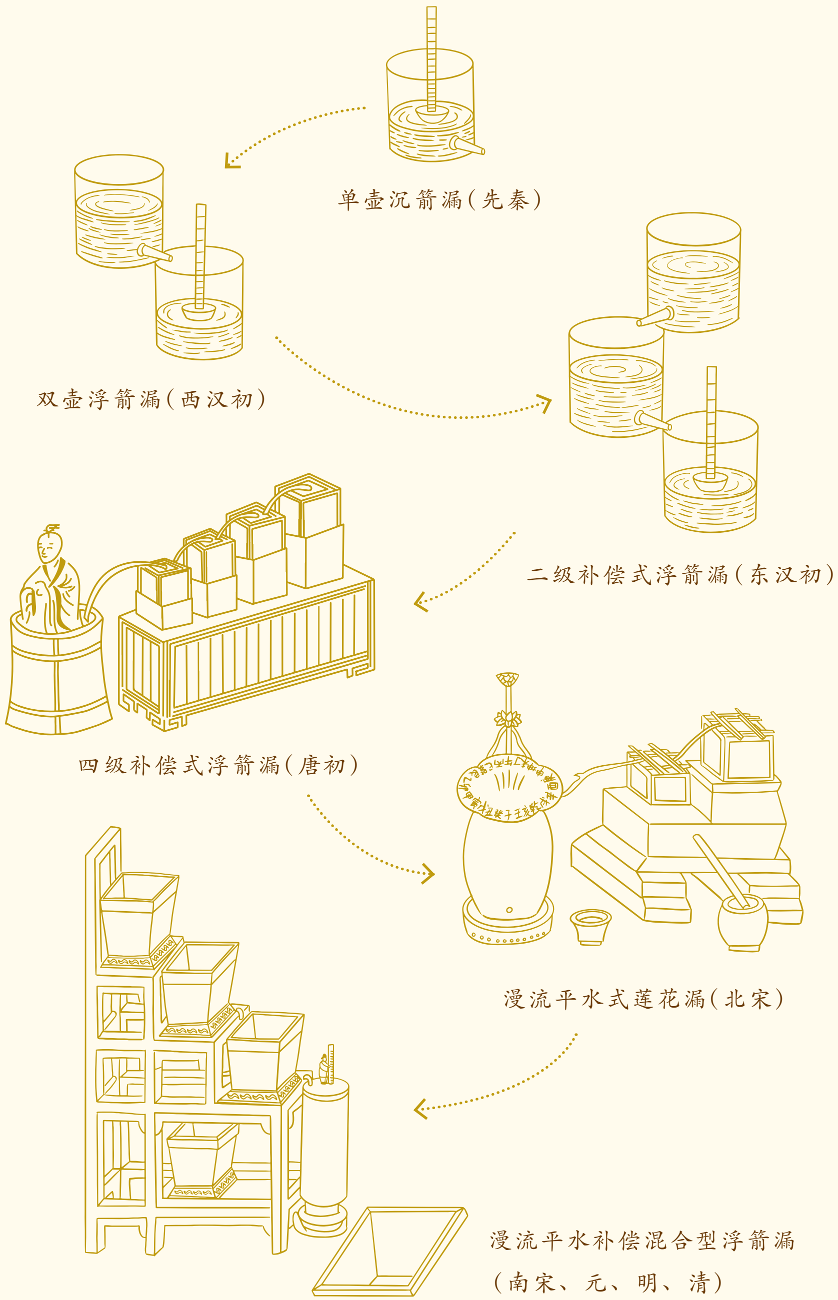


清版《六经图》中的燕肃莲花漏
Yan Su Lotus Clepsydra in *Illustration of Six Classics* from a copy of the Qing Dynasty

公元 1030 年，北宋燕肃创制莲花漏，北宋时曾风行各地。此种刻漏首次采用溢流法，多余的水由平水壶（下匮）通过竹注筒流入减水盎，使下匮水位保持恒定，保证了受水壶水位的均匀增加，从而大大提高了漏刻计时的准确性。

北京故宫交泰殿铜壶滴漏（摄影：侯元超）
Copper clepsydra in the Hall of Union, Forbidden City, Beijing

北京故宫博物院还收藏有两套清代大型浮箭法复式漏壶，均为漫流平水补偿混合型浮箭漏。一套放置于交泰殿，清乾隆十年（1745）制；另一套放置于钟表馆（奉先殿），清嘉庆四年（1799）制。



中国古代漏刻演化历程

The evolution of ancient Chinese clepsydras

西安钟鼓楼

Xi'an Bell and Drum Towers

在中国古代，人们曾经把敲钟和击鼓作为一个城市报时的手段。大城市一般会在城市中心建钟鼓楼，郡县多设谯楼，配备日晷、漏壶等测时和守时设备。在古代，位于城市中心的钟鼓楼几乎都是全城最高的建筑，使清脆的钟声和雄浑的鼓声传遍城市的每一个角落。我国许多城市至今还保留着古代的钟楼和鼓楼，它们已成为印证授时发展的历史遗迹。

据史料记载，在古长安（今西安）“以钟鼓司辰”由来已久，汉魏时期为“晨鼓暮钟”，唐代改为“晨钟暮鼓”，元明清时期，钟鼓报时体制仍得以维持。西安现存的钟楼建于明洪武十七年（1384），通高 36 米；鼓楼位于钟楼西北，建于明洪武十三年（1380），通高 33 米。

Ancient Chinese people used to serve the time in cities by ringing bells and beating drums. Bell and drum towers were generally set up in the center of the large cities, while watchtowers equipped with timing devices like sundial and clepsydra were often set up in prefectures and counties. The bell and drum towers in the city center were almost the tallest buildings in ancient times, from where the sound of clear bell and vigorous drum was loud enough to travel to every corner of the city. Many cities in China still preserve ancient bell and drum towers, which have become historical relics that witness the development of time service.

According to the historical records, the ancient Chang'an city (now Xi'an) had a long history of "heralding the daybreak by using bells and drums". During the Han and Wei Dynasties, time was served by morning drum and evening bell, while during the Tang Dynasty, time was served by morning bell and evening drum. During the Yuan, Ming and Qing Dynasties, the bell and drum time service system had still been maintained. The existing bell tower in Xi'an was built in the seventeenth year of the Hongwu Period (1384) of the Ming Dynasty with a height of 36 meters and the drum tower located in the northwest of the bell tower was built in the thirteenth year of the Hongwu Period (1380) of the Ming Dynasty with a height of 33 meters.

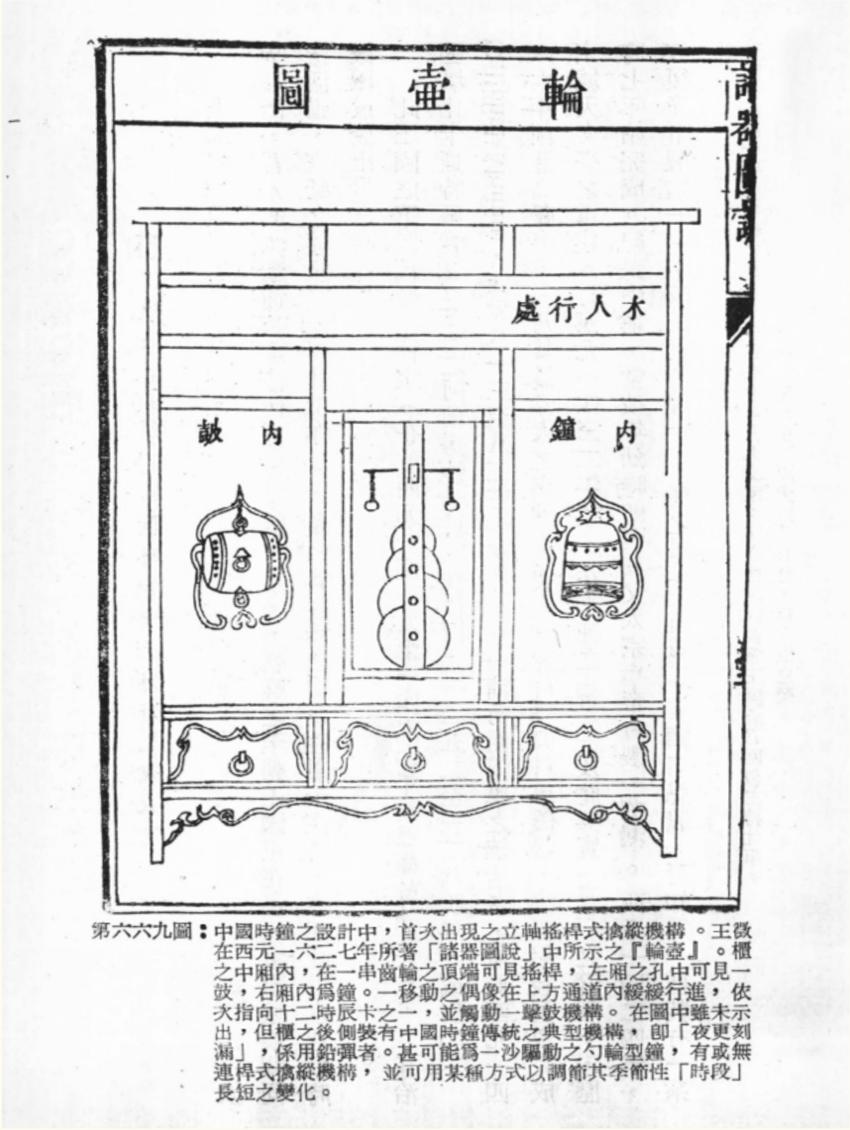
西安鼓楼和钟楼

Xi'an Drum Tower and Bell Tower

王徵轮壶
Wang Zheng Wheel Clock

轮壶又称“轮钟”，是明末科学家王徵（1571—1644）将西方的自鸣钟和中国传统计时制度结合而创制的一种机械计时器。其原理是在内部机构中设立两根直立铁柱，铁柱间安装由 4 个齿轮组成的齿轮组，通过重锤驱动齿轮转动，并牵动报时的木人拨动显示时间的十二时辰牌，同时通过敲钟或击鼓报告时间。王徵在《诸器图说》中绘制了轮壶示意图，其呈木柜状，内分两层，上层指示和报告时间，下层安装动力机构。其中的“天平”状机构即“十字微机”，其实就是立轴摆杆式擒纵机构，“轮壶之妙，全在于此”。

Wang Zheng (1571 A.D.–1644 A.D.), a scientist of the late Ming Dynasty invented a mechanical timer called "wheel clock" that combined the western striking clock with the traditional Chinese timekeeping system. The principle is to set up a mechanical system formed by a set of four mounting gears on a frame of two upright iron rods so that the cards of the 12 two-hour periods can be displayed by the push of the wooden men and the time can be broadcast by the strike of the bell or gong with the rotation of the gear train driven by the heavy bob. Wang Zheng drew a schematic diagram of the wheel clock in *Illustrated Book of Instruments*. It is a wooden cabinet in shape with two layers inside. The upper layer indicates and broadcasts the time and the lower layer is equipped with a powertrain, in which "heavenly balance" is actually a verge and foliot escapement where "the magic of the wheel clock lies".



第六六九圖：中國時鐘之設計中，首次出現之立軸搖桿式擒縱機構。王徵在西元一六二七年所著「諸器圖說」中所示之『輪壺』。櫃之中厢內，在一串齒輪之頂端可見搖桿，左厢之孔中可見一鼓，右厢內爲鐘。一移動之偶像在上方通道內緩緩行進，依次指向十二時辰卡之一，並觸動一擊鼓機構。在圖中雖未示出，但櫃之後側裝有中國時鐘傳統之典型機構，即「夜更刻漏」，係用鉛彈者。甚可能爲一沙驅動之勺輪型鐘，有或無連桿式擒縱機構，並可用某種方式以調節其季節性「時段」長短之變化。

《诸器图说》中的轮壶图
The wheel clock in *Illustrated Book of Instrments*

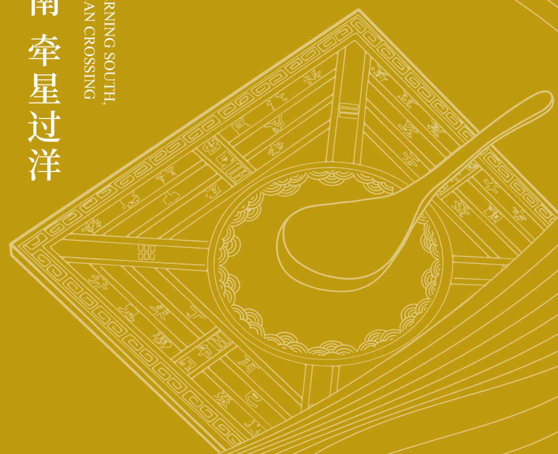
02

导航篇

NAVIGATION SECTION

慈石司南 牵星过洋

LODESTONE GOVERNING SOUTH, STAR-GUIDED OCEAN CROSSING



中国古代导航技术历经了漫长的探索过程，归纳起来，主要是地磁导航和天文导航的方法，以及两类方法与地文导航的综合运用。西晋葛洪的《抱朴子外篇·嘉遯》记载“夫群迷乎云梦者，必须指南以知道，并乎沧海者，必仰辰极以得反”，北宋朱彧的《萍洲可谈》记载“舟师识地理，夜则观星，昼则观日，阴晦观指南针”，讲的就是这两类方法。

在公元前 3 世纪的战国时期，中国人就发现了磁石（亦称慈石）的指极性，并制作成指南工具——司南。后经不断改进，中国人制成了更加灵敏、准确的指南工具——指南鱼、指南龟、缕悬指南针等。北宋时期，中国人发现地磁偏角，开始使用指南针导航定向，并且有了带有方位指示盘的指南针——罗盘。到了元代，人们进一步使用指南针来确定航海路线，这种方法被称为针路。

天文导航方面，早在两千多年前的秦汉时期，中国人就通过观星揆日，辨识方向。人们发明了各种观星的仪器，观测绘制了各种星图。唐朝时期，人们将观星斗与指南针、罗盘结合起来导航定向。宋元明清时期，天文航海技术有了很大发展，人们能够通过观星斗，确定星辰高度，推算航向，这项天文航海技术也称为“过洋牵星术”。

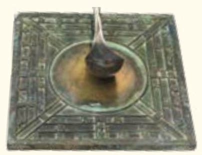
明朝初年，航海家郑和率领庞大船队多次远航西洋，他的远航船队使用了指南针罗盘导航的针路图和天文导航的过洋牵星术。

The ancient Chinese navigation technology has undergone a long process of exploration. In summary, it is mainly by the methods of geomagnetic navigation and astronavigation, as well as the comprehensive application of these two methods with landmark navigation. *Outer Chapters of the Works of Master Bao Pu.Reclusion* by Ge Hong in the Western Jin Dynasty recorded that "Those who travel to Lake Yunmeng must rely on a compass to get the direction. Those who travel to a vast sea must resort to Polaris to return." *Pingzhou Table Talk* written by Zhu Yu in the Northern Song Dynasty recorded "The seamen know geography, who will observe the star when it is dark, observe the sun when it is bright and watch the compass when it is overcast." Both of these two books refer to these two kinds of methods.

During the Warring States Period of the third century B.C., the Chinese discovered the polarity of the lodestone and made it into a south-pointing tool — Sinan. After continuous improvement, more sensitive and accurate guiding tools, such as south-pointing fish, south-pointing turtle and south-pointing needle suspended by silk were made. During the Northern Song Dynasty, the Chinese discovered the magnetic declination and began to use the south-pointing needle for navigation and orientation. Besides, there came the compass with the azimuth bearing. In the Yuan Dynasty, the compass was further used to determine the sea route, called the needle path.

As far as astronavigation is concerned, as early as the Qin and Han Dynasties more than 2,000 years ago, the Chinese people identified the direction by watching stars and the sun. Various instruments for observing stars had been invented and various star maps had been drawn. In the Tang Dynasty, navigation and orietation were by means of the combination of star observation, south-pointing needle and the compass. During the Song, Yuan, Ming and Qing Dynasties, astronavigational technology had been developed greatly. The altitude of a star and heading could be determined by star observation, also known as "star-guided ocean crossing technique".

In the early Ming Dynasty, the navigator Zheng He led a large fleet to voyage to the western ocean many times, during when his fleet used a needle path map alongside the compass and the star-guided ocean-crossing technique of astronavigation.



司南复原模型
Restored sinan model

1953 年发行的印有司南的邮票
A stamp of sinan issued in 1953

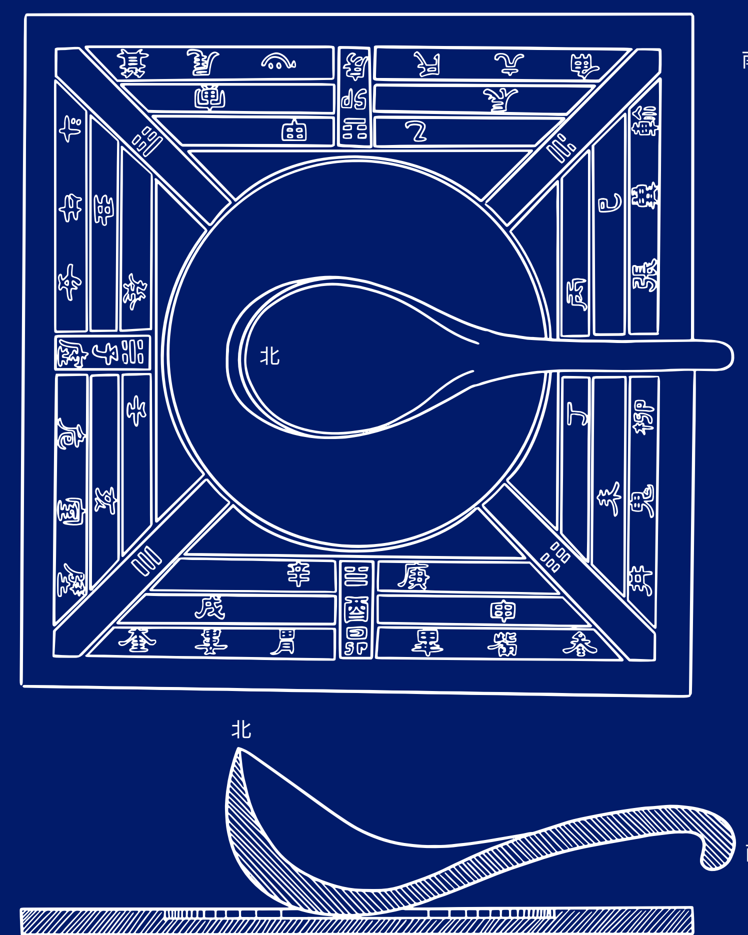
司南
South-pointing Ladle (Sinan)

司南是指南针的始祖，是中国古代四大发明之一。最早出现于 2 000 多年前的战国时期，《韩非子·有度》记载“先王立司南以端朝夕”；公元 1 世纪初，东汉王充的《论衡·是应篇》记载“司南之杓，投之于地，其柢指南”。

20 世纪 40 年代，我国著名科技史学家王振铎根据古籍记载，考证、试验并复原了司南，他在《司南指南针与罗经盘——中国古代有关静磁学知识之发现及发明（上）》中指出：“司南籍磁石琢成，最为直接，取天然赋磁性之磁石一块，顺其南北极向，杓为南极，首为北极。”“况汉世式占之地盘有铜者，用以复原司南之地盘，当不误也。”“地盘面部设计为八干，十二支，四维之二十四向，依等分角罗列。”可见，王振铎先生复原的司南是用整块天然磁石顺着南北磁极，经过雕琢打磨制成汉制勺形，勺柄指南，并使整个勺的重心恰好落到勺底的正中，将勺置于光滑的铜制地盘中，地盘外方内圆，四周刻有用干支四维指示的“二十四向”。

The south-pointing ladle (sinan), the ancestor of compasses, is one of the Four Great Inventions in ancient China. It first appeared in the Warring States Period more than 2,000 years ago. *Han Fei Zi. Rule the Country by Law* recorded "The late king set up a sinan to determine the direction." In the early first century A.D., *Discourses Weighed in the Balance. Auguries Verified* by Wang Chong in the Eastern Han Dynasty recorded "A south-pointing ladle is placed on the ground. When it stops rotating, the handle points to the south."

In the 1940s, famous Chinese historian of science Wang Zhenduo gave sinan a textual analysis, test and restoration. He pointed out in *Sinan, South-pointing Ladle and Compass—The Discovery and Invention of Magnetostatics in Ancient China* (*Part 1*) that "Sinan is carved from a lodestone. It is the most straightforward to take a lodestone first, then align it with the magnetic field, next carve the south-pointing part into the handle, and the north-pointing part into the bowl." "It won't be wrong to restore the base plate of sinan by using Han-style copper divining base plate." "The base plate front is designed with eight heavenly stems, twelve earthly branches and four diagonal directions, totaling twenty-four cardinal directions spaced evenly." It can be seen that the sinan restored by Mr. Wang Zhenduo is made from a whole piece of lodestone along the magnetic field into the shape of the Han-style ladle by scouring and polishing. The handle points to the south and the gravity of the whole ladle falls just into the center of the bowl. The base plate where the ladle is placed is coppery, smooth, square outside and round inside with "stem-branch" and four diagonal directions making up twenty-four cardinal directions around it.



王振铎先生绘制的汉司南与地盘复原图
Image of Han sinan and the base plate drawn by Wang Zhenduo

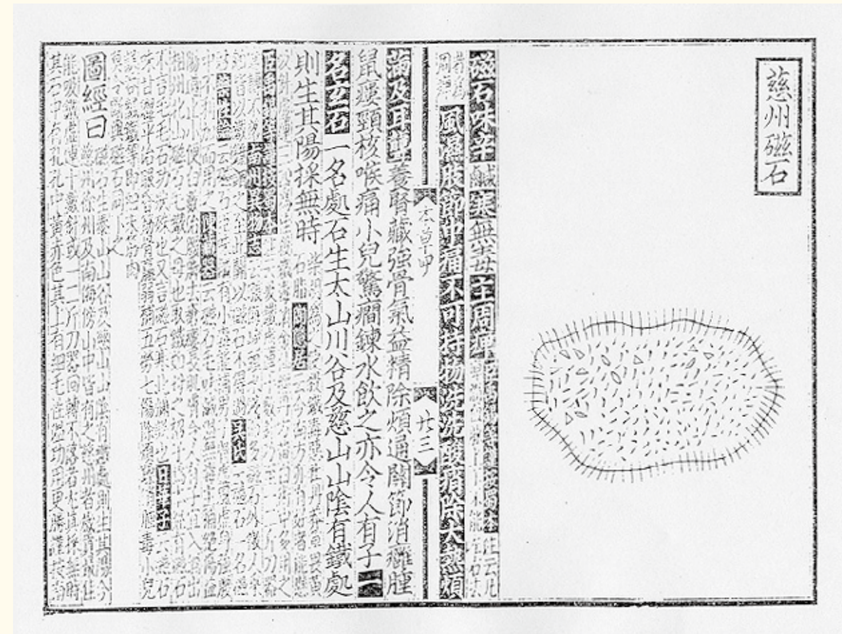
指南针
South-pointing Needle

三国时期魏国术士管辂（210—256）所著《管氏地理指蒙·释中第八》中曰：“（磁针）体轻而径所指必端应一气之所召，土曷中而方曷偏，较轩辕之纪，尚在星虚丁癸之躔。”

北宋沈括（1031—1095）的《梦溪笔谈》记载了人工授磁方法，即“方家以磁石磨针锋，则能指南”，这种用人工授磁制成磁体的方法是一个巨大的进步，据此制出了“旱针”和“水针”，使指南针的大规模应用成为可能。1119 年，北宋朱彧撰写的《萍洲可谈》记载了北宋宣和年间“舟师识地理，夜则观星，昼则观日，阴晦观指南针”以及使用指南针的各种方法。

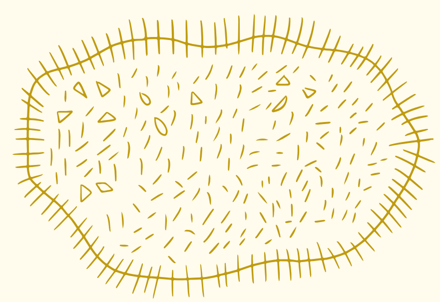
Guan's Geographic Enlightenment. the Eighth Paraphrase which was written by the astrologist Guan Lu (210 A.D.–256 A.D.) in the State of Wei of the Three Kingdoms Period pointed out the use of the south-pointing needle in Fengshui (or Geomancy in English).

The Dream Pool Essays by Shen Kuo (1031 A.D.–1095 A.D.) in the Northern Song Dynasty recorded the method of artificial magnetization "When geomancers rub the needlepoint with a lodestone, it is able to point to the south". The magnet magnetized artificially is a great progress. The "dry needle" and "water needle" were made accordingly, making the mass application of south-pointing needles possible. In 1119, *Pingzhou Table Talk* written by Zhu Yu in the Northern Song Dynasty recorded during the Xuanhe Period of the Northern Song Dynasty, "The seamen know geography, who will observe the stars when it is dark, observe the sun when it is bright and watch the south-pointing needle when it is overcast." Besides, various methods concerning the use of the south-pointing needle were also recorded in this book.



北宋《证类本草》中“慈石”插图

Illustration of lodestones in *Classified Materia Medica* of the Northern Song Dynasty

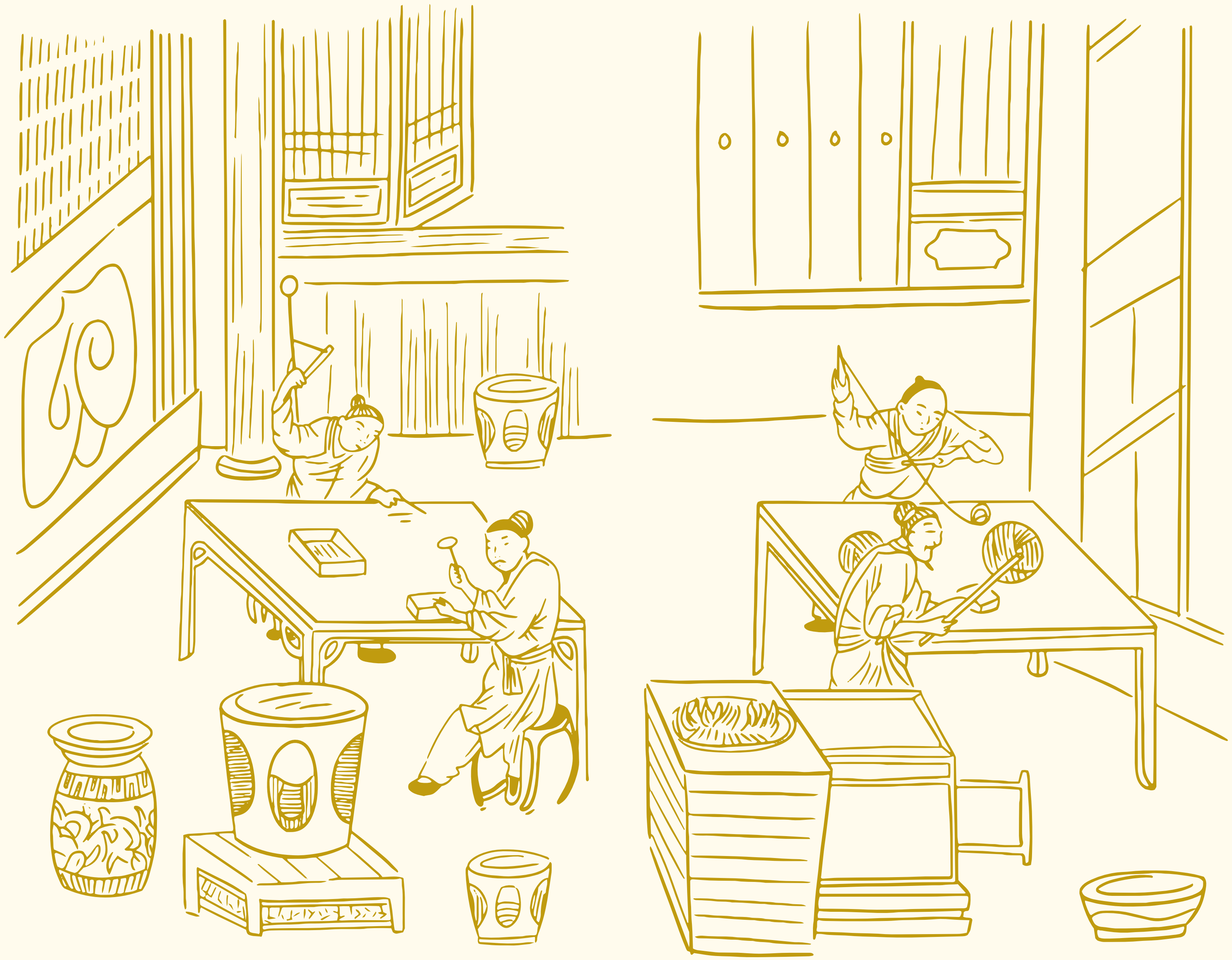


吸满铁砂、铁毛的“慈石”

Lodestones attracting some iron sands and iron fillings

慈石周围画满了铁砂、铁毛，以示其吸引性。

古人称具有磁性的天然磁铁为磁石。最迟在战国时期，人们已经发现了磁石能吸引铁的现象，故写成“慈石”。战国末期成书的《吕氏春秋》中记载：“慈石召铁，或引之也。”汉代高诱注解说：“慈石，能引其子”“取铁，如母之招子焉”。



明宋应星《天工开物》中的"抽线琢针"图
Illustration of "Art of Needle-making" in *Encyclopedia of Technology* (*Tiangong Kaiwu*) by Song Yingxing of the Ming Dynasty

清朝象牙椭圆盘指南针
A compass in an oval ivory case of the Qing Dynasty

清朝银烧蓝蝉形佩式指南针
A wearable compass in shape of blue silver cicada of the Qing Dynasty

清朝铜镀金指南针
A compass in a gilded copper case of the Qing Dynasty

指南鱼
South-pointing fish

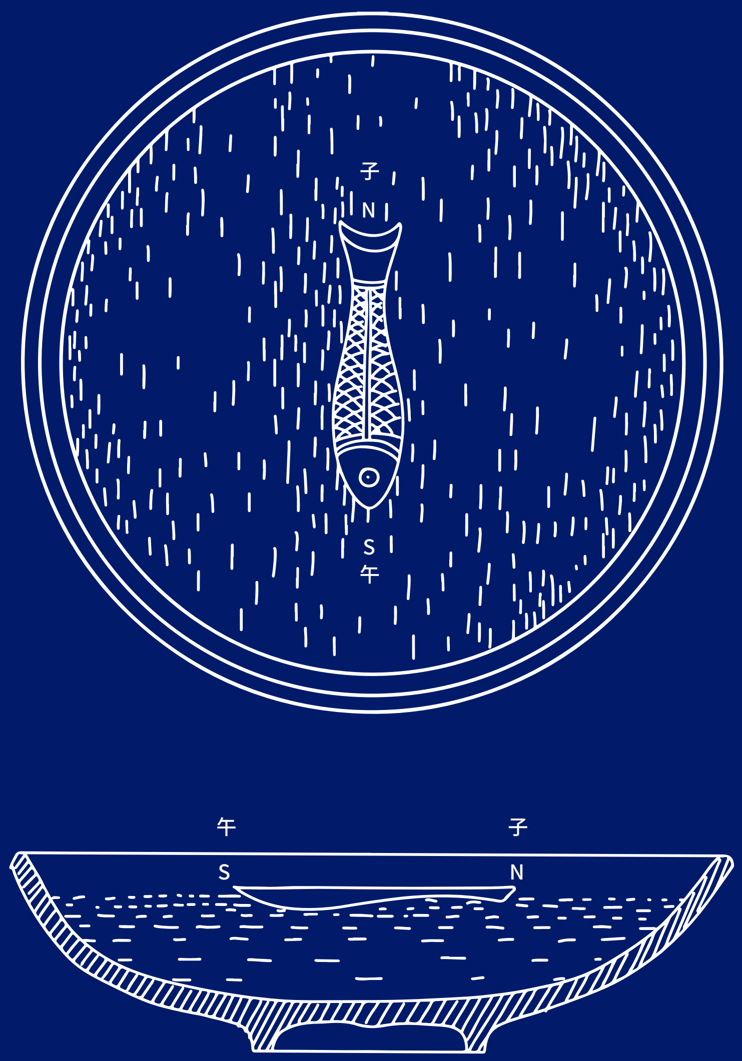
指南鱼
South-pointing Fish

1044 年，北宋曾公亮和丁度的军事著作《武经总要》中提到“指南鱼”，“用薄铁叶剪裁，长二寸，阔五分，首尾锐如鱼形，置炭火中烧之，候通赤，以铁钤钤鱼首出火，以尾正对子位，蘸水盆中，没尾数分则止，以密器收之。用时，置水碗于无风处平放，鱼在水面，令浮，其首常南向午也。”这是另一种人工磁化的方法。

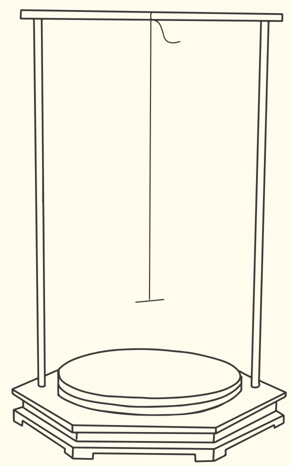
使用指南鱼，比司南要方便、灵敏且更准确。它不需要光滑的铜地盘，只要有一碗水即可，不管碗是否放平，碗中水面总是平的。由于液体摩擦力比固体小，转动起来更加灵活。

A south-pointing fish was mentioned in the military work named *Military Classics* which was written by Zeng Gongliang and Ding Du in the Northern Song Dynasty in 1044 A.D. "First cut a thin iron sheet into a two-cun-long and five-fen-wide piece with its head and tail sharp as a shape of fish, then cast it in a charcoal fire until it turns red all over, next pull it out of the fire and place it in the direction of the meridian with the tail facing to the north, after that dip it into water with the tail tilting slightly downward. When in use, place a water bowl flat in a calm place with the fish floating on the water surface. Its head always points to the south." This is another method of artificial magnetization.

The south-pointing fish is more convenient, sensitive and accurate than sinan. It need not a smooth copper plate but a bowl of water. Regardless of whether the bowl is flat or not, the water surface is always flat. Since the liquid friction is smaller than the solid friction, the south-pointing fish is more flexible to turn.



王振铎先生根据《武经总要》绘制的指南鱼复原图
Image of a south-pointing fish drawn by Wang Zhenduo based on *Military Classics*

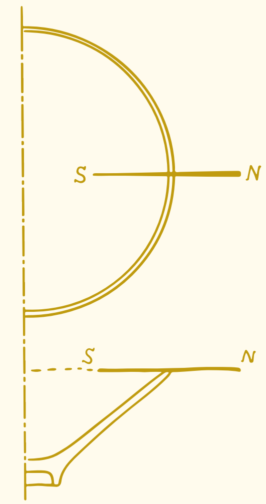


吊针
Hanging needle

吊针（缕悬法指南针）
Hanging Needle (Silk-suspended Needle)

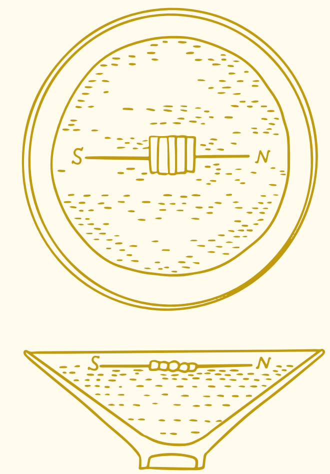
北宋沈括的《梦溪笔谈》中记载：“水浮多荡摇，指爪及碗唇上皆可为之，运转尤速，但坚滑易坠，不若缕悬为最善。其法：取新纩中独茧缕，以芥子许腊缀于针腰，无风处悬之，则针常指南。”这种缕悬法指南针也叫吊针，其灵敏度很高，指向准确。但由于其针线轻盈，易受风吹扰动。

The Dream Pool Essays written by Shen Kuo in the Northern Song Dynasty recorded that "A magnetic needle may be made to float on the surface of water, but it is rather unsteady. It may be made to place on a nail or the edge of a bowl, but it turns too fast and is slippery and easy to fall. It is best to suspend it by a single cocoon fiber of new silk attached to the center of the needle by a piece of wax first, then hang it in a windless place. It will always point to the south". This kind of the south-pointing needle suspended by silk is also called hanging needle. Although it is highly sensitive and accurate, it is susceptible to wind disturbance due to the lightness of the needle and silk.



碗唇法
Magnetic needle on the edge of a bowl

将指南针小心地放在瓷碗的碗唇上，确保指南针的重心恰在其与碗唇接触处。

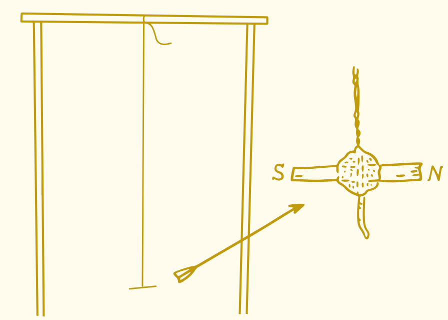


水浮法
Magnetic needle on water

用轻质灯芯草作为磁针的载体，将指南针轻放入盛水的碗中，指南针因受液体表面张力的作用，有时会浮于水面，并慢慢地转向指南方向。水浮法实质上是水罗盘的雏形。

指甲法
Magnetic needle on a nail

将指南针放于指甲上，由于指甲的光滑性，指南针可以自由转动而指南。



缕悬法
Magnetic needle suspended by a silk

用少许蜡将单根蚕丝或棉线粘连于磁针的重心点上，然后将磁针挂起。

王振铎先生绘制的沈括四种指南针装置试验复原图
Wang Zhenduo illustrated the four experiments to set up a south-pointing needle mentioned by Shen Kuo

磁偏角
Magnetic Declination

沈括的《梦溪笔谈》中记载了磁偏角的发现，“方家以磁石磨针锋，则能指南，然常微偏东，不全南也”。对于磁针的装置和用法，沈括做了四种实验：一是将磁针穿过一个灯芯浮在水上，二是将磁针架在碗沿上，三是将磁针横置于指甲上，四是用丝线将磁针悬吊起来。他发现，第四种吊针的灵敏度和准确性最高，而且该实验促使沈括发现了地磁子午线和地理子午线的不一致，即磁偏角。1115 年，寇宗爽在《本草衍义》中记载：“以针横贯灯心，浮水上，亦指南，然常偏丙位”，明确阐述了磁偏角及其方位角度。

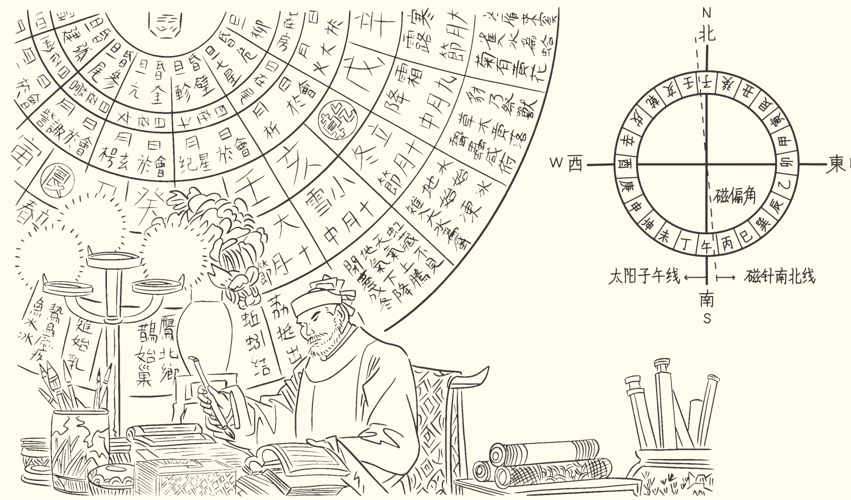
宋代储泳（约 1101—1165）撰写的《祛疑说》中，则明确了磁偏角的角度。《祛疑说》中提到：“地理之学，莫先于辨方，二十四山于焉取正。以百二十位分金言之，用丙午中针则差西南者两位有半，用子午正针则差东南者两位有半，吉凶祸福，岂不大相远哉？”24 山以 120 位分，则每山 5 位，磁偏角则是 2.5 位，即 7.5 度。

一直到 1492 年，欧洲哥伦布在美洲航行时才发现了地磁偏角现象，比沈括的发现晚了大约 400 年。

The Dream Pool Essays written by Shen Kuo recorded the discovery of the magnetic declination "When geomancers rub the needlepoint with a lodestone, it is able to point to the south, but it is always displacing slightly east rather than pointing due south". To set up a magnetic needle, Shen Kuo made four experiments: 1. Float a magnetic needle through a wick on the water. 2. Place a magnetic needle on the rim of a bowl. 3. Place a magnetic needle on the finger nail. 4. Suspend a magnetic needle by a silky thread. He found that the fourth one had the highest sensitivity and accuracy, which further prompted him to discover the discrepancy between the magnetic meridian and the geographical meridian, known as magnetic declination. In 1115 A.D., in *Exhibition of the Meaning of Materia Medica*, Kou Zongshuang stated that "When a magnetic needle through a wick floats on the water, it points to the south but shows a Bing-point variation". He explicitly explained the magnetic declination and its angle in degrees.

Dispelling Doubts by Chu Yong (around 1101 A.D.–1165 A.D.) in the Song Dynasty clearly expressed the magnetic declination in degrees "Geography is the subject to determine the direction first. There are 24 cardinal directions in 120 points. The variation of a needle direction of 'Bing-wu' position is 2.5 points southwest, while the variation of a needle direction of 'Zi-wu' is 2.5 points southeast. Isn't it too far to predict good or back luck?" It means that 120 points divided by 24 cardinal directions is equal to 5 points per cardinal direction, so the magnetic declination is 2.5 points, or 7.5 degrees.

It is a concept unknown in Europe for another four hundred years until Columbus, a European, voyaged to America in 1492 A.D.



堪舆家杨维德撰写《茔原总录》
General Records of the Tombs written by geomancer Yang Weide

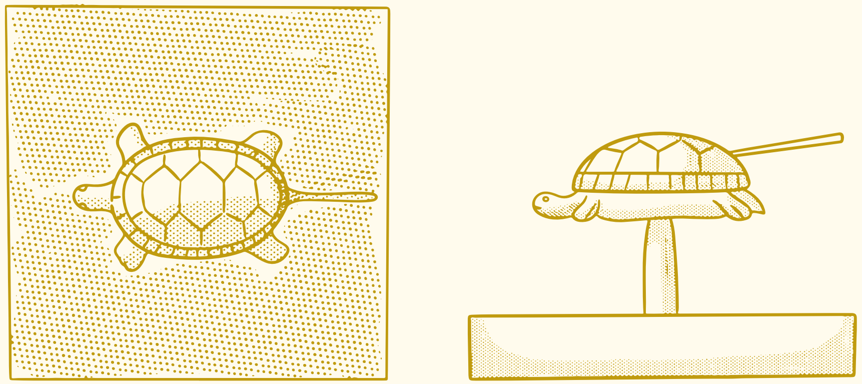
北宋初，堪舆家杨维德于庆历元年（1041）撰写相墓书《茔原总录》，记述了指南针在罗盘上“取丙午、壬子之间”，这是“约而取于大概”的地理南北方向。堪舆师王伋也曾经指出，指南针所指的不是正确的地理南北极方向，而是在罗盘的“虚危之间”。“虚”与“危”是天上星宿的名称，“虚危之间”与“丙午、壬子之间”实则是一个方向。

明代王子朱载堉（1536—1611）又指出“八方之地，各有偏向”，即地磁偏角各地并不相同。

General Records of the Tombs written by geomancer Yang Weide in the first year of the Qingli Period (1041 A.D.) of the early Northern Song Dynasty recorded "the position between a needle direction of 'Bing-wu' and 'Ren-zi'" is approximately equal to the geographic north-south meridian. Geomancer Wang Ji also pointed out a magnetic needle points not to the geographic true north, but to "the position between 'Xu-wei'". "Xu" and "Wei" are the names of the stars. The position between "Xu-wei" is actually the same meaning as the position between "Bing-wu" and "Ren-zi".

The prince Zhu Zaiyu (1536 A.D.–1611 A.D.) of the Ming Dynasty also noted that magnetic declination varies from place to place.

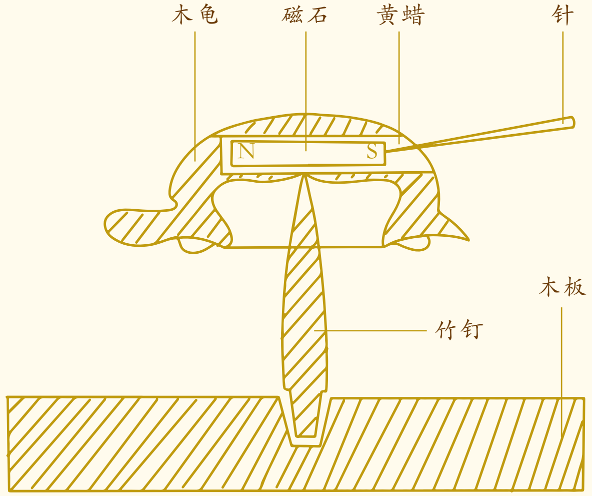
指南龟
South-pointing turtle



指南龟
South-pointing Turtle

南宋末年陈元靓的《事林广记》中记载了“指南龟”，用木头刻成指南龟，将针插在其尾部，但指南龟不放在水里，而是在木龟的腹部下方挖一小洞放入磁石，然后将木龟安装在光滑的竹钉上，使其能够自由旋转，当其静止的时候，龟尾指南。据历史学家考证，指南龟发明年代应早于 1325 年，其后来发展成旱罗盘。

Comprehensive Record of Affairs by Chen Yuanliang in the later Southern Song Dynasty recorded the south-pointing turtle which is carved into a shape of turtle out of wood with a needle inserted in the tail. It is not put in water, but installed on the smooth bamboo nail with a magnet in the hollow lower abdomen so that it can turn freely. When it is still, its tail points to the south. According to historians, a south-pointing turtle should be invented earlier than 1325 A.D. and was later developed into a dry compass.



王振铎先生根据《事林广记》绘制的木刻指南龟复原图
Illustration of a wooden south-pointing turtle by Wang Zhenduo based on *Comprehensive Record of Affairs*

“以木刻龟子一个，一如前法制造，但于尾边敲针入去，用小板子上安以竹钉子，如箸尾大，龟腹下微陷一穴，安钉子上拨转常指北，须是钉尾后。”
——南宋陈元靓《事林广记》

针碗
Needle bowl

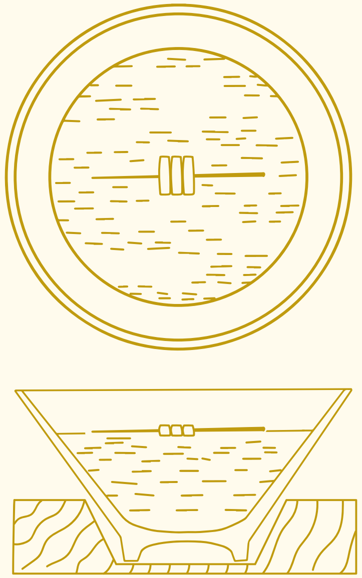
针碗
Needle Bowl

在出土的元代沉船中，发现有一种白釉瓷碗，碗内底用褐釉画了一个大大的像“王”字的符号，而碗外底则写着一个“针”字，经科技史学家王振铎研究证实，“王”字代表 3 枚浮漂着的磁针，这便是航海时指示方向的“指南浮针”所用的针碗。

在使用时，针碗的水面上漂着浮针，碗内底的“王”字形标志则有助于指示方向。先将“王”字中的一竖与船身中心线平行，浮针和竖线的夹角便能指示船身的方向。如船身转向，磁针和该细线的夹角就会变化，从而显示航向转移的角度。故宫博物院所藏明代针碗还有在碗内底标出一圈二十四方位名称的，使用时就更便于观察了。

In an unearthed shipwreck of the Yuan Dynasty, a white glazed ceramic bowl was found. A big symbol shaped like the Chinese character "王" was glazed in brown on the interior bottom of the bowl with another Chinese character "针" on the exterior bottom. According to the research carried out by scientific historian Wang Zhenduo, the character "王" represents three floating magnetic needles. It was in this needle bowl that the south-pointing needles floated to indicate the direction when sailing.

When in use, float the needles in the needle bowl of water, then the direction can be indicated with the help of the character "王". First, arrange the vertical line of "王" parallel to the center line of the hull, then the angle between the floating needles and the vertical line indicates the heading of the hull.The angle changes with the turn of the hull to show the heading shift. Besides, the needle bowl of the Ming Dynasty housed in the Palace Museum has twenty-four cardinal directions around the interior bottom, making it easier to observe when in use.



针碗示意图
Schematic diagram of the needle bowl

南宋咸淳年间（1265—1274）吴自牧在《梦粱录》里记述：“风雨冥晦时，惟凭针盘而行，……”这里所说的“针盘”，就是针碗罗盘，即把针碗放置于罗盘上，以便观察磁针的方向和角度。一直发展到元代，针碗得到大量的生产和使用，我国河北省磁县成为当时针碗最大的生产地。考古专家曾在河北彭城磁州窑遗址元代堆积层中，发现大量的针碗标本。

航海罗盘
Mariner's Compass

最初使用指南针时，没有固定的方位盘，随着测量方位的需要，出现了磁针和方位盘一体的罗盘。将罗盘用于航海，就是航海罗盘。

我国古代航海业起源很早，秦汉时期，就与今朝鲜半岛、日本岛等地有了海上往来。指南针用于航海应起始于唐代末期至北宋末期之间。王振铎先生在《司南指南针与罗经盘——中国古代有关静磁学知识之发现及发明（中）》中指出：“唐开成三年（838）时航行日本朝鲜中国间各国及中国船尚无此项磁针之装备，故知指南针用在航海不能逾唐开成三年，据《萍洲可谈》所记广州方面海舶之用指南针为元符二年（1099）服知广州时之事，自开成三年至元符二年，其间二百六十一年，磁针航海当即始于此二百余年中耶。”

有史料记载的航海罗盘最早可追溯至北宋时期。北宋朱彧在《萍洲可谈》中记述了当时广州航海业的盛况，同时也记述了中国海船在海上航行并运用罗盘导航的情形。南宋吴自牧在他所写的《梦粱录》中也写道：“风雨冥晦时，惟凭针盘而行，乃火长掌之，毫厘不敢差误，盖一舟人命所系也。”由此可以看出罗盘在航海中的重要地位和作用。

航海罗盘通常被划分为 24 个方位。采用天干、地支和四维均匀排列，顺时针依次排序为“子、癸、丑、艮、寅、甲、卯、乙、辰、巽、巳、丙、午、丁、未、坤、申、庚、酉、辛、戌、乾、亥、壬”，其中“子、午”为正南北向，“卯、酉”为正东西向。24 个单字正方位称“单（丹）针”，比如“单卯针”，24 个相邻字中间方位称“缝针”，比如“甲卯针”。这样，共 48 个方位，每个方位精确度为 7.5 度。


（正面）
Front view

（剖面）
Section view

（底面）
Bottom view

明代中针式相墓铜水罗盘
Copper wet card compass with cardinal points for graveyard geomancy in the Ming Dynasty

航海罗盘
Mariner's compass

When the south-pointing needle was first used, there was no fixed azimuth bearing. With the need to measure the direction, a compass with the integration of the magnetic needle and the azimuth bearing appeared. A compass which is applied to the seafaring is a mariner's compass.

The ancient seafaring practices originated very early in China. During the Qin and Han Dynasties, maritime intercourse between China and other areas such as Korean Peninsula and islands of Japan had been practised. The time when the compass was used for seafaring should begin between the later Tang Dynasty and the later Northern Song Dynasty. Mr. Wang Zhenduo pointed out in *Sinan, South-pointing Ladle and Compass—The Discovery and Invention of Magnetostatics in Ancient China* (*Part 2*): "In the third year of the Kaicheng Period of the Tang Dynasty (838 A.D.), vessels sailing between Japan, Korea and China weren't equipped with magnetic needle, so the application of the needle to the seafaring wouldn't be earlier than the third year of Tang Kaicheng Period. According to *Pingzhou Table Talk*, the application of the needle by the seagoing vessels in Guangzhou region was in the second year of the Yuanfu Period (1099 A.D.) when the author's father served as the governor of Guangzhou. Thus, the application of the needle to the seafaring must begin in any year during these 261 years from the third year of the Kaicheng Period to the second year of the Yuanfu Period."

The earliest recorded mariner's compass can be traced back to the Northern Song Dynasty. The earliest recorded mariner's compass can be traced back to the Northern Song Dynasty. *Pingzhou Table Talk* by Zhu Yu in the Northern Song Dynasty described the prosperity of the maritime business in Guangzhou at that time and the use of the mariner's compass by Chinese vessels. Wu Zimu in the Southern Song Dynasty also wrote in his *Dream Sorghum* :"When windy or rainy or overcast, only by the compass can you travel. Mastered by the seaman who dares not make an iota of mistake for it is related to everyone's life on board." From this it can also be seen that the compass plays an important role in navigation.

The compass rose is usually divided into 24 directions. It adopts heavenly stems, earthly branches and four diagonal directions spaced evenly with "Zi, Kui, Chou, Gen, Yin, Jia, Mao, Yi, Chen, Xun, Si, Bing, Wu, Ding, Wei, Kun, Shen, Geng, You, Xin, Xu, Gan, Hai and Ren" in clockwise order among which "Zi" and "Wu" point to the north-south direction, while "Mao" and "You" point to the east-west direction. These 24 cardinal directions are called "single needle point", such as "single needle point of Mao", while the intercardinal directions halfway between the 24 cardinal directions are called "seam needle point", such as "(seam) needle point between Jia and Mao". Thus in total, there are 48 points with an accuracy of 7.5 degrees per point.

针路

Needle Path

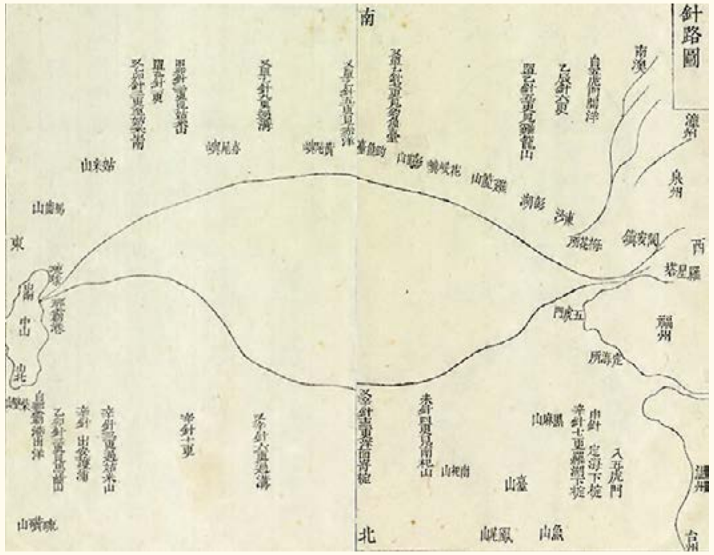
中国古代将罗经方向定航向、以船行更数定航程，以及对打水深浅、能否停泊等详细情况记录说明而形成的航海指南称为“针路”，或者“针经”。从甲地到乙地的某一航线上有不同的航行方向，将这些航向连接成线，绘制成图，并注明每段航程的针向、更数及海况地文信息，这就是所谓的“针路图”。从甲地到乙地，不同航线上的针路各有不同；同一航线上来回往返，因为季风原因，针路也不尽相同。元朝时，温州人周达观奉命随外交使团远赴真腊（今柬埔寨），航海而行，就使用针路指导航向。现存记录较详细的海道针经有明初的《顺风相送》和清初的《指南正法》等。

In ancient China, the needle direction and speed over elapsed time which were used to determine the orientation and course respectively, together with the detailed descriptions of the water depth, anchor location composed the navigation guide called needle path. On a route from place A to place B, there are different courses. Connect these courses into a set of line segments with the needle directions, speed over elapsed time and topographies marked on each of them to create a chart called "needle path". From place A to place B, the needle path varies from route to route, while on the same route back and forth, the needle path also varies because of the monsoon. During the Yuan Dynasty, Zhou Daguan, a native of Wenzhou, was ordered to visit Zhenla (now Cambodia) with the diplomatic corps. On his voyage, he used the needle path to orientate. The existing needle path charts in some detail are *Sail Before the Wind* of the early Ming Dynasty and *Orthodox Laws of Orientation* of the early Qing Dynasty.

往柬埔寨针路示意图
Needle path chart to Cambodia

明初佚名书籍《顺风相送》中的海道针经：往柬埔寨针路

浯屿开船，用丁未及单未七更船平南澳彭山外过。用坤申十更，船用单坤五十更，船用单未七更，船取外罗山外过。用丙午针十更，船取羊屿。用丁未及单丁针十更，船见伽南貌。用坤未针五更，船取罗湾头。用坤申五更，船取赤坎山。用单申四更，船取鹤顶山。用庚申二更，取真屿。用庚申二更，船取嘴贴头山。抛船妙也。有瓜石兰，生开，不出水，去入港，船到使出山头，用坤未针及坤申针，单申及庚申、辛酉针入港为妙也。

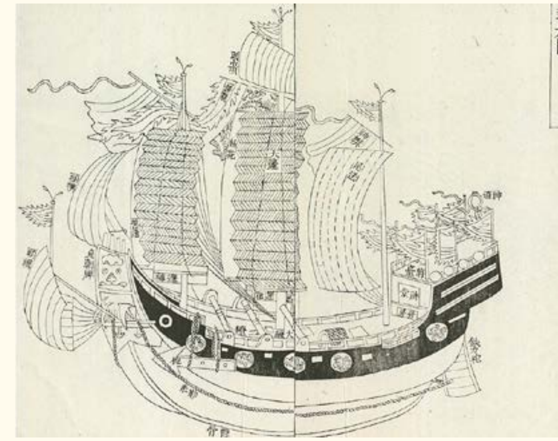


针路图

Needle Path Chart

封舟出洋顺风针路图

Needle Path Chart of Sending the Boat to Sail before the Wind to Bestow the Noble Title



《琉球国志略》中的中国航海帆船

The Chinese sailboat in *Brief Gazetteer of Ryukyu*

《针路图》选自清乾隆二十一年(1756)周煌所辑《琉球国志略》。《针路图》是一幅航海图，表现的是大清“封舟”(代表朝廷出海赐封海外王的舟船)“出洋”的航线，描绘的是乾隆二十年(1755)翰林院侍讲全魁、编修周煌出使琉球国册封世子尚穆为王的往返路线。图中描绘了“封舟”由福州罗星塔(在今福建马尾)出港，依次经东沙岛、鸡笼山(今中国台湾基隆港)、钓鱼台(中国钓鱼岛)、黄尾屿(中国)、赤尾屿(中国)、姑米山等，最终到达琉球那霸港，并由琉球返回福州的航程及针路。钓鱼岛及其附属岛屿最先为中国人发现并命名，自古以来就是中国领土，明朝初期将“钓鱼屿”及附近岛屿纳入福建海防区划。

图中按我国古代航海图的传统绘法，详细地注出了往返航行的针路。其中出航的针路有以下6段：(1)“东沙外放洋，单乙辰针(合现在方位为东偏南和东南偏东之间)十更取鸡笼山”；(2)“自鸡笼山乙卯针(东偏南、正东)、单卯针(正东)十更取钓鱼台”；(3)“自钓鱼台单卯针四更取黄尾屿”；(4)“自黄尾屿甲卯针(东偏北、正东)十更取赤尾屿”；(5)“自赤尾屿乙卯针六更取姑米山”；(6)“自姑米山单卯针取马齿山，甲卯及甲寅(东偏北、东北偏东)收入琉球那霸港”。返航的针路由于主要利用强劲的东南季风，所以过姑米山后一直向着西偏北的方向航行，见南杞山后再转向西市方向沿着台山、里麻山等岛屿，用“单申针(西南偏西)收入定海进闽安镇”。《封舟出洋顺风针路图》是《针路图》的彩绘本，图的内容没变。

地文导航
Landmark Navigation

中国古代海船的地文导航主要采取陆标定位、航路指南和航海图的方法。明《顺风相送》中记载：“历代过洋，知山知沙，知浅知深，知屿知礁，精通海道，寻山认澳，望斗牵星。”这种方法要求船员牢记所经地区的岛屿、大陆海岸地标的方位和自然地貌，测量水深，查看海底泥沙土质，以及海水颜色变化等，并把沿线山屿形势绘制成图，以文字标注，形成《更路薄》《针经图》和《航海图》，以指导航船。

Navigation for ancient Chinese sea vessels typically used landmarks, route guides and nautical charts. *Sail Before the Wind* of the Ming Dynasty recorded "When sailing in the past, people knew mountains, sands, the shallowness and depth of the ocean, the islands and the reefs. They mastered the seamanship and they were able to look for mountains, recognize anchor locations and observe the stars like Polaris". Landmark navigation requires the crew to keep in mind the location and topography of islands and coastal landmarks. It also requires them to measure the depth of water, check the sea-floor sediment texture, the color change of seawater and so on. *Book of Time*, *Needle Path Chart* and *Nautical Chart* are drawn by depicting terrain of mountains and islands along the route marked with text as references for ships.

牵星导航示意图

Schematic diagram of star-guided navigation

天文导航
Astronavigation

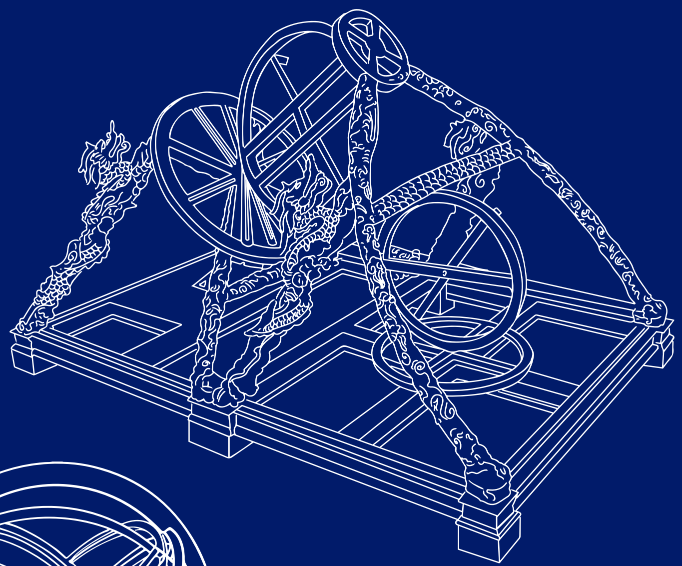
中国是最早掌握天文定向导航技术的国家之一。《诗经·小雅·大东》中记载："东有启明，西有长庚。有捄天毕，载施之行。维南有箕，不可以簸扬。维北有斗，不可以挹酒浆。维南有箕，载翕其舌。维北有斗，西柄之揭。"其意思是说"早晨启明星在东方，晚上长庚星在西方。天毕星长柄弯又长，张设行列在天空中。南天箕星闪烁光芒，这箕不能簸米糠。往北有那南斗星，这斗不能舀酒浆。南天箕星闪烁光芒，伸出舌头口大张。往北有那南斗星，在西举柄向东方"。可见西周时期，人们已经以星辰定方向了。早在公元前 140 年，西汉刘安主编的《淮南子·齐俗训》中记载："夫乘舟而惑者，不知东西，见斗极则寤矣。"可见，那时已经通过观星斗定航向了。东晋高僧法显（约 337—422）的《佛国记》中记载："大海弥漫无边，不识东西，唯望日月星宿以进。"南宋吴自牧的《梦粱录》中写道："舟师观海洋中日出日入，则知阴阳。"这里所谓"阴阳"即指南北而言，而且其还明确指出是以观测太阳出没的方位来认定航向的。到元明时期，"牵星术"得到很大发展，可以测星辰高度、确定航向、制作航海图，成为远洋航行重要的导航手段。

China is one of the earliest countries to master the astronavigation. *The Classic of Poetry. Lesser Court Hymns. Da Dong* recorded "the Phosphorus appears in the east in the morning and the Hesperus appears in the west in the evening. The handle of the Net Asterism is long and curved, open wide in the sky. The Winnowing Basket Asterism is shining in the southern sky with its tongue sticking out, but this basket cannot winnow chaff. The Southern Dipper Asterism is at the side of the Winnowing Basket Asterism, with its handle lifted to the east, but this dipper cannot scoop the wine". It can be seen that in the Western Zhou Dynasty, people can determine the direction by stars. As early as 140 B.C., *Huainanzi. Qi Folklore Admonition* by Liu An in the Western Han Dynasty recorded "If you get lost when riding a boat, knowing nothing about direction, you will be enlightened when you see Polaris." It is obvious that the orientation can be determined at that time by observing the stars. *Buddha Kingdom* by the eminent monk Faxian in the Eastern Jin Dynasty (about 337 A.D. -422 A.D.) recorded "The vast sea is boundless, hard to know the direction. Only by referring to the sun, the moon, and stars, can we progress." Wu Zimu in the Southern Song Dynasty wrote in *Dream Sorghum* that "The seaman observes the sunrise and sunset to know the Yin and Yang". The so-called "Yin and Yang" here refers to north and south. Furthermore, it clearly points out that it is by the direction of the sunrise and sunset that the orientation is determined. "The star-guided ocean crossing technique" had greatly developed during the Yuan and Ming Dynasty. It could be used to determine the latitude, the orientation and make the nautical chart, becoming an important navigation method for ocean voyage.

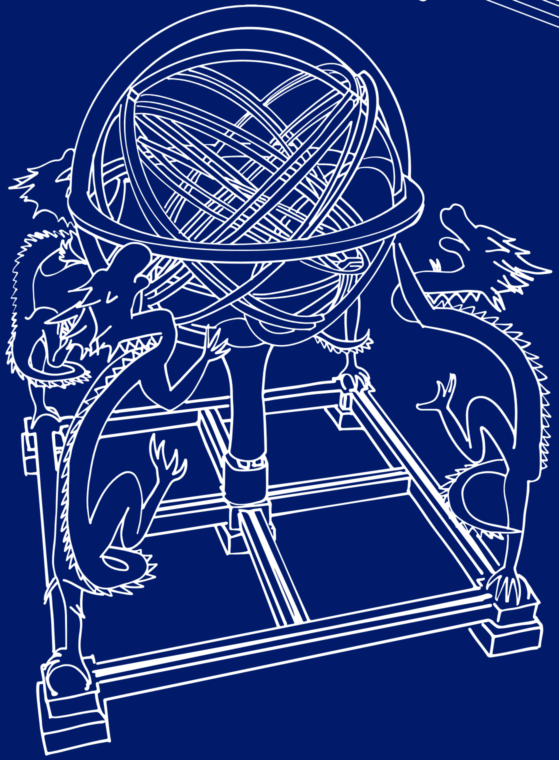
浑仪
Armillary Sphere

浑仪是中国古代的一种天文观测仪器，主要由天球坐标系各基本圈的环规及窥管（瞄准器）构成，用以测定“昏旦中星”和“夜半中星”以及各种天体的赤道坐标、黄道经度或地平坐标。有据可查的最早制作者是西汉落下闳（前 156—前 87），最早的浑仪只有外重六合仪和内重四游仪。到了唐代，天文学家李淳风增加了中间的三辰仪，使其可以测量天体的黄道坐标和白道坐标。到了元代，天文学家郭守敬将其简化，创制了简仪。中国现存最早的浑仪制造于明朝，现陈列在南京紫金山天文台。

An armillary sphere is an astronomical instrument for use in observation in ancient China. It is mainly composed of a spherical framework of rings and a sighting tube (aiming device), which represent the principal circles of the heaven to measure the equatorial, ecliptic and horizontal coordinates of the celestial bodies and the culminant stars at dusk, dawn and midnight. The first well-documented inventor was Luoxia Hong (156 B.C.–87 B.C.) in the Western Han Dynasty. The earliest armillary sphere had only an exterior equatorial ring and an interior sighting-tube ring. In the Tang Dynasty, astronomer Li Chunfeng added a framework of three luminary set to measure the ecliptic and moon's path coordinates of the celestial bodies. In the Yuan Dynasty, astronomer Guo Shoujing simplified it into an abridged armilla. The earliest existing armillary sphere in China was made in the Ming Dynasty and now displayed at the Purple Mountain Observatory in Nanjing.



简仪
An abridged armilla



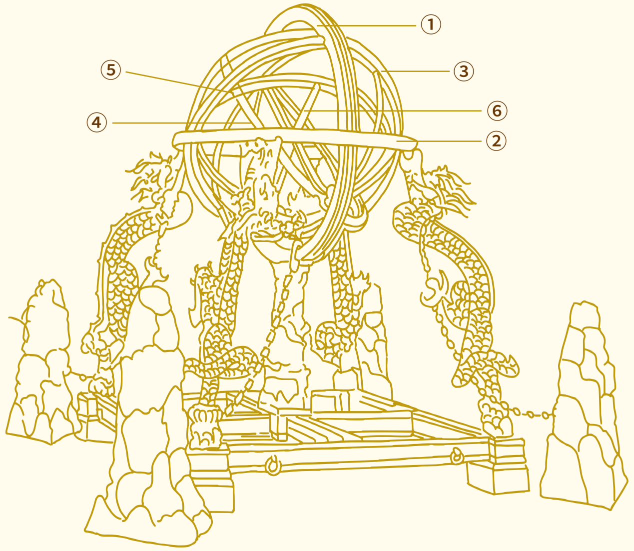
浑仪
An armillary sphere

北宋《新仪象法要》记载的元祐浑仪

The Yuanyou armillary sphere recorded by *Essentials of a New Method for Mechanizing the Rotation of an Armillary Sphere and Celestial Sphere* of the Northern Song Dynasty

明代浑仪

An armillary sphere of the Ming Dynasty



① 天元子午圈
Meridian ring

② 地平圈
Horizon ring

③ 天常赤道圈
Equatorial ring

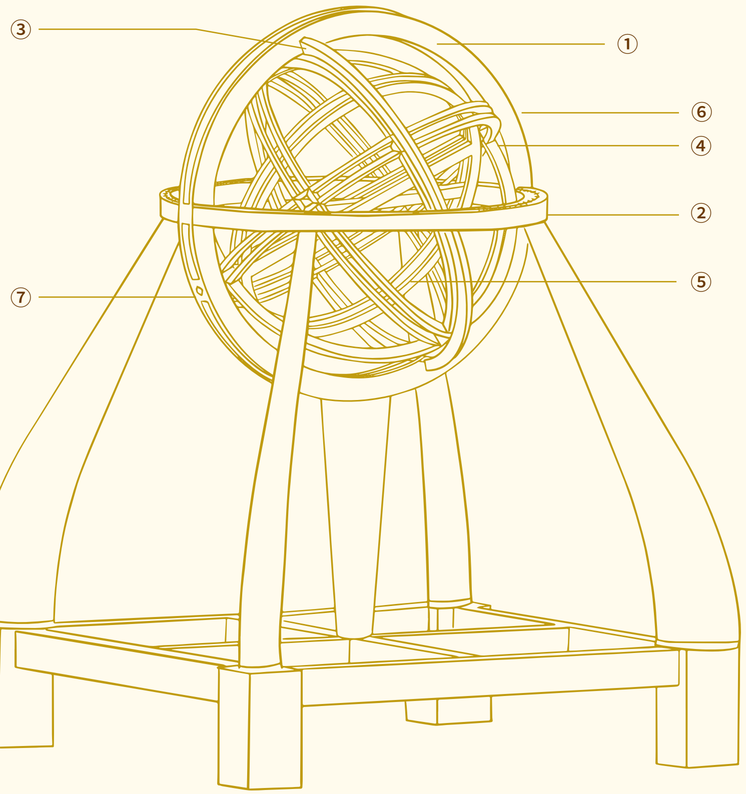
④ 三辰仪
Three luminary set

⑤ 四游仪
Sighting-tube ring

⑥ 窥管
Sighting tube

明代浑仪图解

Illustration of an armillary sphere of the Ming Dynasty



① 天元子午圈
Meridian ring

② 地平圈
Horizon ring

③ 天常赤道圈
Equatorial ring

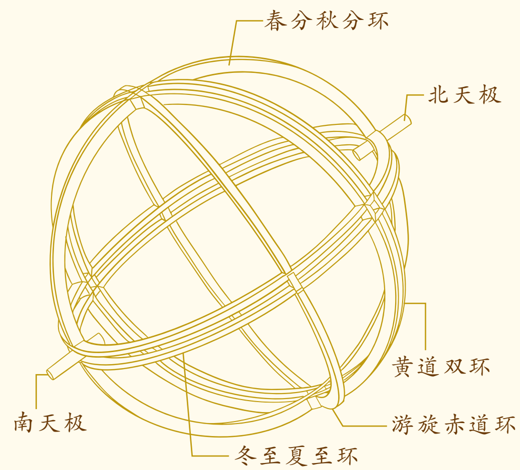
④ 三辰仪
Three luminary set

⑤ 四游仪
Sighting-tube ring

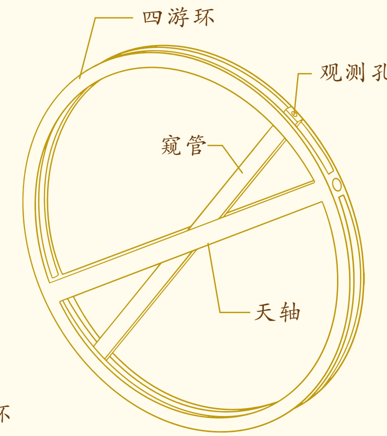
⑥ 北天极
North celestial pole

⑦ 南天极
South celestial pole

明浑仪结构图
Structure of an armillary sphere of the Ming Dynasty



三辰仪结构图
Structure of three luminary set



四游仪结构图
Structure of sighting-tube ring

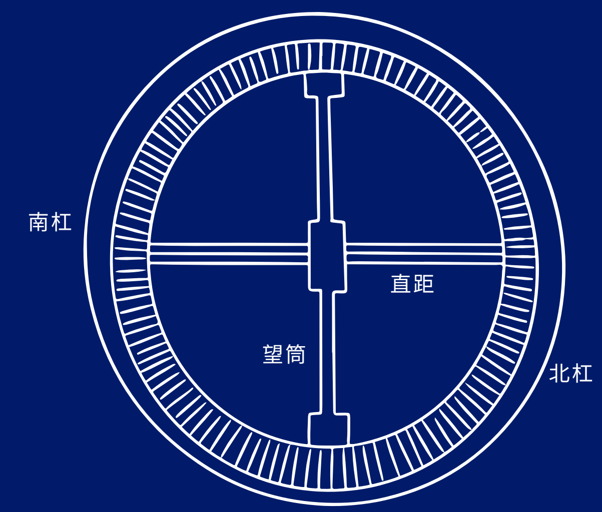
印有浑仪的邮票
A stamp of armillary sphere

在南京紫金山天文台，安置有一架明代铜制浑仪。它是明正统二年（1437）制作的，高 2.75 米，宽 2.46 米，长 2.48 米，分外、中、内 3 层。最外层为六合仪，由地平圈、天常赤道圈和天元子午圈 3 个大圆环组成；第二层为三辰仪，可绕极轴旋转，包括游旋赤道环、黄道环、三辰仪双环和四象环；最内层为四游仪，是仪器的望筒部分，由一对靠近的平行双环及一个瞄准器构成，双环的外径略小于三辰仪的内径，使它可在三辰仪中旋转。望筒以同心圆环的球心为中心，可上下仰游，又可随三辰仪绕极轴旋转。

望筒
Dioptra

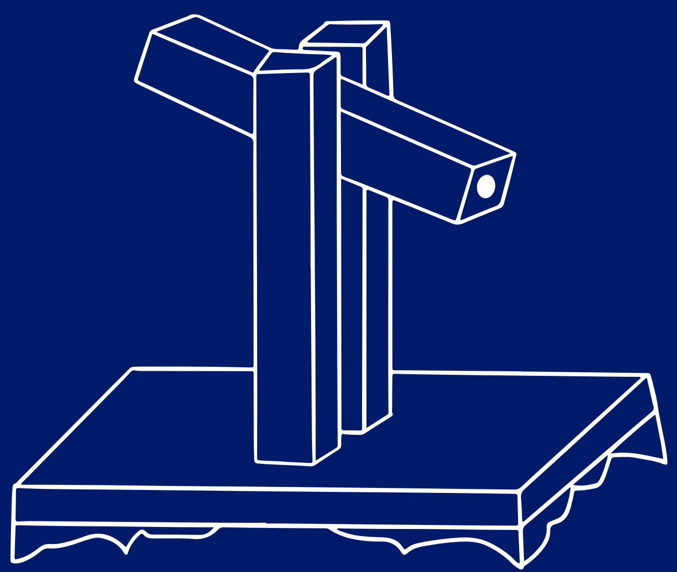
望筒又称“窥管”，是中国古代观察天体的器具，一般指附在浑仪上的一根中空管子，用以瞄准星辰，观测其方位坐标。《庄子·秋水》中记载：“是直用管窥天，用锥指地也，不亦小乎？”西汉东方朔（前 154—前 93）在《答客难》中记载：“以管窥天，以蠡测海”，故推测先秦时期已有简单的窥管，到两汉时期，窥管的规制逐步完善。《宋史·律历志九》中记载：“横箫望筒：长五尺七寸，外方内圆，中通望孔，其径六分，周于日轮，在璇枢直距之中，使南北游仰，以窥辰宿，无所不至。”

A dioptra, also known as "a sighting tube" was used to observe the celestial bodies in ancient China. It generally refers to a hollow tube mounted on an armillary sphere so as to aim at the star and fix its position. *Zhuangzi. The Floods of Autumn* recorded that "This is just like peeping at the heaven through a tube, or aiming at the earth with an awl. Aren't both implements too small for the purpose?" *Answering Difficult Questions of a Guest* by Dongfang Shuo of the Western Han Dynasty (154 B.C.–93 B.C.) recorded "to see the sky through a tube and to measure the sea with a ladle." So it is speculated that there were simple sighting tubes in the pre-Qin period and the size and shape of the sighting tube had been gradually perfected in the Western and Eastern Han Dynasties. *The History of the Song Dynasty. Musical Temperament and Calendar Part Nine* recorded "The dioptra is five chi and seven cun long with roundness inside and squareness outside. It is a hollow rod with six fen in diameter, whose range of vision encircles the angular diameter of the sun. Enclosed in the sighting-tube ring, it can move around, going anywhere to observe the celestial bodies.



宋《新仪象法要》中记载的四游仪中的望筒

A dioptra in a sighting-tube ring recorded by *Essentials of a New Method for Mechanizing the Rotation of an Armillary Sphere and Celestial Sphere*



宋《营造法式》记载的望筒图

A dioptra recorded by *State Building Standards* of the Song Dynasty

陕西靖边汉墓星图
Shaanxi Jingbian Han Dynasty Tomb Star Map

2015 年发掘的陕西靖边杨桥畔渠树壕东汉砖室墓，发现了保存较精美的汉代星象图等珍贵壁画，其绘制时期在东汉中晚期（约 100—200）。壁画星象图表示了三垣二十八宿、中外星官以及银河和日月相对位置，是中国考古首次发现的四宫二十八星宿星形、星数、图像、题名四要素俱全的天文星象图。

In a brick-chambered tomb of the Eastern Han Dynasty which was excavated in 2015 in Qushu Trench by Yangqiao River, Jingbian county, Shaanxi Province, precious murals such as a well-preserved star map of the Han Dynasty were discovered, dating back to the middle and late Eastern Han Dynasty (about 100 A.D.–200 A.D.). The star map mural represents the relative locations of three enclosures, twenty-eight lunar lodges, central and peripheral asterisms, galaxy, the sun and the moon. It is the first star map discovered by Chinese archaeologists that contains all four elements of the four symbols and twenty-eight lunar lodges: asterism shape, asterism number, asterism sign and asterism name.

陕西靖边汉墓星图
Shaanxi Jingbian Han Dynasty tomb star map

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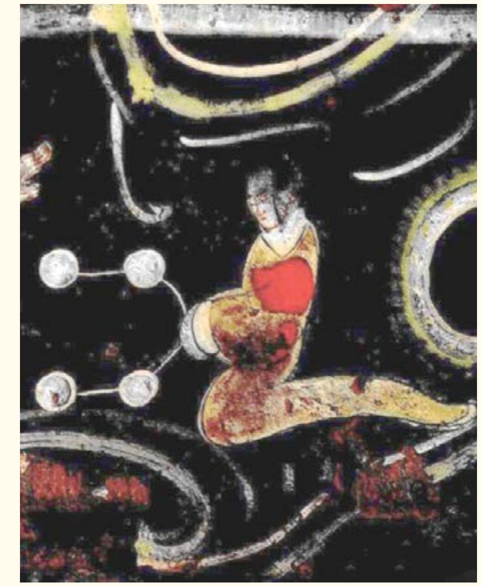

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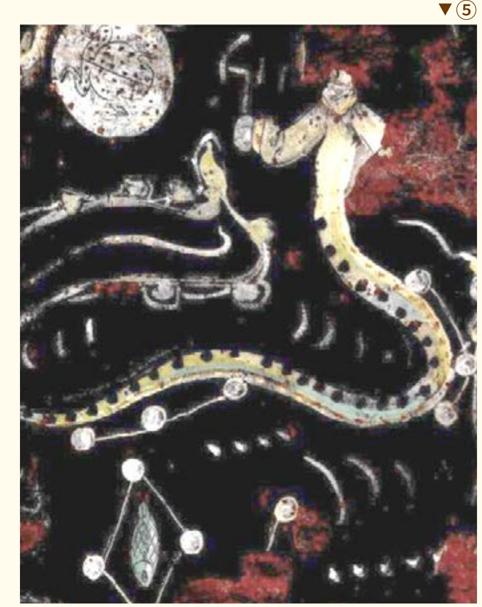


▼ ②

▼ ③

① 北京徐刚先生复原图
（微博“坐井观星_徐刚”）
The restored image by Mr. Xu Gang in Beijing
(Weibo "Zuo Jin Guan Xing_Xu Gang")

② 靖边汉墓星图——月
The moon

③ 靖边汉墓星图——觜宿
The Turtle Beak Asterisms

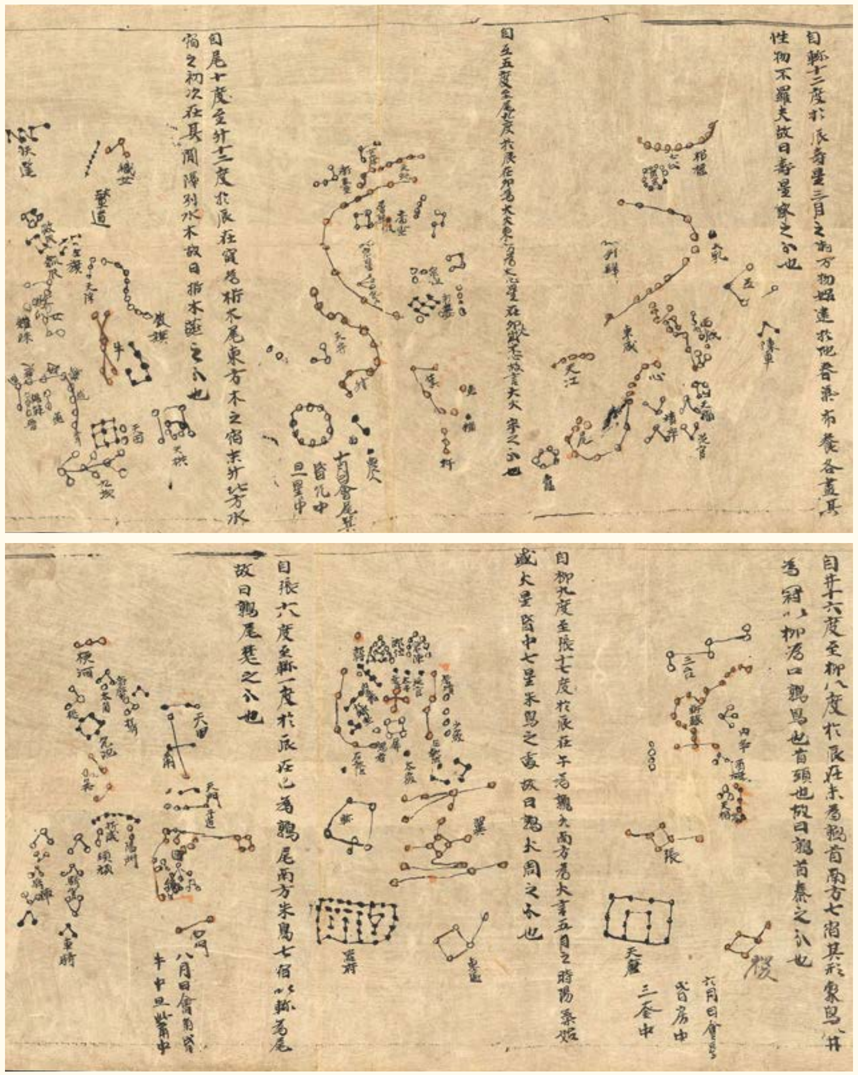
④ 靖边汉墓星图——箕宿
The Winnowing Basket Asterisms

⑤ 靖边汉墓星图——女娲
Nüwa (Mother Goddess of Chinese mythology)

《敦煌星图》
Dunhuang Star Map

《敦煌星图》1900 年发现于敦煌藏经洞，是迄今为止发现的第一张用不同颜色和形状符号区别不同星官恒星的手绘星图，是世界现存古星图中星数较多又较为古老的一幅。《敦煌星图》包括了紫微垣（北极区）星图一幅和紫微垣以南诸星的“十二次”星图 12 幅（按一年中太阳沿黄道、赤道带的运行位置，分成 12 段），展示了中国可见的完整的北天星图。另有 25 幅云气图，附占文，星图最后画有一电神。其中“十二次”星图，采用了类似墨卡托圆筒投影的方法画出，具有创新性。《敦煌星图》按黑色圆圈、黑点和圆圈涂黄 3 种方式将 1 339 颗星绘出，划分为 257 个星群，每张星图旁都附有文字说明名称、隐含寓意，以及据说会受这个天体区域影响的地上疆域。现在普遍认为，该星图绘制年代大约在唐中宗李显时期（705—710）。在《敦煌星图》的注释中，出现了“臣淳风言”字样，有学者认为唐太宗时期天文学家、道士李淳风参与了该星图绘制，现存《敦煌星图》很可能是抄绘本。该星图观测位置应为北纬 34 度左右，很可能是古长安（今西安）或洛阳。《敦煌星图》现存于伦敦大英图书馆。

Discovered in a cave containing a cache of manuscripts in Dunhuang in 1900, it is to date the first hand-painted star map that distinguishes constellations of the three schools with different colors and symbols and it is also one of the world's oldest extant star maps with relatively more stars. The atlas consists of a map of Purple Forbidden Enclosure (North Polar region) and 12 maps of equatorial and ecliptic regions south of Purple Forbidden Enclosure (the apparent path of the sun across the celestial sphere which is divided into 12 segments), showing a complete northern sky visible in China. There are also 25 drawings of cloud with divination texts, followed by the god of lightning at the end of the atlas. Twelve maps in the atlas are creatively plotted by using a projection system which is very similar to Mercator projection. It also uses three different styles of dots — black open circle, black dot and yellow dot — to mark the positions of 1,339 stars grouped into 257 asterisms. The text accompanying each star map describes the name, the astrological prediction and the terrestrial territories thought to be influenced by that region. It is generally believed that the star map was drawn during the reign of Emperor Li Xian, Zhongzong of the Tang Dynasty (705 A.D.–710 A.D.). There is a line of text which reads "your servant Chunfeng says", referring to astronomer and Taoist Li Chunfeng during the reign of Emperor Taizong of Tang, one of the possible authors believed by some scholars. The extant *Dunhuang star map* is probably a copy of the original manuscript. The observation site might have been in Chang'an (present-day Xi'an) or Luoyang, both at latitude of 34°N. Now it is housed in British Library in London.



《敦煌星图》的细节图
Dunhuang Star Map's details

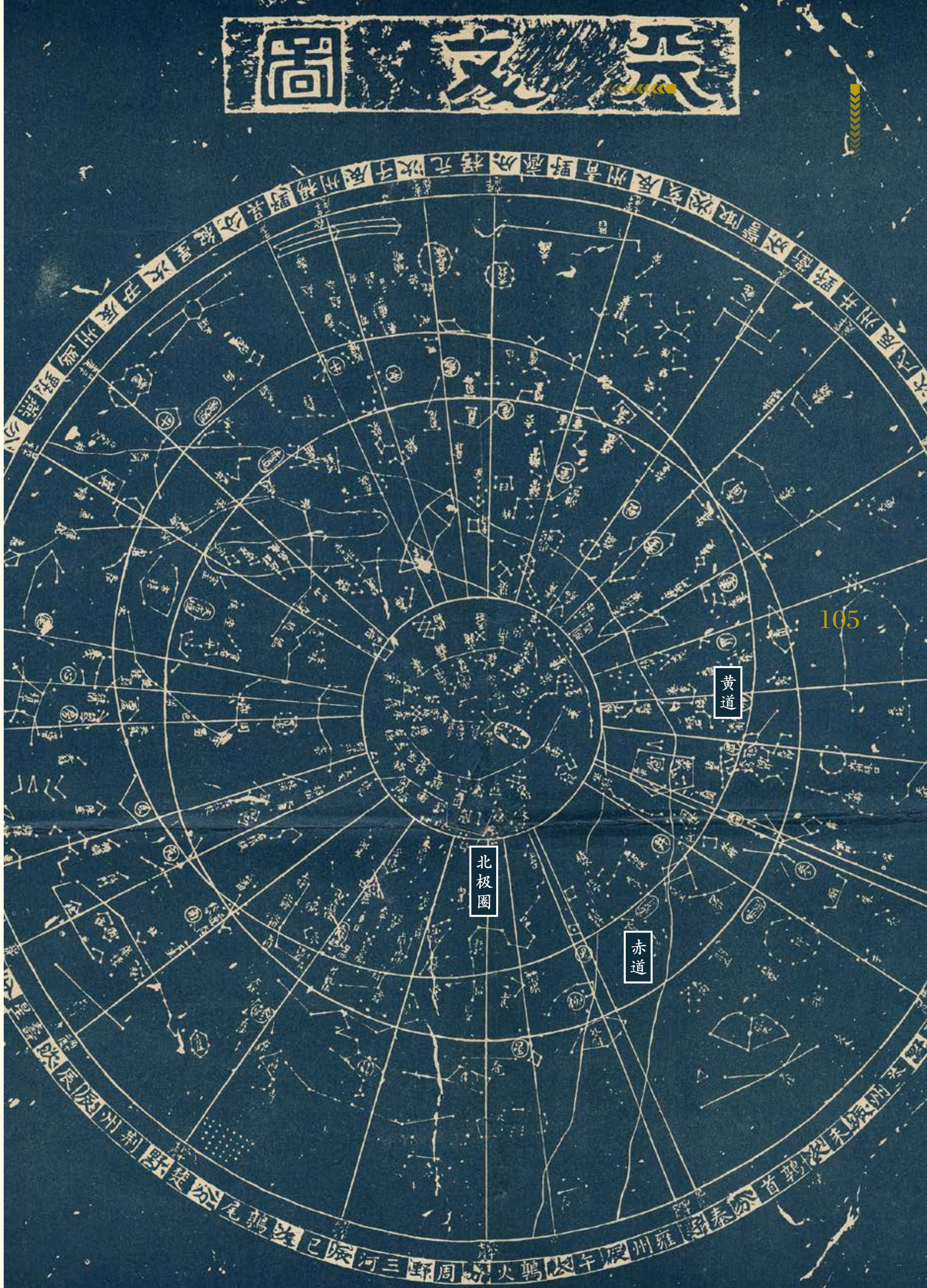
唐代《敦煌星图》的细节，描绘了北极天区(British Library Or.8210/S.3326)。
Dunhuang Star Map's detail drawn in the Tang Dynasty showing the North Polar region

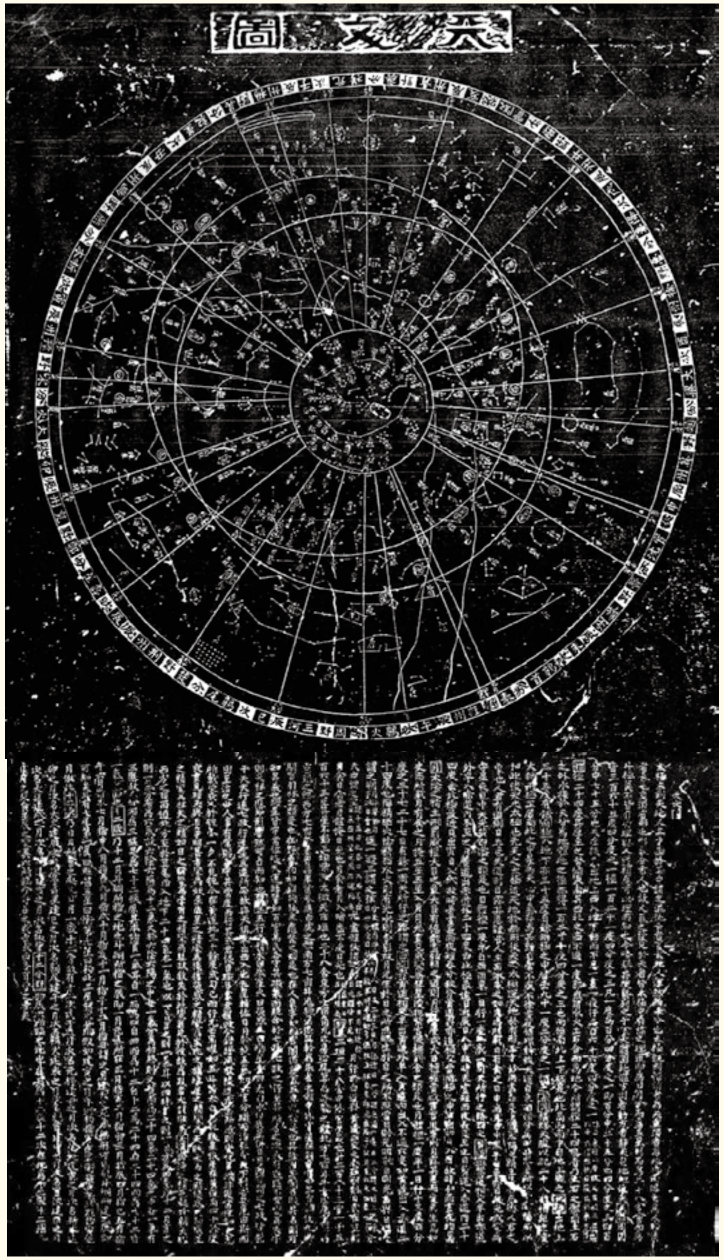
苏州石刻天文图

Suzhou Stone-carved Planisphere

这是世界上现存最古老的根据实测绘制的全天石刻星图。它的观测年代在北宋元丰年间（1078—1085），黄裳绘制于南宋绍熙元年（1190），王致远刻制于南宋淳祐七年（1247）。碑石高 216 厘米、宽 108 厘米，碑额题“天文图”三字，故又称“天文碑”。碑石上部是一幅圆形全天星图，星图外圈直径约 91.5 厘米，星图本身直径约 85 厘米。该图的画法是按古法，以天球北极为圆心，用 3 个同心圆加宿度线来表示的，二十八宿分明。图上绘制了赤道和黄道，两者夹角 24 度，还绘制了银河的轮廓。星图下方有两千多字的说明，概括地叙述当时人们所知的一些天文知识，其指出：“计二百八十三宫，一千五（四）百六十五星。”该星图的观测地点大约在北纬 35 度，应该是当时开封府的位置。它保存了我国在 11 世纪恒星观测的部分资料，提供了古代星宿位置的重要信息，具有极高的科学研究价值。

It is the world's oldest extant whole-sky planisphere engraved on stone by Wang Zhiyuan in the seventh year of the Chunyou Period in the Southern Song Dynasty (1247 A.D.). Drawn by Huang Shang in the first year of the Shaoxi Period in the Southern Song Dynasty (1190 A.D.) according to observations made during the Yuanfeng Period in the Northern Song Dynasty (1078 A.D.–1085 A.D.), it is a circular whole-sky chart at the upper part of the stele. Its outer circle is about 91.5 centimeters in diameter and the chart itself is about 85 centimeters in diameter. The stele is 216 centimeters high and 108 centimeters wide with caption "Tian Wen Tu" (astronomical chart) at the top, hence the name "Astronomical Stele". The planisphere depicts the sky in a classical way, adopting the three concentric circles along with radiating lines which demarcate the 28 mansions, extending to a circle centered on the north celestial pole. Two intersecting circles represent the celestial equator and ecliptic with an angle of 24 degrees. An irregular band running across the chart outlines the Milky Way. A text of more than two thousand words below the planisphere summarizes some astronomical knowledge known at that time and points out "a list of 1,565 stars in 283 asterisms". The observations were made from a latitude of about 35° north, which corresponds to Kaifeng, the capital city at that time. It preserves some information about star observations and star positions in the 11th century, which has very high scientific value.





苏州石刻天文图
Suzhou stone-carved planisphere

苏州石刻天文图下方的碑文原文：

太極未判，天地人三才函於其中，謂之“混沌”云者，言天地人渾然而未分也。太極既判，輕清者為天，重濁者為地，清濁混者為人。清者為氣也，重濁者形也，形氣合者人也。故凡氣之發見於天者，皆太極中自然之理。運而為日月，分而為五星，列而為二十八舍，會而為斗極，莫不皆有常理，與人道相應，可以理而知也。今略舉其梗概，列之于下。

天體圓，地體方。圓者動，方者静。天包地，地依天。“天體”周圍皆三百六十五度四分度之一，徑一百二十一度四分度之三。凡一度為百分，四分度之一即百分中二十五分也，四分度之三即百分中七十五分也。天左旋，東出地上，西入地下，動而不息。一晝一夜，行三百六十六度四分度之一（緣日東行一度故。天左旋三百六十六度然後復出於東方）。“地體”徑二十四度，其厚半之，勢傾東南，其西北之高不過一度。邵雍謂“水火土石合而為地”，今所謂“徑二十四度”者，乃土石之體爾。土石之外，水接於天，皆為地體。地之徑亦得一百二十一度四分度之三也。兩極：南北上下樞是也。北高而南下，自地上觀之，“北極”出地上三十五度有餘，“南極”入地下亦三十五度有餘。兩極之中，皆去九十一度三分度之一，謂之“赤道”，横絡天腹，以紀二十八宿相距之度。大抵兩極正居南北之中，是為天心，中氣存焉。其動有常，不疾不徐晝夜循環①，斡旋天運，自東而西，分為四時，寒暑所以立，陰陽所以和，此後天之太極也。先天之太極，造天地於無形；後天之太極，運天地於有形。三才妙用盡在是矣。

“日”：太陽之精，主生養恩德，人君之象也。人君有道則日五色，失道則日露其慝，譴告人主而儆戒之。如史志所載“日有食之”“日中烏見”“日中黑子”“日色赤”“日無光”或“變為孛星，夜見中天，光芒四溢”之類是也。日體徑一度半，自西而東，一日行一度，一歲一周天，所行之路謂之“黄道”，與赤道相交，半出赤道外，半入赤道内。冬至之日，黄道出赤道外二十四度，去極最遠，日出辰，日入申，故時寒，晝短而夜長。夏至之日，黄道入赤道内二十四度，去北極最近，日出寅，日入戌，故時暑，晝長而夜短。春分、秋分，黄道與赤道相交當兩極之中，日出卯，日入酉，故時和晝夜均焉。

①此为自造字，斡旋，据后文，或亦为“斡旋”。

“月”：太陰之精，主刑罰、威權，大臣之象。大臣有德，能盡輔相之道，則月行□②度。或大臣擅權，貴戚宦官用事，則月露其慝而變異生焉。如史志所載“月有食之”，“月掩五星”，“五星入月”，“月光晝見”，或“變為彗星陵犯紫宮、侵掃列舍”之類是也。月體徑一度半，一日行十三度百分度之三十七，二十七日有餘一周天，所行之路謂之“白道”，與黄道相交，半出黄道，外半入黄道内，出入不過六度，如黄道出入赤道二十四度也。陽精猶火，陰精猶水，火則有光，水則會影。故月光生於日之所照，魄生於日之所不照，當日則光明，就日則光盡。與日同度謂之“朔” 月行潛於日下於日會也 邇一遐三謂之“弦” 分天體為四分，謂初八日及二十三日，月行近日一分謂之邇一，遠日三分謂之遐三。邇日一分受光之半，故半明半魄如弓長弦，上弦昏見，故光在西；下弦 旦見，故光在東也。

衡分天中謂之望 謂十五日之昏，日入西，月出東，東西相望，光滿而魄死也 光盡體伏謂之晦 謂三十日月行近於日光體皆不见也 月行於白道，與黄道正交之處在朔，則日食，在望則月食。日食者，月體掩日光也，月食者，月入暗虛不受日光也 暗虛者，日正對照處。

“經星”：三垣、二十八舍中外官星是也。計二百八十三官，一千五百六十五星，其星不動。三垣：紫微、太微、天市垣也。二十八舍：東方七宿，角亢氐房心尾箕，為蒼龍之體；北方七宿，斗牛女虛危室壁，為靈龜之體；西方七宿，奎婁胃昴畢觜參，為白虎之體；南方七宿，井鬼柳星張翼軫，為朱雀之體。中外官星：在朝象官，如三台，諸侯，九卿，騎官，羽林之類是也。在野象物，如雞狗狼魚龜鱉之類是也。在人象事，如離宮、閣道、華蓋、五車之類是也。其餘因義制名，觀其名，則可知其義也。經星皆守常位，隨天運轉，譬如百官萬民各守其職業，而聽命於七政。七政之行，至其所居之次，或有進退不常、變異失序，則災祥之應，如影響然，可占而知也。

“緯星”：五行之精，木曰歲星，火曰熒惑，土曰填星，金曰太白，水曰辰星，併日月而言謂之七政，皆麗于天。天行速，七政行遲，遲为速所帶，故與天俱東出西入也。五星輔佐日月斡旋，五氣如六官分職而治，號令天下，利害安危由斯而出。至治之世，人事有常，則各守其常度而行。其或君侵臣職，臣專君權，政令錯繆，風教陵遲，乖氣所感，則變化多端，非復常理。如史志所載“熒惑入於瓜瓠，一夕不見”，瓠瓜在黄道北三十餘度，或勾已而行，光芒震曜如五斗器。“太白忽犯狼星”，狼星在黄道南四十餘度，或晝見，經天與日爭明，甚者變為妖星。“歲星之精變為攙搶”“熒惑之精變為蚩尤之旗”“填星之精變為天賊”“太白之精變為天狗”“辰星之精變為枉矢”之類。如日之精變為孛，月之精變為彗，政教失於此，變異見於彼，故為政者尤謹候焉。

“天漢”：四瀆之精也。起於鶉火，經西方之宿而過北方，至於箕尾而入地下。二十四氣：本一氣也。以一歲言之，則一氣耳；以四時言之，則一氣分為四氣；以十二月言之，則一氣分為六氣。故六陰、六陽為十二氣。又於六陰、六陽之中，每一氣分為初、終，則又裂為二十四氣。二十四氣之中，每一氣有三應，故又分而為三候，是為七十二候。原其本始，實一氣耳。自一而為四，自四而為十二，自十二為二十四，自二十四為七十二，皆一氣之節也。

“十二辰”：乃十二月斗綱所指之地。斗綱所指之辰，即一月元氣所在。正月指寅，二月指卯，三月指辰，四月指已，五月指午，六月指未，七月指申，八月指酉，九月指戌，十月指亥，十一月指子，十二月指丑，謂之月建。天之元氣無形可見，觀斗綱所建之辰即可知矣。斗有七星，第一星曰魁，第五星曰衡，第七星曰杓，此三星謂之“斗綱”。假如建寅之月，昏則杓指寅，夜半衡指寅，平旦魁指寅，他月倣此。

“十二次”：乃日月所會之處。凡日月一歲十二會，故有十二次。建子之月，次名元枵；建丑之月，次名星紀；建寅之月，次名析木；建卯之月，次名大火；建辰之月，次名壽星；建已之月，次名鶉尾；建午之月，次名鶉火；建未之月；次名鶉首；建申之月，次名實沈；建酉之月，次名大梁；建戌之月，次名降婁；建亥之月，次名陬訾。

“十二分野”：即辰次所臨之地也。在天為十二辰、十二次，在地為十二國、十二州。凡日月之交食，星辰之變異，所臨分野，占之或吉或凶，各有當之者矣。

②此处字迹漫灭不辨。度其文意，或为“其”，或为“常”，供参考。

过洋牵星术

Star-guided Ocean Crossing Technique

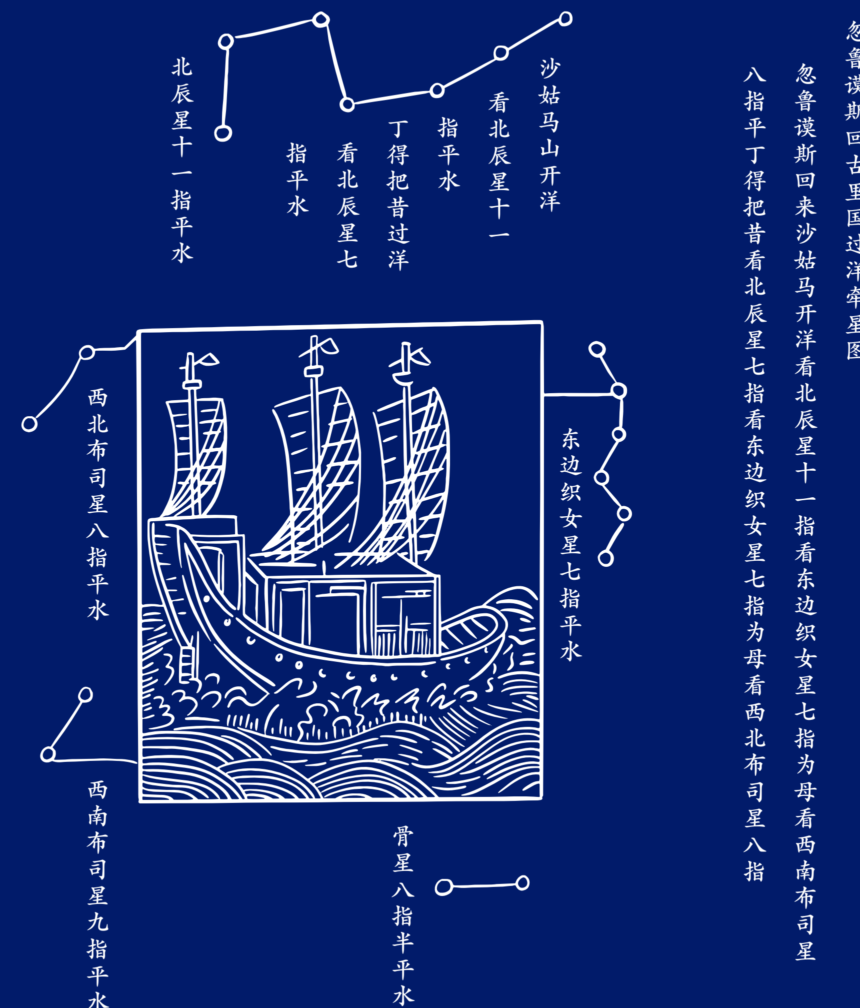
中国人早在 2 000 多年前的秦汉时期就开始了航海活动，也掌握了观星辨向、确定位置的天文方法。过洋牵星术是通过观测北极星等星辰的海平面高度角，来确定船舶纬度和地理位置的航海技术。在深海中，茫茫大海，无所凭依，只能以观测星象来确定航位。

明朝初年，郑和下西洋时就运用了过洋牵星术，其主要就是依据“惟观日月升坠，以辨东西，星斗高低，度量远近”的方法，指导船队航行。牵星术的工具叫牵星板，一共 12 块正方形木板，最大的一块木板的边长约 24 厘米，以下每块木板的边长递减 2 厘米，最小的一块边长约 2 厘米，用一根细线穿于牵星板的中心。用牵星板观测北极星，左手拿木板一端，手臂伸直，右手紧拉细线，贴近眼睛，眼看天空，用一块尺寸合适的牵星板，使得木板上缘对准北极星，下缘对准海平面，这样就可以测出所在地的北极星高度。计算单位为“指”与“角”，“一指”等于“四角”，“一指”相当于天体高度的 1.9°。测出北极星高度后，就得到所在地的地理纬度，亦可通过其他恒星或太阳中天高度算地理纬度，结合航向和航速还可以进行航迹推算。

As early as 2,000 years ago during the Qin and Han Dynasties, the Chinese began a few sailing activities and mastered the astronomical method of distinguishing direction and position by observing stars. Star-guided ocean crossing technique is the art of navigation that determines the vessel's latitude and geographic position by observing the altitude of stars such as Polaris. When sailing at deep ocean, vast sea, where there is nothing to rely on, only by celestial bodies can you determine the location.

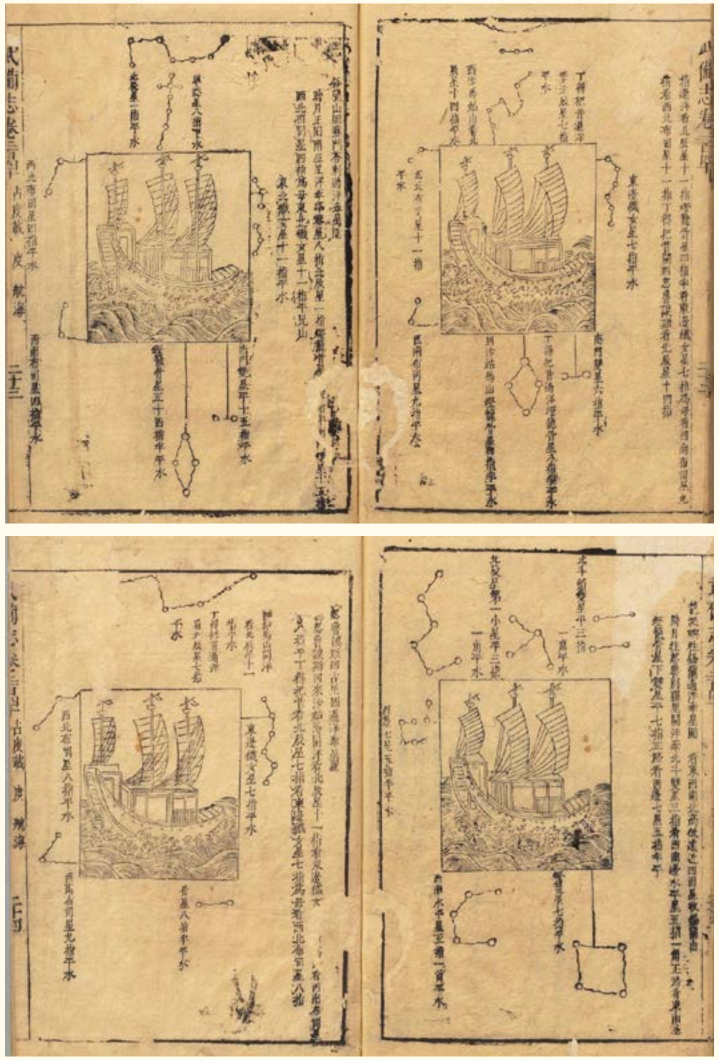
In the early Ming Dynasty, Zheng He employed the star-guided ocean crossing technique in his voyages to the west ocean on the basis of "determining the east and west by the rise and set of the sun and the moon, judging near and far by the rise and fall of the stars". The tool of this technique is called Chinese latitude hook which is a set of 12 square wooden cards. The side of the largest card is about 24 centimeters long with the remaining pieces decreasing 2 centimeters one by one in size, and thus the side of the smallest one is about 2 centimeters long. A string is attached

through a hole in the middle of the card. When using the latitude hook, pull one end of the string tight in the right hand towards the eye while hold the other end in the left hand away from the body until the arm is straight. If the card is the right size, the lower edge of the card will be even with the horizon and the upper edge be occluding Polaris, then the elevation of Polaris can be indicated. The units are "zhi" (finger) and "jiao" (quarter). One "zhi" is equal to four "jiaos", which is about 1.9°. Latitude can be obtained by measuring the altitude of Polaris, the Midday Sun or other stars. The dead reckoning can also be plotted in a combination of the latitude,the heading and speed.



摹过洋牵星图（局部）

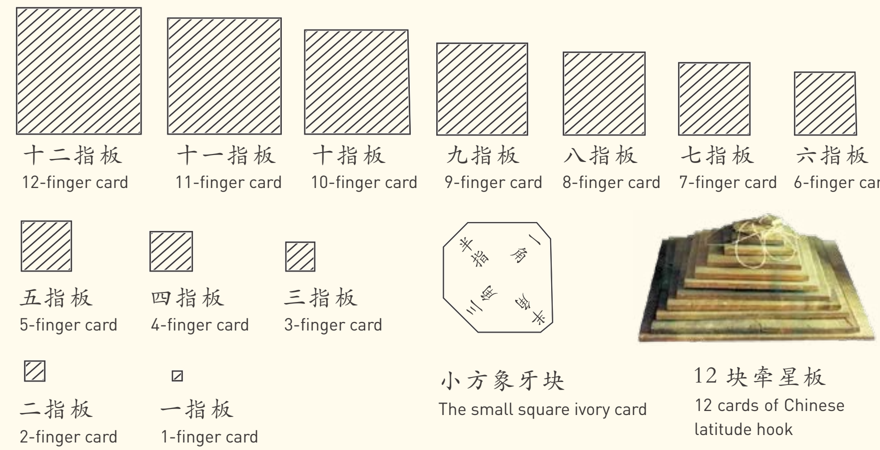
A copy of a star-guided ocean crossing map (part)



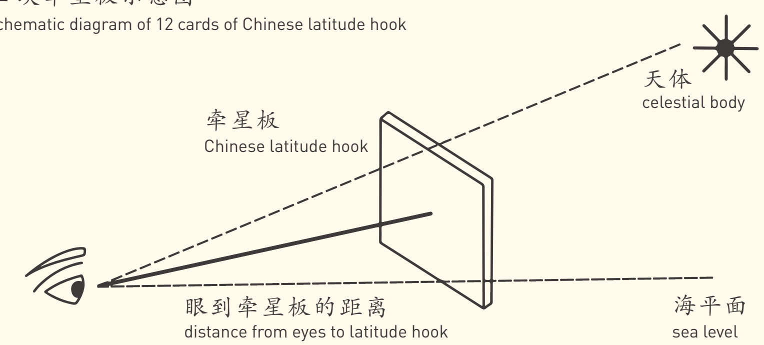
《郑和航海图》中的牵星图
A star-guided ocean crossing map in *Zheng He's Nautical Chart*

收录在明代茅元仪《武备志》的《郑和航海图》中的 4 幅牵星图，它们记下了航船过某地时所测得的某些天体的角高度（“指”数）。

这 4 幅过洋牵星图记录了郑和航海运用天文定位技术，是我国最完备、最精确的航海天文导航原始记录。



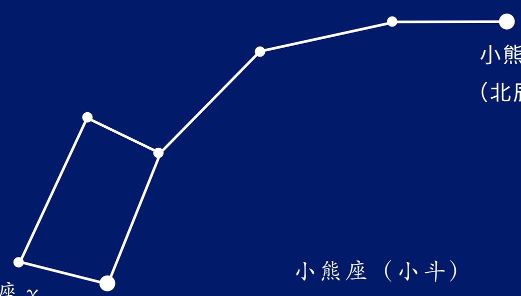
12 块牵星板示意图
Schematic diagram of 12 cards of Chinese latitude hook



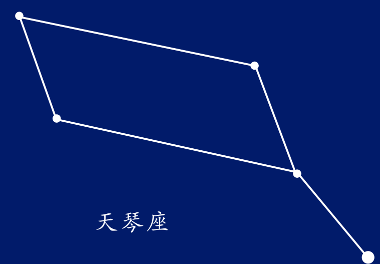
牵星板测天体高度示意图
Schematic diagram of Chinese latitude hook measuring the height of a celestial body

明代李翊撰写的《戒庵老人漫笔》中记载：“苏州马怀德牵星板一副，十二片，乌木为之，自小渐大，大者长七寸余，标为一指、二指以至十二指，俱有细刻，若分寸然。又有象牙一块，长二寸，四角皆缺，上有半指、半角、一角、三角等字，颠倒相向，盖周髀算尺也。”根据这一记载，可知一副牵星板有 12 块乌木方板，另有一块小的象牙板。

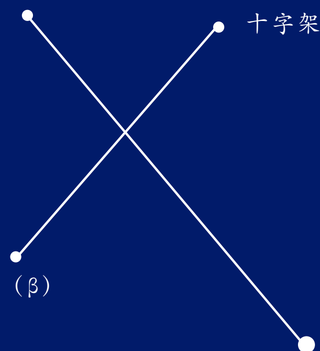
牵星板除了有 12 块木板，还有由象牙制成的一个小方块。这个小方块的形状十分奇怪——它的四角全部都缺刻掉了，而缺刻四面的长度又分别是上面描述的 12 块木板中最小的那块边长的 1/8、1/4、1/2 和 3/4；上面标有半角、一角、二角（半指）、三角。



小熊座 α
（北辰星）
小熊座（小斗）
小熊座 γ
小熊座 β
（华盖双星）



天琴座
天琴座 α
（织女星）



十字架一（γ）
十字架四（δ）
十字架三（β）
十字架二（α）
南十字座
（灯笼骨星）

牵星术常用的参考星
Commonly used reference stars for star-guided ocean crossing technique

双子座 α
（西北和西南布司星）
双子座 β
双子座

（南门双星）
半人马座 β
半人马座 α
半人马座

牵星术常用的参考星
Commonly used reference stars for star-guided ocean crossing technique

牵星术常用的参考星体有：北辰星（小熊座 α），华盖双星（小熊座 β、γ），灯笼骨星（南十字座 α、β、γ、δ），织女星（天琴座 α），西北和西南布司星（双子座 α、β），南门双星（半人马座 α、β），另外，“小斗”指小熊座，“七星”指昴星团等。

03 测绘篇

GEODESY SECTION

计里画方 甄度四海

GRID MAPPING, LAND SURVEYING

测绘和制图学是导航技术的重要组成部分。中国人在2 000多年前就发明了测量、测绘的各种工具，如准绳、规矩、圭表、罗盘、望筒、指南车、记道车等，逐渐总结出测量、测绘和制图的各种方法，如勾股定理、计里画方、制图六体等，还开展了很多重要的测绘实践，如匠人建国、僧一行测地、绘制大宋疆域《禹迹图》等。这些测绘和制图方面的理论和实践在中国历代王朝社会治理，促进东西方科技文化交流等方面发挥了重要作用。

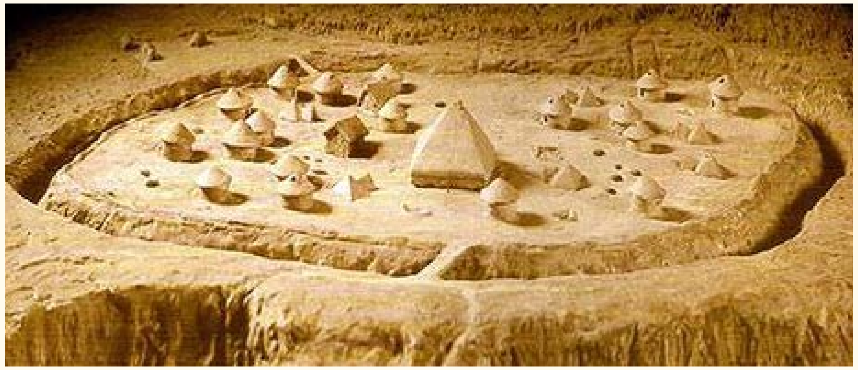
Surveying and mapping are important parts of navigation technology. The Chinese invented various tools of surveying and mapping more than 2,000 years ago, such as the level and ink line, the pencil compass and carpenter's square, the gnomon and ruler, the compass, the sighting tube, the south-pointing carriage, li-recording carriage and so on. Various methods of surveying and mapping had been gradually summed up, such as the right triangle theorem, squared map with grid system and scale, the six principles of cartography. Moreover, many important surveying and mapping practices had been carried out, such as craftsmen constructing the capital, the monk Yixing's geodetic survey, a drawing of *Yuji Tu* map of territories of the Song Dynasty and so on. These theories and practices in surveying and mapping played an important role in the social governance of Chinese dynasties and the exchange of science, technology and culture between the East and the West.

计里画方 甄度四海
GRID MAPPING
LAND SURVEYING

西安半坡遗址
Xi'an Banpo Site

1952 年，考古学家在陕西省西安市半坡村发现了一处原始社会母系氏族公社村落遗址，属新石器时代仰韶文化，距今约六七千年。在这个遗址中，有聚集连片的住宅区，其中有 46 座圆形或方形的房子，门都是朝南开的。由此可以判断，半坡人是能准确地辨别方向的，所用方法或许是观察日月星辰。

In 1952, archaeologists discovered a site of matrilineal clan of primitive society in Banpo Village, Xi'an City, Shaanxi Province, dating back to the Yangshao culture of the Neolithic Period around 6,000 to 7,000 years ago. In this site, there are clusters of residential areas, including 46 round or square houses with doors facing south, from which it can be inferred that Banpo people were able to distinguish directions accurately, probably by observing the sun, the moon and stars.



半坡遗址房屋复原模型
Models of restored Banpo houses

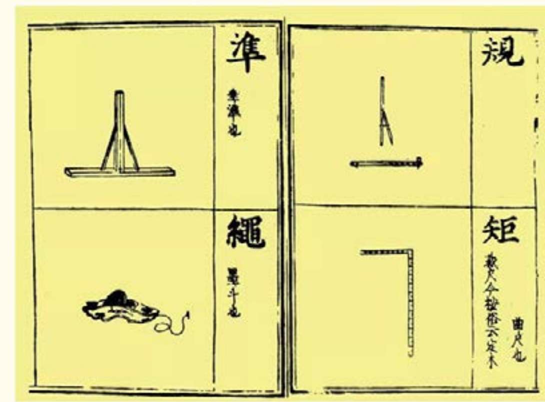
从发掘资料看，半坡人已经能够确定方向，他们的选址、建房、埋葬都朝着一定的方向。比如墓坑和人骨埋葬通常为西偏北 20°左右；而墓地大部分集中在居住区以北。由此可以推测半坡人一定有确定方向的方法，这个过程一定与观察日出日落、实地考察、观察地形、“尝水相土”等地理调查和测量活动有关。

准绳与规矩

Level, Ink Line, Pencil Compass, Carpenter' s Square

欲知平直，则必准绳；欲知方圆，则必规矩。《史记·夏本纪》中记载大禹治水“左准绳，右规矩”。“准”是古代用的水准器，是用来测量水平度的工具，这在《汉书》上就有记载；“绳”是一种测量长度、引画直线和测定垂直度的工具。“规”是画圆形的工具；“矩”是古代画方形和测直角的用具，也就是曲尺。《汉书·律历志》中记载：“权与物钧而生衡，衡运生规，规圆生矩，矩方生绳，绳直生准，准正则平衡而钧权矣。是为五则。”这也就是说，“权、衡、规、矩、绳、准”是测量权衡事物的基本工具。

If you want to know the flat and straight, you must have the level and ink line. If you want to know the circle and square, you must have the pencil compass and carpenter's square. *Records of the Grand Historian. Annals of Xia Dynasty* recorded Dayu controlled flood with "the level and ink line in the left hand, pencil compass and carpenter's square in the right hand". A "level" is a tool used to measure true horizontal, which was recorded in *Book of Han*. An "ink line" is a tool used to measure distance, draw straight line and find true vertical. A "pencil compass" is a tool used to inscribe circle or arc. A "carpenter's square" is a tool used to lay out square structure and measure right angle, that is to say a framing square. *Book of Han. Musical Temperament and Calendar* recorded that "The balance is generated when the weight and the object are even. The operation of the balance generates the pencil compass. The circle drawn by the pencil compass generates the carpenter's square. The square drawn by the carpenter's square generates the ink line. The straight line drawn by the ink line generates the level. The accurate level in turn generates the balance of the weight and the object. These are the five laws". In other words, "weight, balance, pencil compass, carpenter's square, ink line and level" are the basic requirements for measuring and weighing things.



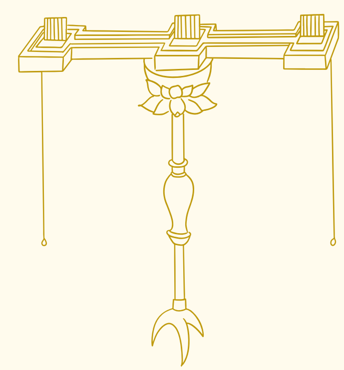
明《三才图会》中绘制的准绳规矩

The level, ink line, pencil compass and carpenter's square from *Collected Illustrations of the Three Realms* of the Ming Dynasty

伏羲氏手持矩
女娲氏手持规

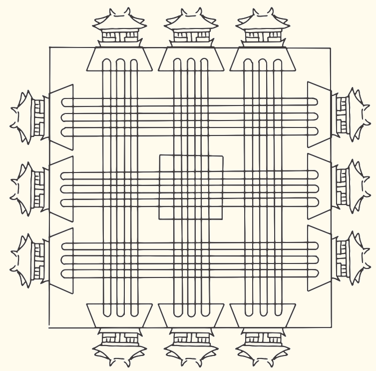
Fuxi holds the carpenter's square.
Nüwa holds the pencil compass

唐代佚名作者所画《伏羲女娲图》，1965年出土于新疆阿斯塔那，现藏于新疆维吾尔自治区博物馆。



《钦定四库全书》中的水平仪

The level in *Complete Books of the Four Imperial Repositories*



北宋聂崇义绘《考工记》“王城图”
"The capital city" in *Artificers' Record* drawn by Nie Chongyi of the Northern Song Dynasty

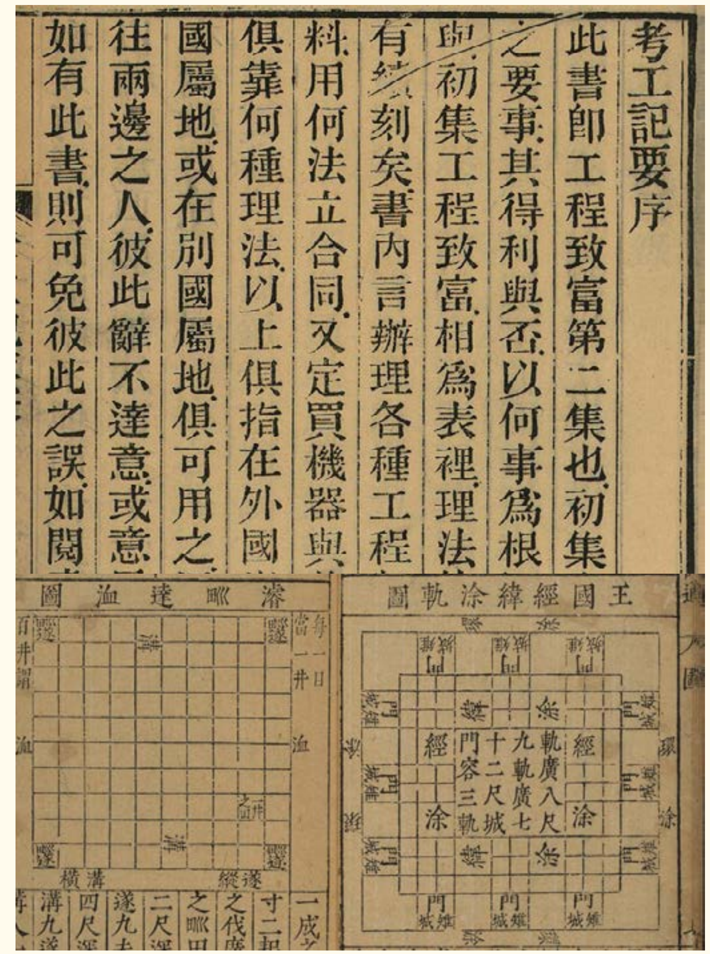
匠人建国
Craftsmen Constructing the Capital

成书于春秋战国时期的《周礼·考工记》记述了关于周代王城建设的空间布局，以及建设城邑求水平定方位的测量问题，提出了利用水准及晷影找水平、定方位的方法。

书中记载：“匠人建国，水地以县，置槷以县，眡以景，为规，识日出之景与日入之景，昼参诸日中之景，夜考之极星，以正朝夕。匠人营国，方九里，旁三门。国中九经九纬，经涂九轨，左祖右社，面朝后市，市朝一夫。”意思是：匠人们营造都城的时候，悬水准以找地平，悬准绳以置标杆，观察其影子，是为日晷，标记日出和日落时的影子（确定东西方位），白天参考正午日影，夜晚观察北极星（确定南北方位），以确定四大方位。匠人在营建都城的时候，九里见方，每边辟三门，纵横各九条街道，分别容纳九条车轨，东面为宗庙，西面为社稷坛，前面是朝廷，后面是市集，朝廷宫室和市集各占地一百步见方。

Rites of Zhou. Artificers' Record written in the Spring and Autumn Period and the Warring States Period, described the spatial layout of the capital city of the Zhou Dynasty, as well as the questions of measuring the horizontality and the direction when constructing the capital. It also put forward the methods of using the level and sundial shadow to determine the horizontality and the direction.

It recorded that "When craftsmen construct the capital city, they use the level to ensure the levelness of the land. They raise the pole to make a sundial to correct the east and west directions by observing the pole shadow at sunrise, sunset, and midday. They correct the north and south directions by observing Polaris at night. When craftsmen construct the capital city, they square the city with nine li (Chinese unit of distance) in length and three gates on each side. There are nine vertical and nine horizontal roads in the city, all of which have nine carriageways. The temple is on the east and the altar is on the west. The imperial palace is at the front and the market is at the back, both of which cover one hundred mu (Chinese unit of land measurement)".



考工記要序
此書即工程致富第二集也初集
之要事其得利與否以何事爲根
由初集工程致富相爲表裡理法
有續刻矣書內言辦理各種工程
料用何法立合同又定買機器與
俱葉何種理法以上俱指在外國
國屬地或在別國屬地俱可用之
往兩邊之人彼此辭不達意或意
如有此書則可免彼此之誤如閱

明、清版本的《周礼·考工记》部分图文
Some images in *Rites of Zhou. Artificers' Record* from a copy of the Ming and Qing Dynasties

勾股定理

Shang Gao Theorem (Right Triangle Theorem)

勾股定理也叫商高定理或毕达哥拉斯定理。成书于公元前 1 世纪的《周髀算经》中记载了公元前 11 世纪的西周初年，数学家商高提出了“勾三股四弦五”的勾股定理及其在大地测量和天文上的应用。

《周髀算经》的开头，记载着一段周公向商高请教数学知识的对话。周公问：“我听说您对数学非常精通，我想请教一下：天那么高，没有一把梯子可以上去，地那么广，也没有一把尺子可以丈量，那么怎样才能得到关于天地的数据呢？”商高回答说：“数的产生来源于对方和圆这些形状的认识。其中有一条原理：当直角三角形的一条直角边‘勾’等于 3，另一条直角边‘股’等于 4 的时候，那么它的斜边‘弦’就必定是 5。这个原理是大禹在治水的时候就总结出来的啊。”《周髀算经》还记载了周公后人陈子对勾股定理的应用：“若求邪至日者，以日下为勾，日高为股，勾股各自乘，并而开方除之，得邪至日”。

The right triangle theorem is also called Shang Gao theorem or Pythagorean theorem. "Arithmetical Classic of the Gnomon and the Circular Paths of Heaven" (*Zhoubi Suanjing*) written in the 1st century B.C. recorded that as early as the 11th century B.C. in the early Western Zhou Dynasty, mathematician Shang Gao put forward the right triangle theorem for the case of the 3-4-5 triangle and its application in geodesy and astronomy.

In the beginning of *Zhoubi Suanjing*, a dialogue between the Duke of Zhou and Shang Gao about mathematical knowledge was recorded. The Duke of Zhou asked: "I heard that you are very proficient in mathematics. I would like to ask: the sky is so high that there is no ladder to go up and the earth is so wide that there is no ruler to measure, then how can we get the data about the sky and the earth?" Shang Gao replied: "The generation of numbers comes from the understanding of the shapes like square and circle. One of these principles is that when the length of the perpendicular is 3 and the length of the base is 4, then the length of its hypotenuse must be 5. This principle was summed up by Da Yu when he was controlling the flood." *Zhoubi Suanjing* also recorded the application of the right triangle theorem by Chenzi, the descendant of the Duke of Zhou: "In order to calculate the hypotenuse from right triangle sides, first take the sum of the squares of the lengths of the two legs, next take the square root of the sum, and this root is the length of the hypotenuse."

宋版本的《周髀算经》

Arithmetical Classic of the Gnomon and the Circular Paths of Heaven (Zhoubi Suanjing) from a Song Dynasty copy

马王堆汉墓古地图
Ancient Maps of Mawangdui Han Dynasty Tombs

中国绘制地图有悠久的历史。早在先秦时期的《周礼》《管子》等古籍中，就有关于地图的记载，不过那时的地图都已失传了。1973 年湖南长沙马王堆三号汉墓（下葬于汉文帝十二年，即公元前 168 年）出土了 3 幅绘在帛上的古地图，分别是《地形图》《驻军图》和《城邑图》。这是世界上现存最古老的以实测为基础绘制的地图，距今约 2 200 年，反映了秦汉时期中国高超的制图技术。这 3 幅图所示的方位都是上南下北、左东右西，与现在通用的地图正好相反。经故宫博物院等有关单位考证鉴定和修复的有 2 幅，即《地形图》和《驻军图》。

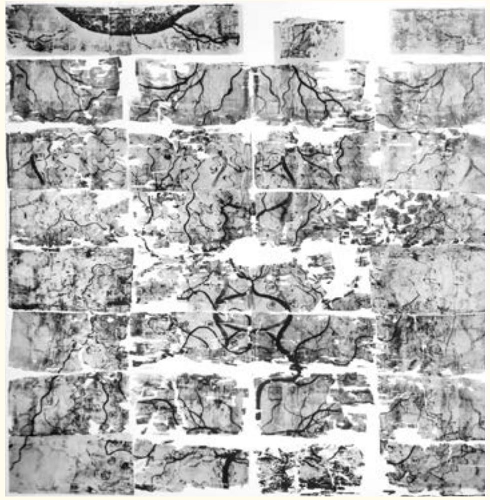
其中《西汉初期长沙国深平防区图》，又名《地形图》，长宽各 96 厘米，为正方形地图。现代地形图上的四大基本要素，即水系、山脉、道路和居民点，图上都有比较详细的表示。

《驻军图》是世界上现存最早的彩色军事地图，长 98 厘米，宽 78 厘米，是用红、黑、田青 3 种颜色绘成的守备地图。此图突出军事内容，以山川作衬托，置于第二平面。此图用黑底套红勾框，着重表示 9 支驻军的驻地及其指挥中心。此图用红线沿四周山脊绘出防区界线，防区界上标注了边塞烽燧点。

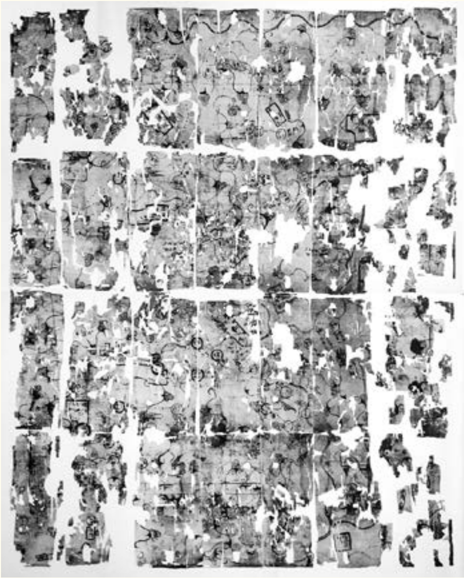
The history of cartography in China is very long. There are records of maps in ancient books such as *Rites of Zhou* and *Guanzi* in the pre-Qin period, but maps at that time have been lost. In 1973, three ancient maps drawn on silk were unearthed in Tomb 3 of Mawangdui Han Dynasty Tombs in Changsha City, Hunan Province (buried in the 12th year of Emperor Wen of the Han Dynasty, i.e., 168 B.C.). They are *Topographic Map*, *Military Map* and *Prefecture Map*. Dating back to about 2,200 years ago, they are the world's oldest extant maps based on actual measurement and they reflect the superb Chinese cartographic techniques during the Qin and Han Dynasties. The orientation of the cardinal directions displayed on these maps is south at the top, north at the bottom, east to the left and west to the right, contrary to conventional maps today. Two of the maps—*Topographic Map* and *Military Map* have been verified and restored by the Palace Museum and other relevant institutions.

The Deep and Flat Defense Zone Map of Changsha State in the Early Western Han Dynasty, also known as *Topographic Map*, is a square map whose each side measures 96 cm. The four basic elements of the modern topographic map, namely river, mountain, road and residential area, are all displayed on the map in detail.

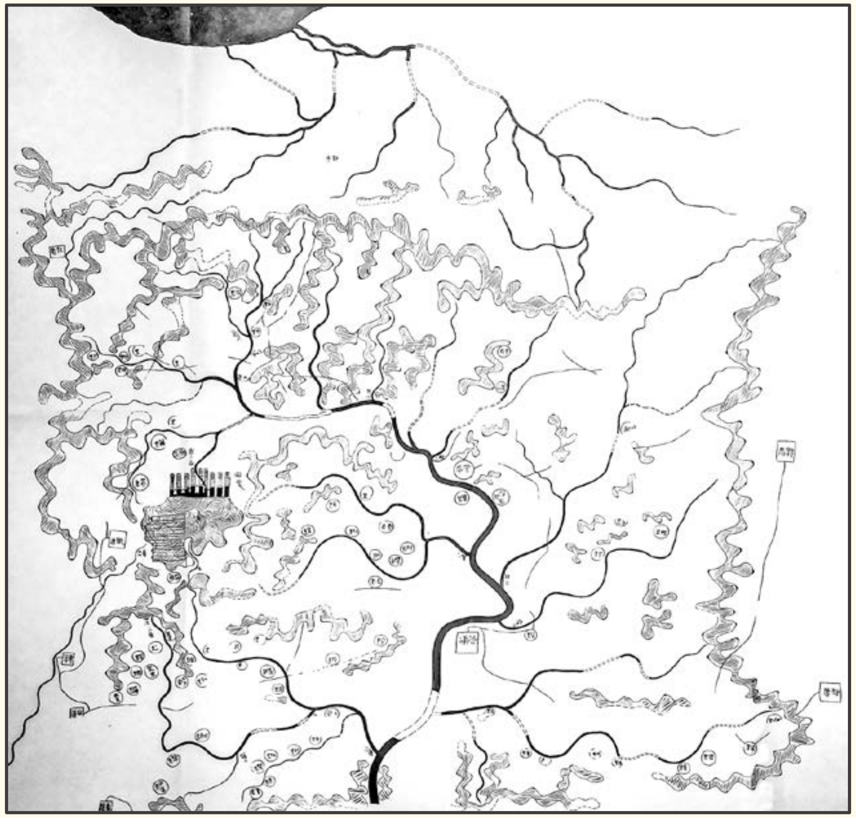
Military Map is the world's earliest extant color-coded military map. Being 98 cm long and 78 cm wide, it is a garrison map drawn in three colors — red, black and cyan. The map highlights military contents, with mountains and rivers as foils placed on the second plane. A red outline with black background is adopted to highlight the nine garrison locations and their command centers. The boundary of the defense zone is drawn in red along the surrounding ridges on which the beacon towers are indicated.



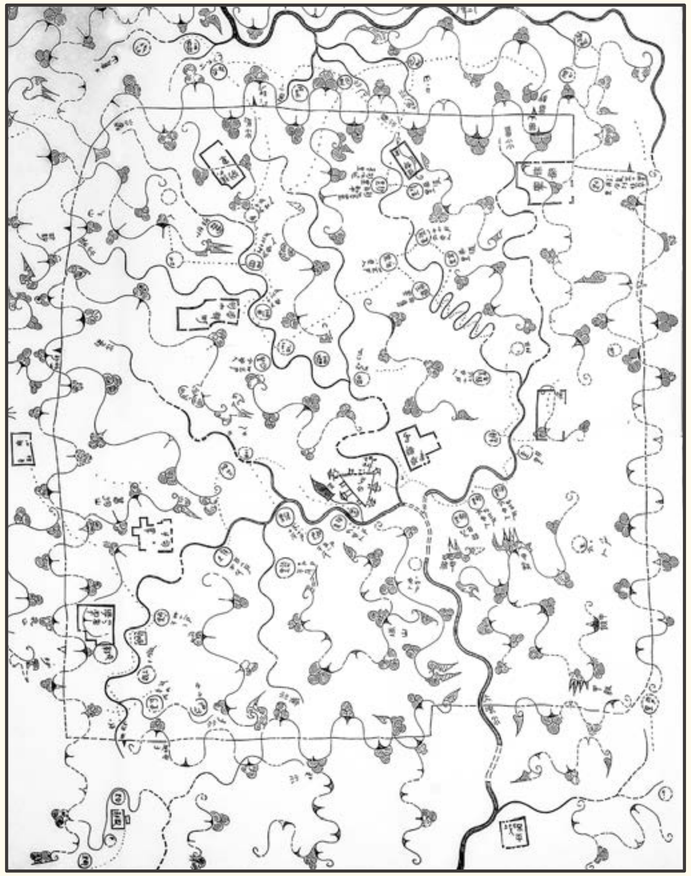
马王堆三号汉墓
出土的《地形图》
Topographic Map unearthed in Tomb 3 of Mawangdui Han Dynasty Tombs



马王堆三号汉墓
出土的《驻军图》
Military Map unearthed in Tomb 3 of Mawangdui Han Dynasty Tombs



《地形图》复原图
Restored *Topographic Map*



《驻军图》复原图
Restored *Military Map*

《地形图》的所绘范围相当于今湖南省南部、广西壮族自治区东北部、广东省北部，即湘江上游第一大支流潇水流域、南岭及九嶷山邻近地区。

据考订，该图所绘主区为西汉诸侯国之一的长沙国南部。地图用粗细变化均匀的线条表示河流，有的在河口处标注了名称；用闭合曲线加绘晕线表示山脉走向，将复杂的地形脉络简单、清楚地表现出来，内用鱼鳞状图形表示九嶷山一带峰峦起伏的特征。图中除了山脉、河流，还有居民点，县级居民点用矩形符号表示，乡里用圆圈符号表示，大小不等。地名写在矩形或圆圈符号之内。

《驻军图》是一幅表现西汉初期长沙国南部边防形势的军事图。全图用黑、红、田青三色详细地描绘了长沙国南部的山脉、河流、居民点、道路、城堡及军事布防等。

用颜色来区分不同的地理要素是《驻军图》的特色，图中用黑色"山"字形符号表示山脉，用青色绘制河流且显示了河流的宽窄，用黑色单线表示山脉走向，用红色曲线表示道路，用红色三角形表示城堡，用红色线条表示疆界，用黑色圆圈表示居民点，用黑色和红色勾框表示驻军和基地。另外，图中的居民点除标注了地名以外，还旁注了户数及迁并情况。

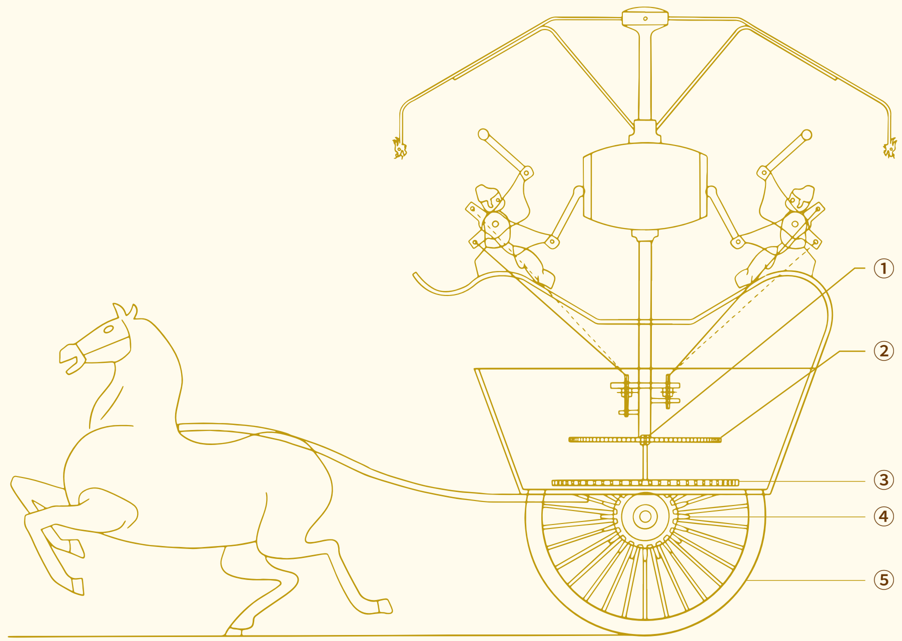
记里鼓车

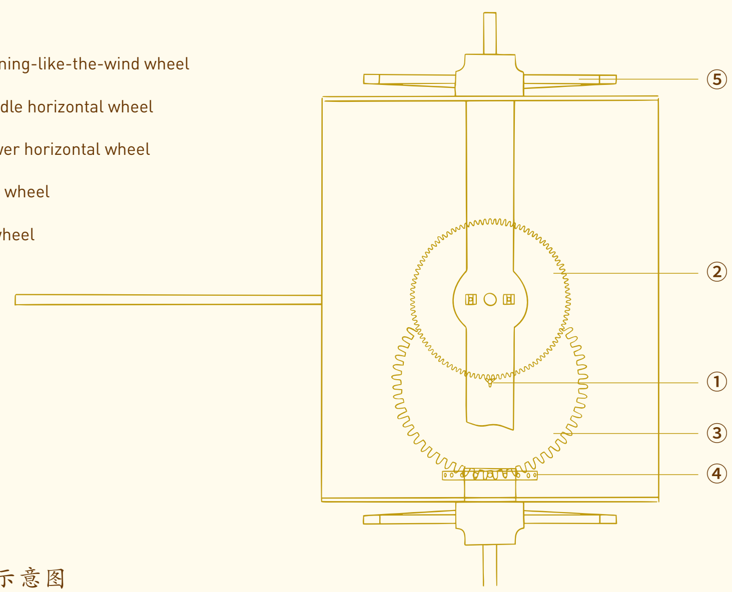
Li-recording Drum Carriage（Odometer Cart）

记里鼓车是中国古代用于计算车辆行驶里程的车，由“记道车”发展而来，其原理是利用齿轮差动关系计算道路里程。有关记道车的文字记载最早见于汉代刘歆（前 50—23）的《西京杂记》，可见至迟在西汉时期，即已有了这种可以计算道路里程的车。《晋书·舆服志》中记载：“记里鼓车，驾四。形制如司南。其中有木人执槌向鼓，行一里则打一槌。”

A li-recording drum carriage is an odometer cart used in ancient China for calculating the mileage. It is developed from the "li-recording carriage". Its principle is to calculate the mileage by means of differential gears. The earliest written records about the li-recording carriage were found in *Miscellaneous Records of the Western Capital* by Liu Xin of the Han Dynasty (50 B.C.–23 A.D.). It is thus evident that there had been carts that could be used to calculate the mileage by the Western Han Dynasty. *The Book of Jin. Carriage and Costume* recorded: "Li-recording drum carriage, which is drawn by four horses, takes a similar style to the south-pointing carriage. A carved wooden figure inside holds a drumstick. At the completion of every li, the wooden man strikes a drum."

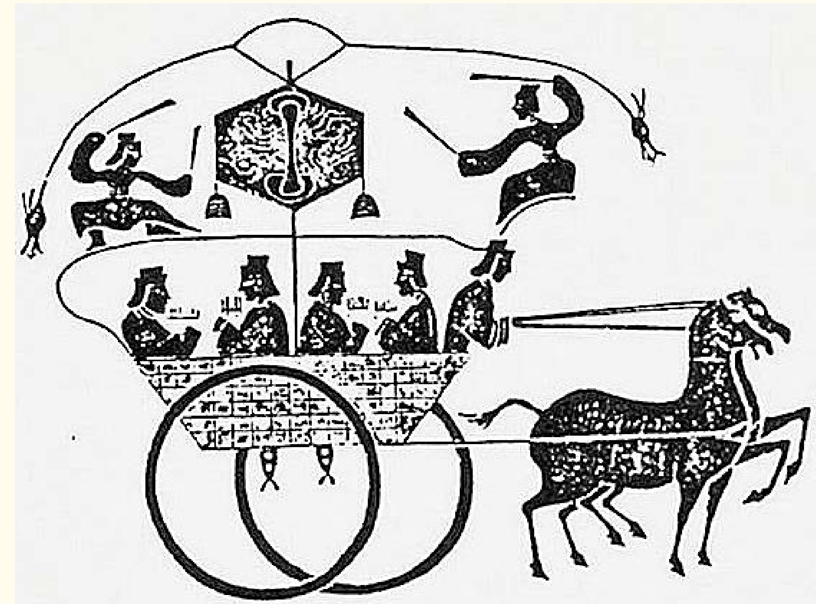
记里鼓车
Li-recording drum carriage



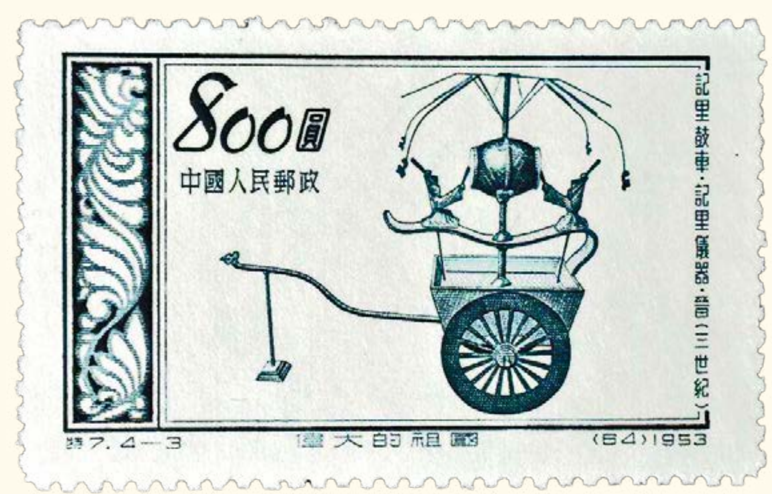


① 旋风轮 Turning-like-the-wind wheel
② 中平轮 Middle horizontal wheel
③ 下平轮 Lower horizontal wheel
④ 立轮 Vehicle wheel
⑤ 车轮 Road wheel

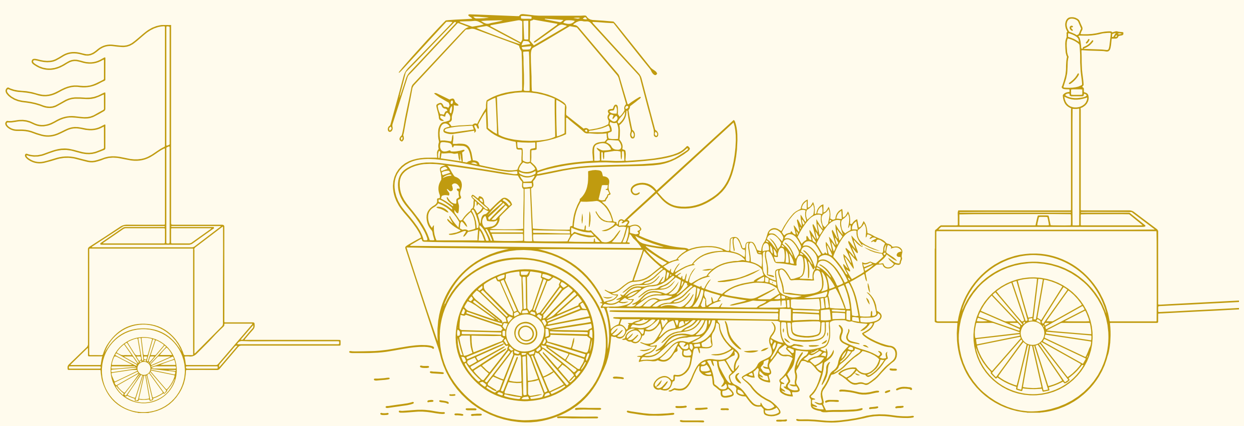
记里鼓车结构示意图
Schematic diagram of li-recording drum carriage



山东孝堂山画像石墓中出土的有记里鼓车的画像石
Stone relief of a "li-recording drum carriage" on an ancient tomb unearthed from Mount Xiaotang in Shandong Province



1953 年发行的印有记里鼓车的邮票
A stamp of "li-recording drum carriage" issued in 1953



记里鼓车复原模型
Model of a restored li-recording drum carriage

记里鼓车，一名大章车。赤质，四面画花鸟，重台，勾阑，镂拱。行一里，则上层木人击鼓；十里，则次层木人击镯。一辕，凤首，驾四马。驾士旧十八人，太宗雍熙四年，增为三十人。

仁宗天圣五年，内侍卢道隆上记里鼓车之制："独辕双轮，箱上为两重，各刻木为人，执木槌。足轮各径六尺，围一丈八尺。足轮一周，而行地三步。以古法六尺为步，三百步为里，用较今法五尺为步，三百六十步为里。立轮一，附于左足，径一尺三寸八分，围四尺一寸四分，出齿十八，齿间相去二寸三分。下平轮一，其径四尺一寸四分，围一丈二尺四寸二分，出齿五十四，齿间相去与附立轮同。立贯心轴一，其上设铜旋风轮一，出齿三，齿间相去一寸二分。中立平轮一，其径四尺，围一丈二尺，出齿百，齿间相去与旋风等。次安小平轮一，其径三寸少半寸，围一尺，出齿十，齿间相去一寸半。上平轮一，其径三尺少半尺，围一丈，出齿百，齿间相去与小平轮同。其中平轮转一周，车行一里，下一层木人击鼓；上平轮转一周，车行十里，上一层木人击镯。凡用大小轮八，合二百八十五齿，递相钩锁，犬牙相制，周而复始。"诏以其法下有司制之。

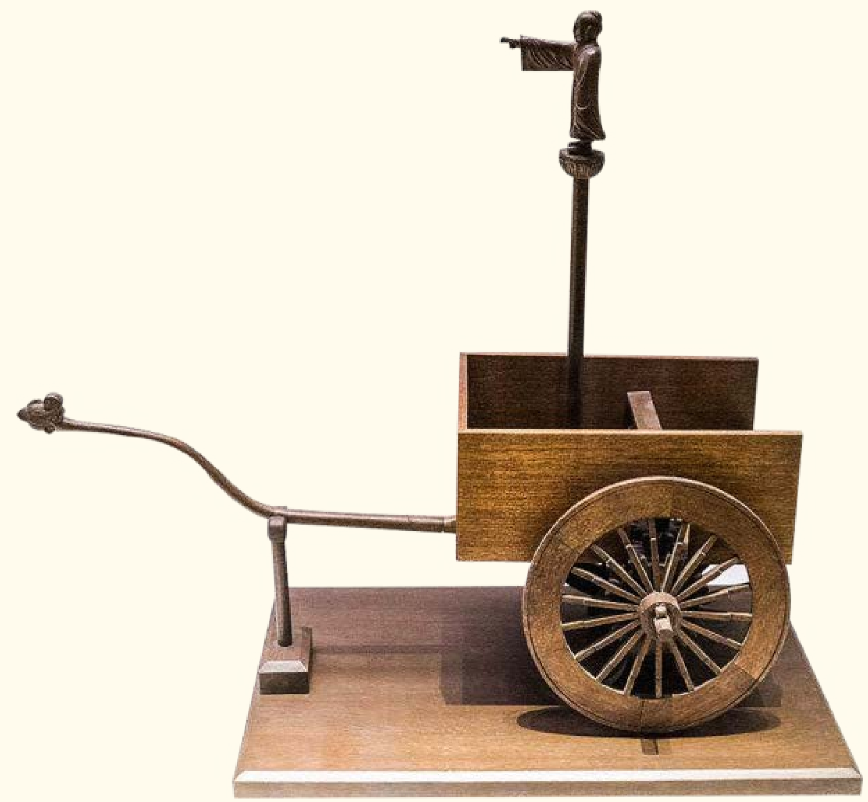
大观之制，车箱上下为两层，上安木人二，身各手执木槌。轮轴共四。内左壁车脚上立轮一，安在车箱内，径二尺二寸五分，围六尺七寸五分，二十齿，齿间相去三寸三分五厘。又平轮一，径四尺六寸五分，围一丈三尺九寸五分，出齿六十，齿间相去二寸四分。上大平轮一，通轴贯上，径三尺八寸，围一丈一尺，出齿一百，齿间相去一寸二分。立轴一，径二寸二分，围六寸六分，出齿三，齿间相去二寸二分。外大平轮轴上有铁拨子二。又木横轴上关戾、拨子各一。其车脚转一百遭，通轮轴转周，木人各一击钲、鼓。

——《宋史·舆服志》

指南车
South-pointing Carriage

指南车是中国古代利用机械传动系统来指示方向的一种车辆，不论车轮转向何方，车上木人的手始终指向指南车出发时木人的指向。指南车起源很早，相传，黄帝与蚩尤战于涿鹿之野时就制作了指南车。魏青龙三年（235），马钧制造了指南车，其采用的是齿轮传动系统和自动离合装置。

A south-pointing carriage is an ancient Chinese vehicle that uses a geared mechanism to indicate direction. No matter how the carriage turns, the wooden figure placed at the top is aimed southward by hand at the start of a journey. The origin of the south-pointing carriage was very early. There is a legend of an early south-pointing carriage made by the Yellow Emperor when he engaged in battle with Chiyou in the field of Zhuolu. In the third year of the Qinglong Period (235 A.D.) of the Wei Dynasty, Ma Jun made a south-pointing carriage that employed a geared mechanism and an automatic clutch device.



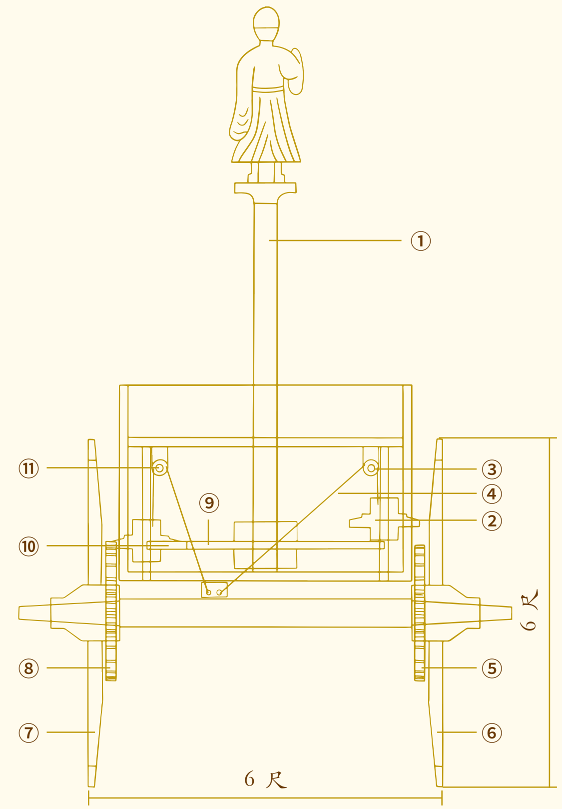
指南车复原模型
Model of a restored south-pointing carriage

中国古代的历史文献资料中记载，指南车起源于黄帝与蚩尤大战于涿鹿之野的故事中。古籍记载中，较为人所接受的说法是三国时代的马钧最早制造了指南车。指南车在历史上屡废屡制，各代指南车的内部结构都有所不同，但元代以后失传。1924 年英国学者穆尔（Moule）发表了研究指南车的论文，并根据《宋史》文献记载给出了指南车的具体复原方案。1937 年王振铎曾发表《指南车记里鼓车之考证及模制》，后改良穆尔的设计，成功复制出指南车模型。

北宋天圣五年（1027），燕肃献指南车。

其法：用独辕车，车箱外笼上有重构，立木仙人于上，引臂南指。用大小轮九，合齿一百二十。足轮二，高六尺，围一丈八尺。附足立子轮二，径二尺四寸，围七尺二寸，出齿各二十四，齿间相去三寸。辕端横木下立小轮二，其径三寸，铁轴贯之。左小平轮一，其径一尺二寸，出齿十二；右小平轮一，其径一尺二寸，出齿十二。中心大平轮一，其径四尺八寸，围一丈四尺四寸，出齿四十八，齿间相去三寸。中立贯心轴一，高八尺，径三寸。上刻木为仙人，其车行，木人指南。若折而东，推辕右旋，附右足子轮顺转十二齿，击右小平轮一匝，触中心大平轮左旋四分之一，转十二齿，车东行，木人交而南指。若折而西，推辕左旋，附左足子轮随轮顺转十二齿，击左小平轮一匝，触中心大平轮右转四分之一，转十二齿，车正西行，木人交而南指。若欲北行，或东，或西，转亦如之。诏以其法下有司制之。

——《宋史·舆服志》



① 贯心轴（高 8 尺径 3 寸）
Vertical shaft piercing the center

② 右小平（齿）轮
Right small horizontal wheel

③ 右小轮
Right small wheel

④ 竹绳
Bamboo cord

⑤ 右附足立子（齿）轮
Right vehicle wheel attached to the road wheel

⑥ 右足（车）轮
Right road wheel

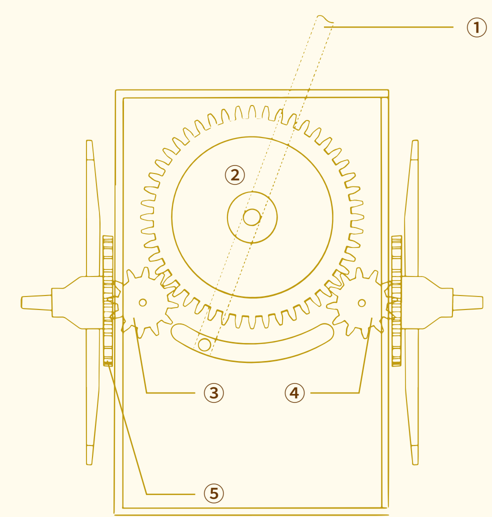
⑦ 左足（车）轮
Left road wheel

⑧ 左附足立子（齿）轮
Left vehicle wheel attached to the road wheel

⑨ 中心大平（齿）轮
Middle large horizontal wheel

⑩ 左小平（齿）轮
Left small horizontal wheel

⑪ 左小轮
Left small wheel



① 转弯状态下的车辕
Vertical shaft when turning

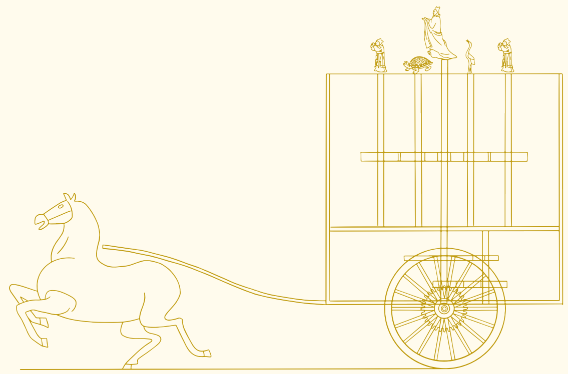
② 中心大平（齿）轮
Middle large horizontal wheel

③ 左小平（齿）轮啮合中
The fall of the left small horizontal wheel

④ 右小平（齿）轮悬空中
The rise of the right small horizontal wheel

⑤ 左附足立子（齿）轮
Left vehicle wheel attached to the road wheel

燕肃指南车结构示意图
Schematic diagram of Yan Su south-pointing carriage

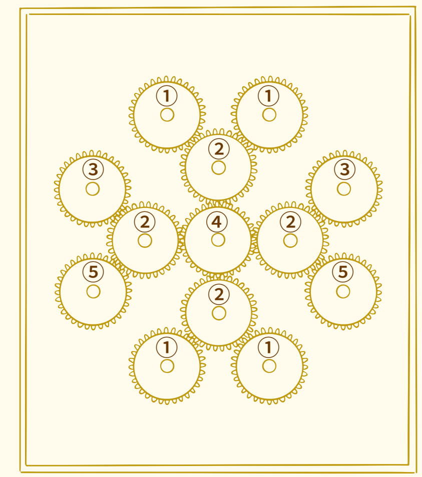


吴德仁指南车示意图
Schematic diagram of Wu Deren south-pointing carriage

北宋大观元年（1107）吴德仁又重新研制了指南车。

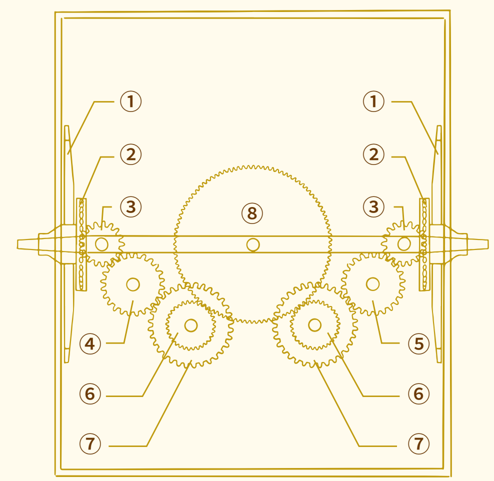
大观元年，内侍省吴德仁又献指南车、记里鼓车之制，二车成，其年宗祀大礼始用之。其指南车身一丈一尺一寸五分，阔九尺五寸，深一丈九寸，车轮直径五尺七寸，车辕一丈五寸。车箱上下为两层，中设屏风，上安仙人一执仗，左右龟鹤各一，童子四各执缨立四角，上设关戾。卧轮一十三，各径一尺八寸五分，围五尺五寸五分，出齿三十二，齿间相去一寸八分。中心轮轴随屏风贯下，下有轮一十三，中至大平轮。其轮径三尺八寸，围一丈一尺四寸，出齿一百，齿间相去一寸二分五厘，通上左右起落。二小平轮，各有铁坠子一，皆径一尺一寸，围三尺三寸，出齿一十七，齿间相去一寸九分。又左右附轮各一，径一尺五寸五分，围四尺六寸五分，出齿二十四，齿间相去二寸一分。左右叠轮各二，下轮各径二尺一寸，围六尺三寸，出齿三十二，齿间相去二寸一分；上轮各径一尺二寸，围三尺六寸，出齿三十二，齿间相去一寸一分。左右车脚上各立轮一，径二尺二寸，围六尺六寸，出齿三十二，齿间相去二寸二分五厘。左右后辕各小轮一，无齿，系竹并索在左右轴上，遇右转使右辕小轮触落右轮，若左转使左辕小轮触落左轮。行则仙童交而指南。车驾赤马二，铜面，插羽，鞶缨，攀胸铃拂，绯绢屜，锦包尾。……

——《宋史·舆服志》



① 童子
Boy
② 中间轮
Intermediate wheel
③ 龟
Tortoise
④ 指路仙人
The immortal who shows the way
⑤ 鹤
Crane

第一层齿轮排布及齿轮上部各装饰部件图
Diagram of the gear arrangement on the upper story and each decorative part on top of the gear



① 车轮
Road wheel
② 车脚立轮
Vertical wheel
③ 小平轮
Small horizontal wheel
④ 左附轮
Left subordinate wheel
⑤ 右附轮
Right subordinate wheel
⑥ 上叠轮
Upper component of double gear-wheels
⑦ 下叠轮
Lower component of double gear-wheels
⑧ 大平轮
Large horizontal wheel

第二层齿轮排布及各部齿轮名称图
Diagram of the gear arrangement on the lower story and the name of each part

吴德仁重新研制的指南车结构示意图
Schematic diagram of the south-pointing carriage reinvented by Wu Deren

制图六体
Six Principles of Cartography

制图六体是已知中国古代最早的制图理论，是西晋时裴秀在总结前人制图经验的基础上提出的。裴秀（224—271）字季彦，河东闻喜（今山西省闻喜县）人，晋武帝时官任司空，后任宰相。在其《禹贡地域图》序中，他明确提出六条地图绘制原则：“制图之体有六焉。一曰分率，所以辨广轮之度也。二曰准望，所以正彼此之体也。三曰道里，所以定所由之数也。四曰高下，五曰方邪，六曰迂直，此三者各因地而制宜，所以校夷险之异也。”

一为“分率”，用以折算地图与实际地形的比例关系，即“比例尺”；

二为“准望”，用以确定地物彼此间的相互方位关系，即“方位”；

三为“道里”，用以确定地物彼此间的距离，即“距离”；

四为“高下”，即“地势起伏”；

五为“方邪”，即“倾斜角度”；

六为“迂直”，即“河流、道路等的曲直”。

裴秀认为，“此六者参而考之”，制图六体是相互联系的，在地图绘制中极为重要。这六条原则的综合运用正确地解决了地图比例尺、方位关系和距离高程等制图要素问题。制图六体由此成为中国西晋以后地图制图学理论的基础，一直到明代末期有经纬线的世界地图传播到中国后，中国的制图方法才开始改变。制图六体在中国和世界地图制图学史上有重要地位。

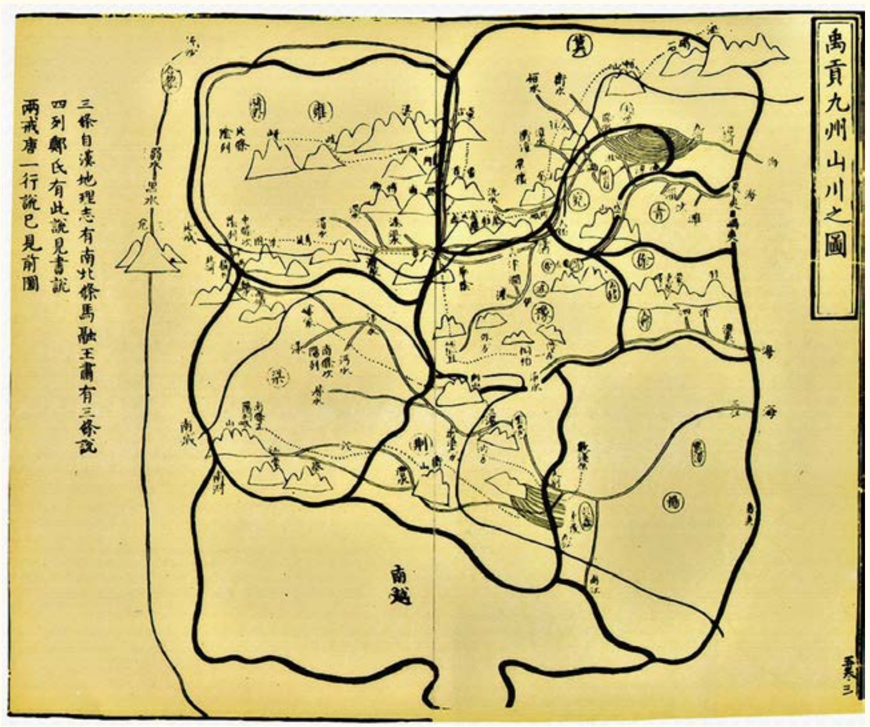
The six principles of cartography are the earliest cartographic theories in ancient China. It was put forward in the Western Jin Dynasty by Pei Xiu who summed up the predecessors' experiences in cartography. Pei Xiu (224 A.D.–271 A.D.), courtesy name Jiyan, a native of Wenxi County, Shanxi Province, was the Minister of Works and was later promoted to prime minister during the reign of Emperor Wu of Jin. He explicitly described six mapping principles in the preface of his *Yu Gong Geographical Map*:

In making a map there are six observable principles: 1. the graduated scale (Fen Lv), which is a means of determining the map's scale; 2. the rectangular grid (Zhun Wang), which is the way of depicting correct relations between various parts of the map; 3. road distance (Dao Li), which is the way of fixing the lengths of derived distances; 4. measuring the high and the low (Gao Xia), that is, land measurement in the terrian; 5. measuring right angles and acute angles (Fang Xie), that is, angles of elevation and depression; 6. measuring curves and straight lines of the rivers and roads (Yu Zhi).

Pei Xiu stated that the six principles of cartography are interrelated and very important in map making. The comprehensive application of these six principles has solved the problems of the graduated scale, the rectangular grid, road distance and so on. Therefore, the six principles of cartography had become the basis of the Chinese cartographic theories since the Western Jin Dynasty. It was not until the end of the Ming Dynasty when the world map with parallels and meridians spread to China, China began to adopt new cartographic methods. It has an important position in the history of cartography in China and around the world.

西晋裴秀创立“制图六体”

Six principles of cartography established by Pei Xiu of the Western Jin Dynasty



《禹贡九州山川之图》，南宋淳熙十二年（1185）雕版墨印

Woodblock print in ink of *Yu Gong Map of the Nine Provinces and Mountains* in the twelfth year of the Chunxi Period of the Southern Song Dynasty

《禹贡九州山川之图》主要表现禹贡九州的分布及山川大势，采取中国古代地图传统形象符号等示意画法来描绘山川、水脉和建筑，如用笔架状的线条表示山脉，用实线、虚线表示水道，用带圈汉字表示地名。

现藏于中国国家图书馆。

《晋书·裴秀传》书影图

Photoprint of Book of *Jin. Biography of Pei Xiu*

秀儒学洽闻，且留心政事，当禅代之际，总纳言之要，其所裁当，礼无违者。又以职在地官，以《禹贡》山川地名，从来久远，多有变易。后世说者或强牵引，渐以暗昧。于是甄摘旧文，疑者则阙，古有名而今无者，皆随事注列，作禹贡地域图十八篇，奏之，藏于秘府。其序曰：

图书之设，由来尚矣。自古立象垂制，而赖其用。三代置其官，国史掌厥职。暨汉屠咸阳，丞相萧何尽收秦之图籍。今秘书既无古之地图，又无萧何所得，惟有汉氏舆地及括地诸杂图。各不设分率，又不考正准望，亦不备载名山大川。虽有粗形，皆不精审，不可依据。或荒外迂诞之言，不合事实，于义无取。

大晋龙兴，混一六合，以清宇宙，始于庸蜀，冞入其岨。文皇帝乃命有司，撰访吴蜀地图。蜀土既定，六军所经，地域远近，山川险易，征路迂直，校验图记，罔或有差。今上考禹贡山海川流，原隰陂泽，古之九州，及今之十六州，郡国县邑，疆界乡陬，及古国盟会旧名，水陆径路，为地图十八篇。

制图之体有六焉。一曰分率，所以辨广轮之度也。二曰准望，所以正彼此之体也。三曰道里，所以定所由之数也。四曰高下，五曰方邪，六曰迂直，此三者各因地而制宜，所以校夷险之异也。有图象而无分率，则无以审远近之差；有分率而无准望，虽得之于一隅，必失之于他方；有准望而无道里，则施于山海绝隔之地，不能以相通；有道里而无高下、方邪、迂直之校，则径路之数必与远近之实相违，失准望之正矣，故以此六者参而考之。然远近之实定于分率，彼此之实定于道里，度数之实定于高下、方邪、迂直之算。故虽有峻山钜海之隔，绝域殊方之迥，登降诡曲之因，皆可得举而定者。准望之法既正，则曲直远近无所隐其形也。

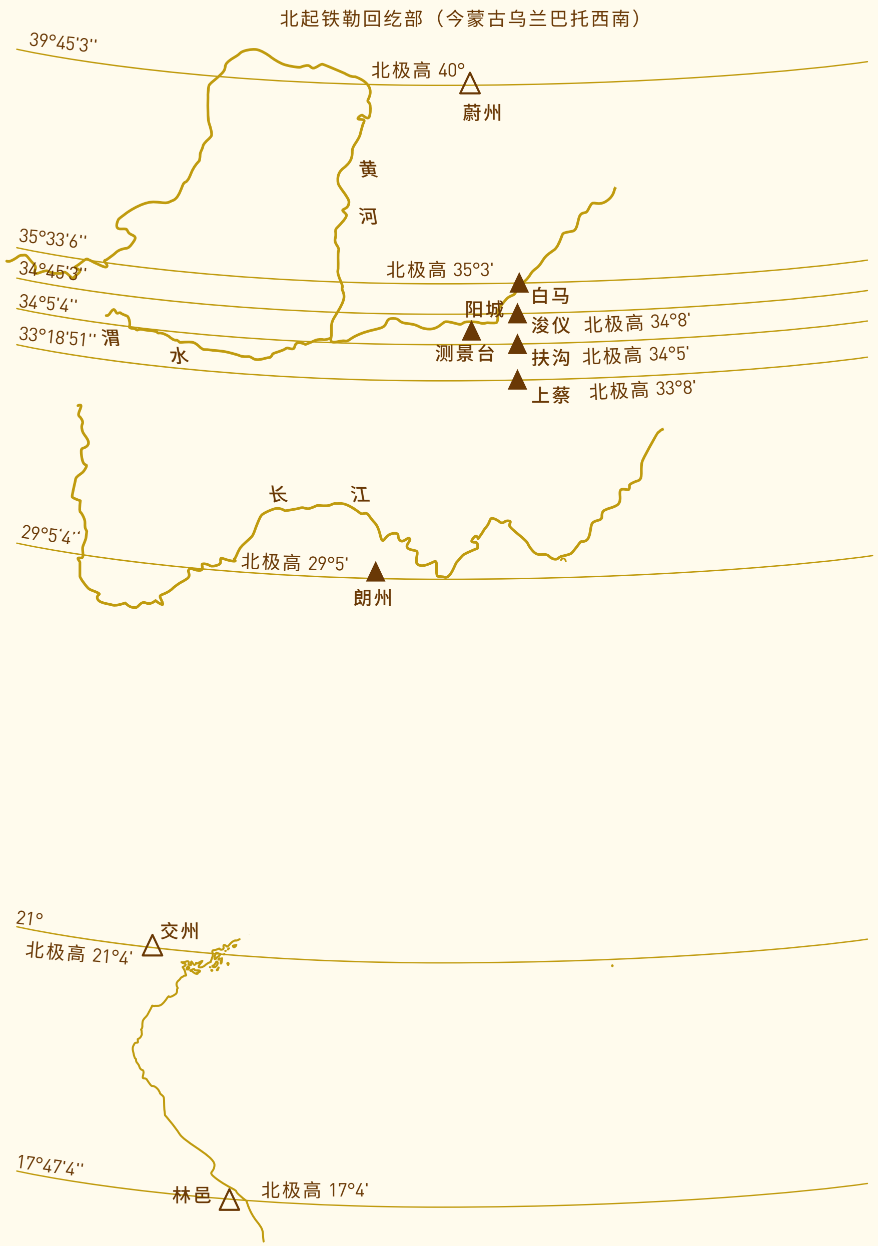
——《晋书·裴秀传》

僧一行测地
Monk Yixing's Geodetic Survey

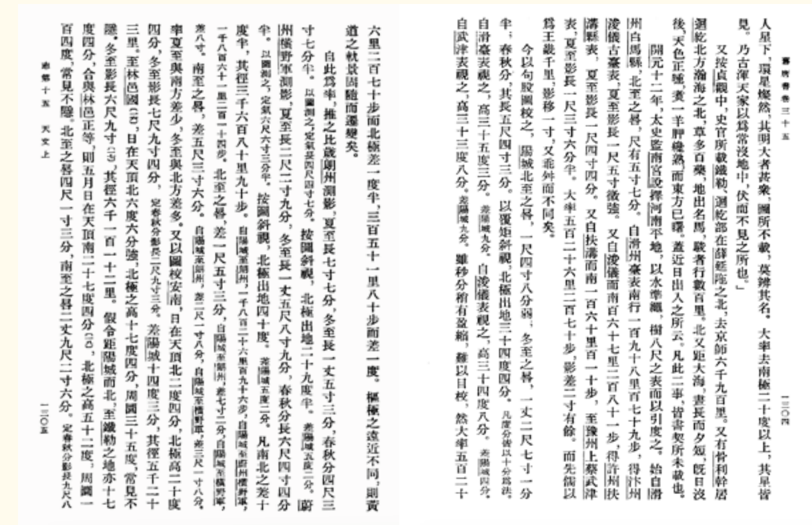
僧一行（683—727），唐代僧人，本姓张，名遂，对天文历法有很深造诣。唐开元十二年（724），他发起和组织了一次大规模的天文大地测量活动，测量范围以今河南省为中心，北起铁勒回纥部（今蒙古乌兰巴托西南），南达林邑（今越南中部），测量地点达 12 处，测量范围之大前所未有。在测量过程中，由太史监南宫说和太史官大相元太等人分赴各地主持测量，“测候日影，回日奏闻”，僧一行“则以南北日影较量，用勾股法算之”。测量内容包括每个测量地点的北极高度，以及“二至二分”日正午八尺之竿（表）的日影长度和昼夜长短等。此次测量活动选取了在同一条经线上的白马（今滑县）、浚仪、扶沟、上蔡 4 个地方作为重点进行测量。从白马到上蔡南北距离有 526 里 270 步，日影长相差 2.1 寸，否定了历史上“日影一寸，地差千里”的错误理论。僧一行根据测量数据，计算出南北两地相差 351 里 80 步（唐朝尺度，合现代长度 129.22 千米），北极高度相差一度。这个数据就是地球子午线一度的长度，现代测量子午线一度的长是 111.2 千米，僧一行的数据虽有较大误差，但这是世界上第一次实测子午线长度的记录，有着十分宝贵的科学价值。

Monk Yixing (683 A.D.–727 A.D.), secular name Zhang Sui, was deep in astronomical almanac. In the 12th year of the Kaiyuan Period of the Tang Dynasty (724 A.D.), he initiated and organized a largest-ever terrestrial-astronomical survey covering 12 locations from the Uighur, a tribe of Teli (now southwest of Ulaanbaatar, Mongolia) in the north to Linyi (now central Vietnam) in the south, with today's Henan Province as the center. The survey was under the direction of imperial astronomer Nangong Yue and others who went to these locations to "take gnomonic measurements and then report to the court". Monk Yixing adopted "the right triangle theorem to calculate the difference between shadow lengths of the sun (observed at the same time at two places) along the same meridian". There were several observations done for each site—one for the height of Polaris, one for the noon shadow length of an 8-chi-high pole at the two solstices and two equinoxes, one for the lengths of day and night. The four major observation sites along the same meridian were Baima (Now Hua County), Junyi, Fugou and Shangcai. For 2.1 cun in shadow length, the corresponding distance running from the Baima to Shangcai was 526 li and 270 bu. Thus the erroneous concept that 1 cun in shadow length corresponded to 1,000 li in distance was overthrown. According to the measurement data, Monk Yixing concluded that for one degree of height of Polaris, the corresponding distance between two places along the same meridian was 351 li and 80 bu (Tang Dynasty's unit of distance, or 129.22 km), which was longer than the present-day value of the length of one degree of meridian arc, that is, 111.2 km. Although Monk Yixing's calculation was fairly accurate, it was the world's first record of the length of meridian arc based on field measurement, which was very scientifically valuable.

僧一行
Monk Yixing
（683—727）



僧一行测地活动示意图（724—725）
Monk Yixing's geodetic survey



舊唐書卷三十五　一三〇四

人星下，環星燦然，其明大者甚衆，圖所不載，莫辨其名。大率去南極二十度以上，其星皆見。乃古渾天家以爲常沒地中，伏而不見之所也。」

又按貞觀中，史官所載鐵勒、迴紇部在薛延陀之北，去京師六千九百里。又有骨利幹居迴紇北方瀚海之北，草多百藥，地出名馬，駿者行數百里。北又距大海，晝長而夕短，既日沒後，天色正曛，煑一羊胛纔熟，而東方已曙。蓋近日出入之所云。凡此二事，皆書契所未載也。

開元十二年，太史監南宮說擇河南平地，以水準繩，樹八尺之表而以引度之。始自滑州白馬縣，北至之晷，尺有五寸七分。自滑州臺表南行一百九十八里百七十九步，得汴州浚儀古臺表，夏至影長一尺五寸微強。又自浚儀而南百六十七里二百八十一步，得許州扶溝縣表，夏至影長一尺四寸四分。又自扶溝而南一百六十里百一十步，至豫州上蔡武津表，夏至影長一尺三寸六分半。大率五百二十六里二百七十步，影差二寸有餘。而先儒以爲王畿千里，影移一寸，又乖舛而不同矣。

今以句股圖校之，陽城北至之晷，一尺四寸八分弱，冬至之晷，一丈二尺七寸一分半，春秋分，其長五尺四寸三分。以覆矩斜視，北極出地三十四度四分。凡度分皆以十分爲法。自滑臺表視之，高三十五度三分。差陽城九分。自浚儀表視之，高三十四度八分。差陽城四分。自武津表視之，高三十三度八分。差陽城九分。雖秒分稍有盈縮，難以目校，然大率五百二十六里二百七十步而北極差一度半，三百五十一里八十步而差一度。樞極之遠近不同，則黃道之軌景固隨而遷變矣。

自此爲率，推之比歲朗州測影，夏至長七寸七分，冬至長一丈五寸三分，春秋分四尺三寸七分半。以圖測之，定氣長四尺四寸七分。按圖斜視，北極出地二十九度半，差陽城五度三分。蔚州橫野軍測影，夏至長二尺二寸九分，冬至長一丈五尺八寸九分，春秋分長六尺四寸四分半。以圖測之，定氣六尺六寸三分半。按圖斜視，北極出地四十度。差陽城五度三分。凡南北之差十度半，其徑三千六百八十里九十步。自陽城至朗州，一千八百二十六里百九十六步，自陽城至橫野軍，一千八百六十一里二百一十四步。北至之晷，差一尺五寸三分，自陽城至朗州，差七寸二分，自陽城至橫野軍，差八寸。南至之晷，差五尺三寸六分。自陽城至朗州，差二尺一寸八分，自陽城至橫野軍，差三尺一寸八分。率夏至與南方差少，冬至與北方差多。又以圖校安南，日在天頂北二度四分，北極高二十度四分，冬至影長七尺九寸四分，定春秋分影長二尺九寸三分。差陽城十四度三分，其徑五千二十三里。至林邑國，日在天頂北六度六分強，北極之高十七度四分，周圓三十五度，常見不隱。冬至影長六尺九寸，其徑六千一百一十二里。假令距陽城而北，至鐵勒之地亦十七度四分，合與林邑正等，則五月日在天頂南二十七度四分，北極之高五十二度，周圓一百四度，常見不隱。北至之晷四尺一寸三分，南至之晷二丈九尺二寸六分。定春秋分影長九尺八

志第十五　天文上　一三〇五

《旧唐书·天文志》对僧一行测地活动的记载
Monk Yixing's geodetic survey recorded by *Old Book of Tang. Historical Record of Astronomical Observations*

《旧唐书·天文志》中详细记载了唐开元十二年（724）由僧一行领导、太史监南宫说主持的大规模测地活动。

太史监南宫说择河南平地，设水准绳墨植表而以引度之，自滑台始白马，夏至之晷，尺五寸七分。又南百九十八里百七十九步，得浚仪岳台，晷尺五寸三分。又南百六十七里二百八十一步，得扶沟，晷尺四寸四分。又南百六十里百一十步，至上蔡武津，晷尺三寸六分半。大率五百二十六里二百七十步，晷差二寸余。而旧说王畿千里，影差一寸，妄矣。今以句股校阳城中晷，夏至尺四寸七分八厘，冬至丈二尺七寸一分半，定春秋分五尺四寸三分，以覆矩斜视，极出地三十四度十分度之四。自滑台表视之，极高三十五度三分，冬至丈三尺，定春秋分五尺五寸六分。自浚仪表视之，极高三十四度八分，冬至丈二尺八寸五分，定春秋分五尺五寸。知扶沟表视之，极高三十四度三分，冬至丈二尺五寸五分，定春秋分五尺三寸七分。上蔡武津表视之，极高三十三度八分，冬至丈二尺三寸八分，定春秋分五尺二寸八分。其北极去地，虽秒分微有盈缩，难以目校，大率三百五十一里八十步，而极差一度。极之远近异，则黄道轨景固随而变矣。

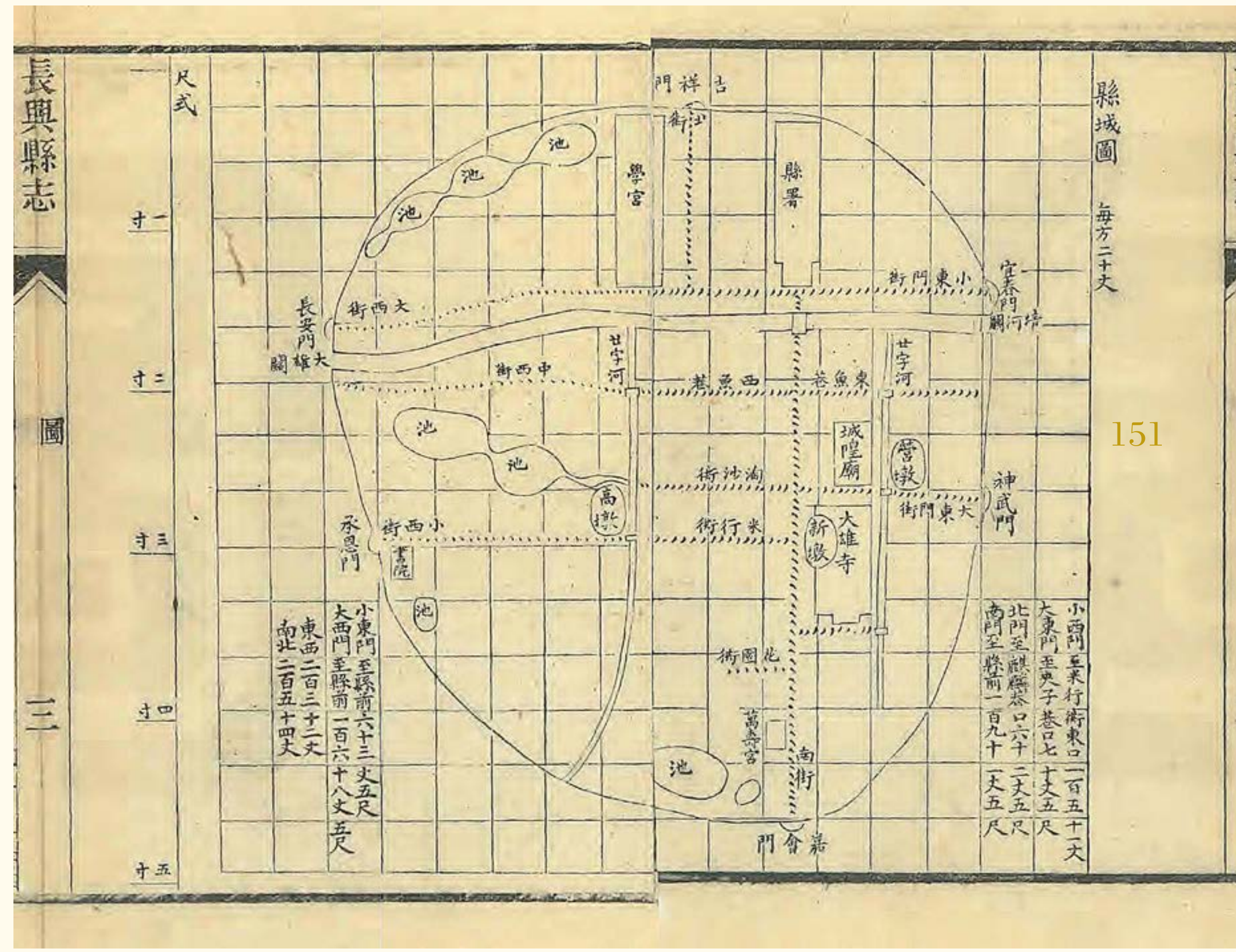
——《旧唐书·天文志》

计里画方

Squared Map with Grid System and Scale

“计里画方”又称“开方记里”，是在地图上按一定的比例关系制成的方格坐标网，并以此方格网来约束控制图上要素方位和距离的一种制图方法，用这种方法绘制的地图有很高的精确度。

"Squared map with grid system and scale" refers to a cartographic method of making coordinate grids on the map in accordance with certain proportion to control the direction and distance among various objects. Maps drawn by this method have very high accuracy.

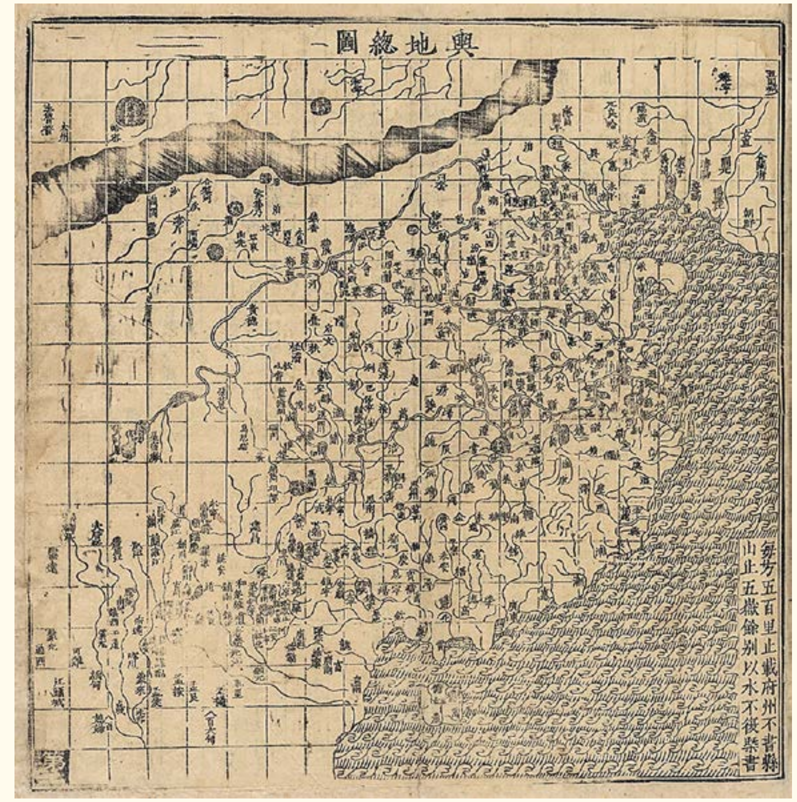


清光绪年间浙江《长兴县志》中用计里画方法绘制的县城图

The county map drawn by the method of squared map with grid system and scale in *Changxing County Annals* of Zhejiang Province during the Guangxu Period of the Qing Dynasty

禹迹图
Yu Ji Tu map

《禹迹图》是我国现存最早的计里画方石刻地图，石刻于齐“阜昌七年四月”，亦即南宋绍兴六年（1136），作者不详。原石现保存于陕西西安碑林博物馆。图上有“计里画方”的格网形式和“每方折地百里”的注记。整幅图横 71 方，竖 73 方，共 5 113 方，每方边长 1.11 厘米，具有相当高的精度，各要素和今实测地图比较接近。海岸线走向比较准确，长江、黄河、汉水、沅水、湘水、珠江等各大水系曲折流势和今天相似；太湖、洞庭湖、巢湖等的位置比较准确，河流线条刻绘得流畅光滑，而且上细下粗，体现了河流水量的自然变化。英国科技史专家李约瑟评论说：“这幅地图在当时是世界上最杰出的地图。”



广舆图
Guang Yu Tu atlas

《广舆图》是明代罗洪先（1504—1564）采用计里画方方法编绘的地图集，共绘制地图 113 幅，绘画工整、刻镌精细，并首次采用 24 种地图符号，丰富了地图内容，提高了地图科学性。因为该图为图集形式，方便实用，易于保存，故先后翻刻 6 次，影响甚广。各种刻本现分别藏于中国国家图书馆、首都图书馆、故宫博物院图书馆、河南省图书馆、辽宁省图书馆、上海图书馆、美国国会图书馆等地。

《广舆图》含舆地总图 1 幅，南北两直隶及十三布政司图 16 幅（其中陕西 2 幅），九边图 11 幅，洮河、松潘、虔镇、建昌、麻阳诸边图 5 幅，黄河图 3 幅，漕运图 3 幅，海运图 2 幅，朝鲜、朔漠、安南、西域图 4 幅，其后翻刻时又增补琉球、日本及东南海夷总图、西夷海夷总图、华夷总图等。此图也是中国最早的分省地图集。

04

交流篇

EXCHANGE SECTION

一带一路 民心相通

ONE BELT ONE ROAD
PEOPLE TO PEOPLE BOND

“一带一路”是“丝绸之路经济带”和“21 世纪海上丝绸之路”的简称。公元前 139 年张骞从长安出使西域，首次开拓“丝绸之路”，史称“凿空之旅”。丝绸之路成为连接中国和西域的贸易通道。唐太宗时，高僧玄奘由丝绸之路经中亚前往印度取经、讲学，历时 16 年。唐天宝年间鉴真先后 6 次东渡，终于在公元 754 年沿着海上丝绸之路的东海航线到达日本。《马可·波罗游记》中有几处写道：元大都外城常有“无数商人”来往止息。15 世纪初郑和七下西洋，开辟了亚非的洲际航线，海上丝绸之路发展到巅峰。从古到今，导航技术为“一带一路”的开拓和发展做出了重要贡献。《大唐西域记》成为世界著名的历史地理名著，《郑和航海图》在世界地图学、地理学史和航海史上占有重要的地位。

"One Belt One Road" is the short name of "Silk Road Economic Belt" and "21st Century Maritime Silk Road". In 139 B.C., Zhang Qian led a group of people to Central Asia from Chang'an to explore the "Silk Road" for the first time, which was called "a journey to explore the virgin land" in history. Thus the Silk Road had become a trade access between China and Central Asia. During the reign of Emperor Taizong of Tang, the eminent monk Xuan Zang spent 16 years on a pilgrimage to India along the Silk Road via Central Asia for Buddhist scriptures and sermons. In the Tianbao Period of the Tang Dynasty, Monk Jian Zhen attempted to visit Japan six times and finally made it to Japan along the maritime Silk Road in 754 A.D. *The Travel of Marco Polo* wrote in several places: "Many merchants come and stop at the outskirt of the Yuan capital." In the early 15th Century, Zheng He conducted seven voyages to the "Western" or Indian Ocean. He opened up the intercontinental routes between Asia and Africa, marking the peak of the maritime Silk Road. From past to present, navigation technology has made important contributions to the development of "One Belt One Road". *Great Tang Records on the Western Regions* is a famous historical and geographical masterpiece. *Zheng He's Nautical Chart* plays an important role in the world history of cartography, geography and navigation.

张骞通西域

Zhang Qian's Mission and Exploration to Central Asia

张骞（前164—前114），字子文，汉中郡城固（今陕西省汉中市城固县）人，中国汉代杰出的外交家、旅行家、探险家，丝绸之路的开拓者。汉武帝建元二年（前139），为联合大月氏共同对抗匈奴，张骞奉汉武帝之命出使西域，至元朔三年（前126）归汉，共历13年。元狩四年（前119），张骞第二次出使西域，历时4年。

张骞两次西域之行，打通了汉朝通往西域的南北两线道路，客观上促进了汉朝与西域各族的交流往来，汉武帝以军功封其为博望侯。史学家司马迁称赞张骞出使西域为"凿空"之旅，意思即"开通大道"。张骞出使西域过程中，历尽千辛万苦，在途经戈壁大漠时，他主要通过"昼观日、夜观星"来辨别方向，加上有汉朝匈奴族人甘父（也叫堂邑父）做向导，才能圆满完成"凿空"壮举。后人正是沿着张骞的足迹，走出了誉满全球的丝绸之路。

1877年，德国地质地理学家李希霍芬在他的著作《中国》一书中，把从公元前114年至公元127年两百多年间，中国与中亚、印度间主要以丝绸贸易为媒介的这条西域通道命名为"丝绸之路"，这一名词很快被学术界和大众所接受。

Zhang Qian (164 B.C.–114 B.C.), courtesy name Ziwen, a native of Chenggu, Hanzhong County (now Chenggu County, Hanzhong City, Shaanxi Province), was an outstanding diplomat, traveler, explorer and the pioneer of the Silk Road in the Han Dynasty. In the second year of the Jianyuan Period of Emperor Wu of Han (139 B.C.), Emperor Wu dispatched Zhang Qian to the Western Regions (Central Asia) to build an alliance with Rouzhi against Xiongnu. He returned in the third year of the Yuanshuo Period (126 B.C.), which lasted 13 years. In the fourth year of the Yuanshuo Period (119 B.C.), Zhang Qian was sent on a second mission to the Western Regions, which lasted 4 years.

Zhang Qian's two expeditions to the Western Regions opened up the northern and southern routes for the Han Dynasty to the Western Regions, which objectively promoted the exchanges between each other. Emperor Wu of Han bestowed Bowang Marquis on him because of his military glory. Historian Sima Qian also praised him for his great mission to the Western Regions as "a journey to explore the virgin land". He went through all kinds of hardships on his mission to

Central Asia. When he passed through the Gobi Desert, he determined the direction by observing the sun by day and the stars at night. Also accompanied by a guide named Ganfu (also called Tang Yi Fu), he achieved the feat of exploration. Following the footsteps of Zhang Qian, later generations blazed the world-renowned Silk Road.

In 1877 A.D., German geographer Ferdinand von Richthofen coined the term "Silk Road" in his book *China* to refer to the corridor mediated by silk trade for more than two hundred years from 114 B.C. to 127 A.D. between China, Central Asia and India. This term was quickly accepted by the academia and the public.

张骞
（前164—前114）
Zhang Qian (164 B.C.–114 B.C.)

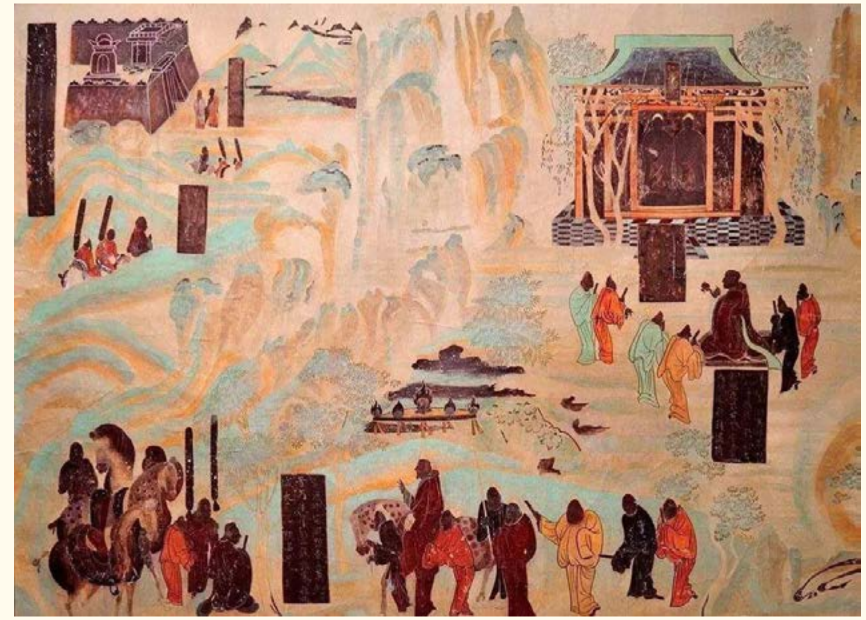
公元前140多年的中国汉代，一支从长安出发的和平使团，开始打通东方通往西方的道路，完成了"凿空"之旅，这就是著名的张骞出使西域。

“汉西域诸国图”南宋景定年间（1260—1264）
雕版印，现藏于中国国家图书馆

Woodblock print of "Countries in Central Asia in the Han Dynasty" during the Jingding Period of the Southern Song Dynasty(1260 A.D.–1264 A.D.), now housed in National Library of China

汉代的西域，是指玉门关、阳关以西包括今新疆、中亚在内的广大地区。西汉初年，西域地区为匈奴所控制。西域一带有乌孙、楼兰、若羌、精绝、于阗、车师、龟兹、疏勒等 36 个小国，有的国家从事农业，有的国家以游牧为主。

在汉代以前，中原地区和西域之间几乎没有往来。西汉初年，中原的人们逐渐从东西往来的行商的描述中了解到西域的一些情况，联系仍很有限。汉武帝时期，随着国力的强大，汉武帝两次派张骞出使西域，并且对匈奴用兵取得胜利，加强了中原与西域各族的联系。汉宣帝时设立西域都护府总管西域事务，对西域广大地区施行管辖。汉元帝时，又增设戊己校尉。王莽新朝，贬去西域各国王号，降为侯，西域与汉关系趋紧，匈奴趁机再入。东汉明帝又恢复与西域的关系，并派班超（32—102）出使西域，镇抚西域各国，加强了与西域各国的紧密联系。



张骞通西域图（壁画，莫高窟第 323 窟）

A mural depicting Zhang Qian's mission and exploration to Central Asia (Mogao Cave 323)

“张骞通西域图”的画面由 4 个部分组成，各个部分间以山峦相互分隔。壁画右上侧的建筑是甘泉宫，汉武帝执香炉跪拜两个金像，周边有六个人持笏侍立。旁边的榜题上书写着：“汉武帝将其部众讨匈奴，并获得二金人，长丈余，列之于甘泉宫，帝为大神，常行拜谒时。”壁画的下部，张骞持笏跪在地上，向骑在马上的汉武帝辞别。张骞和汉武帝之间的榜题上写着：“前汉中，帝既获金人，莫知名号，乃使博望侯张骞往西域大夏国，访问名号时”，这是说张骞出使西域的目的。壁画的左侧中部，三人匆匆而行，越走越远。最后是在壁画的左上角，绘一西域风格的城池，城门外站两位穿袈裟的僧人，正在迎接张骞一行的到来。

2017 年中国发行的《张骞》特种邮票和小型张
A *Zhang Qian* special sheet and a minisheet issued by China in 2017

《张骞》特种邮票一套 2 枚，图案内容分别为“凿空西域”和“开辟丝路”，小型张为张骞像。

张骞出使西域的事迹在《史记·大宛列传》中有记载：

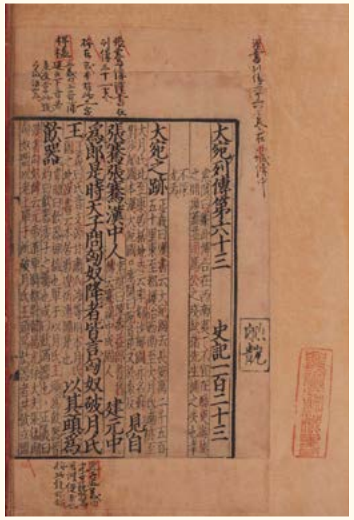
大宛之迹，见自张骞。张骞，汉中人。建元中为郎。是时天子问匈奴降者，皆言匈奴破月氏王，以其头为饮器，月氏遁逃而常怨仇匈奴，无与共击之。汉方欲事灭胡，闻此言，因欲通使。道必更匈奴中，乃募能使者。骞以郎应募，使月氏，与堂邑氏胡奴甘父俱出陇西。经匈奴，匈奴得之，传诣单于。单于留之，曰：“月氏在吾北，汉何以得往使？吾欲使越，汉肯听我乎？”留骞十余岁，与妻，有子，然骞持汉节不失。

居匈奴中，益宽，骞因与其属亡乡月氏，西走数十日至大宛。大宛闻汉之饶财，欲通不得，见骞，喜，问曰：“若欲何之？”骞曰：“为汉使月氏，而为匈奴所闭道。今亡，唯王使人导送我。诚得至，反汉，汉之赂遗王财物不可胜言。”大宛以为然，遣骞，为发导绎，抵康居，康居传致大月氏。大月氏王已为胡所杀，立其太子为王。既臣大夏而居，地肥饶，少寇，志安乐，又自以远汉，殊无报胡之心。骞从月氏至大夏，竟不能得月氏要领。

留岁余，还，并南山，欲从羌中归，复为匈奴所得。留岁余，单于死，左谷蠡王攻其太子自立，国内乱，骞与胡妻及堂邑父俱亡归汉。汉拜骞为太中大夫，堂邑父为奉使君。

骞为人强力，宽大信人，蛮夷爱之。堂邑父故胡人，善射，穷急射禽兽给食。初，骞行时百余人，去十三岁，唯二人得还。

骞身所至者大宛、大月氏、大夏、康居，而传闻其旁大国五六，具为天子言之。曰：“大宛在匈奴西南，在汉正西，去汉可万里。其俗土著，耕田，



《史记·大宛列传》南宋（庆元年间）建安黄善夫家塾刊本
Records of the Grand Historian. Treatise on Dayuan published by Huang Shanfu's bookstore in Jianan County during the Qingyuan Period of the Southern Song Dynasty

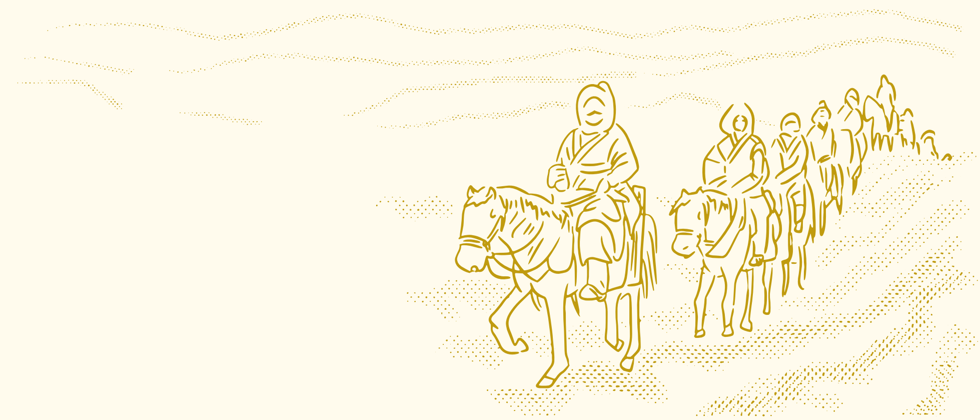
田稻麦。有蒲陶酒。多善马，马汗血，其先天马子也。有城郭屋室。其属邑大小七十余城，众可数十万。其兵弓矛骑射。其北则康居，西则大月氏，西南则大夏，东北则乌孙，东则扜罙、于阗。于阗之西，则水皆西流，注西海；其东水东流，注盐泽。盐泽潜行地下，其南则河源出焉。多玉石，河注中国。而楼兰、姑师邑有城郭，临盐泽。盐泽去长安可五千里。匈奴右方居盐泽以东，至陇西长城，南接羌，鬲汉道焉。”

……

汉已伐宛，立昧蔡为宛王而去。岁余，宛贵人以为昧蔡善谀，使我国遇屠，乃相与杀昧蔡，立毋寡昆弟曰蝉封为宛王，而遣其子入质于汉。汉因使使赂赐以镇抚之。

而汉发使十余辈至宛西诸外国，求奇物，因风览以伐宛之威德。而敦煌置酒泉都尉；西至盐水，往往有亭。而仑头有田卒数百人，因置使者护田积粟，以给使外国者。

太史公曰：“禹本纪言‘河出昆仑。昆仑其高二千五百余里，日月所相避隐为光明也。其上有醴泉、瑶池。’今自张骞使大夏之后也，穷河源，恶睹本纪所谓昆仑者乎？故言九州山川，尚书近之矣。至禹本纪、山海经所有怪物，余不敢言之也。”



张骞第一次出使西域路线图
Route map of Zhang Qian's first mission to Central Asia

张骞第二次出使西域路线图
Route map of Zhang Qian's second mission to Central Asia

张骞出使西域路线图（示意图）
Route map of Zhang Qian's mission to Central Asia

玄奘西行
Monk Xuan Zang's Journey to the West

玄奘（602—664）是唐代著名的三藏法师，历史上杰出的佛学家、翻译家和旅行家。唐太宗贞观二年（628），玄奘为探究佛教各派学说分歧，踏上西行取经之路。他沿着张骞开辟的古丝绸之路西行，主要通过揆日观星辨向导航，西行途中有时与商旅同行，有时也能得到官方或朋友相助，如过铁门关时有突厥军官专职护送。玄奘历经艰辛到达印度佛教中心那烂陀寺取得真经，历时 16 年（628—643）。他学遍了当时的大小乘等各种学说，带回了许多印度的佛教典籍，并长期从事翻译佛经的工作。此外，玄奘于 646 年完成《大唐西域记》，全书共 12 卷，记述了他西游 30 000 里，亲身游历的 110 个国家，以及听闻的 28 个国家的地理、物产、人文和习俗等，为后人留下了记述丝绸之路沿线国家的宝贵资料，是一部闻名世界的历史地理名著。《大唐西域记》为唐太宗后来的西征提供了地理指南。

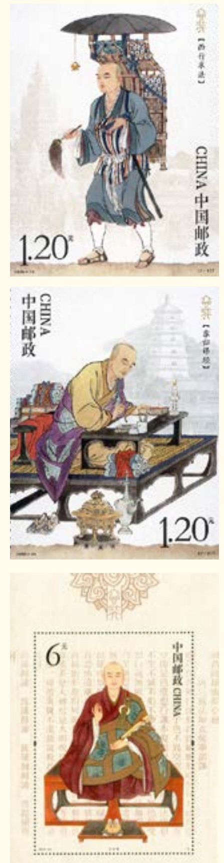
Xuan Zang (602 A.D.–664 A.D.) was a famous Buddhist monk, an outstanding Buddhist scholar, translator and traveler in the Tang Dynasty. In the second year (628 A.D.) of the Zhenguan Period of Emperor Taizong of Tang, Xuan Zang set out to the west to explore the contradictions and discrepancies in the Buddhist texts. Moving westward along the ancient Silk Road opened up by Zhang Qian, he navigated by the sun and stars. On his westward journey, sometimes he traveled with business travelers and sometimes he was helped by authorities or friends, like when he passed through the Iron Gate Pass, he was full-time escorted by a Turkic officer. Xuan Zang went through hardships during his sixteen-year (628 A.D.–643 A.D.) overland journey to Nalanda Temple, the Indian Buddhist center where he obtained Buddhist scriptures, studied various schools such as the Mahayana and Hinayana. He also acquired many Indian Buddhist texts, which he had long been engaged in translating. In addition, in his 12 volumes of *Great Tang Records on the Western Regions* completed in the year 646 A.D., Xuan Zang recorded his thirty-thousand-li journey to the west with 110 countries he visited and the geographies, products, cultures and customs of the 28 countries on hearsay. This "Records" is a valuable document of Central Asia along the Silk Road, a world-famous historical and geographical masterpiece and the best geographical guide for Emperor Taizong's later westward expedition.

2016 年 9 月 4 日发行的 2016-24《玄奘》特种邮票中使用的《玄奘东归译经图》

A 2016-24 *Xuan Zang* special sheet issued on September 4, 2016 depicts *Xuan Zang was translating the Scriptures after he returned to China.*

玄奘三藏像（日本东京国立博物馆藏）

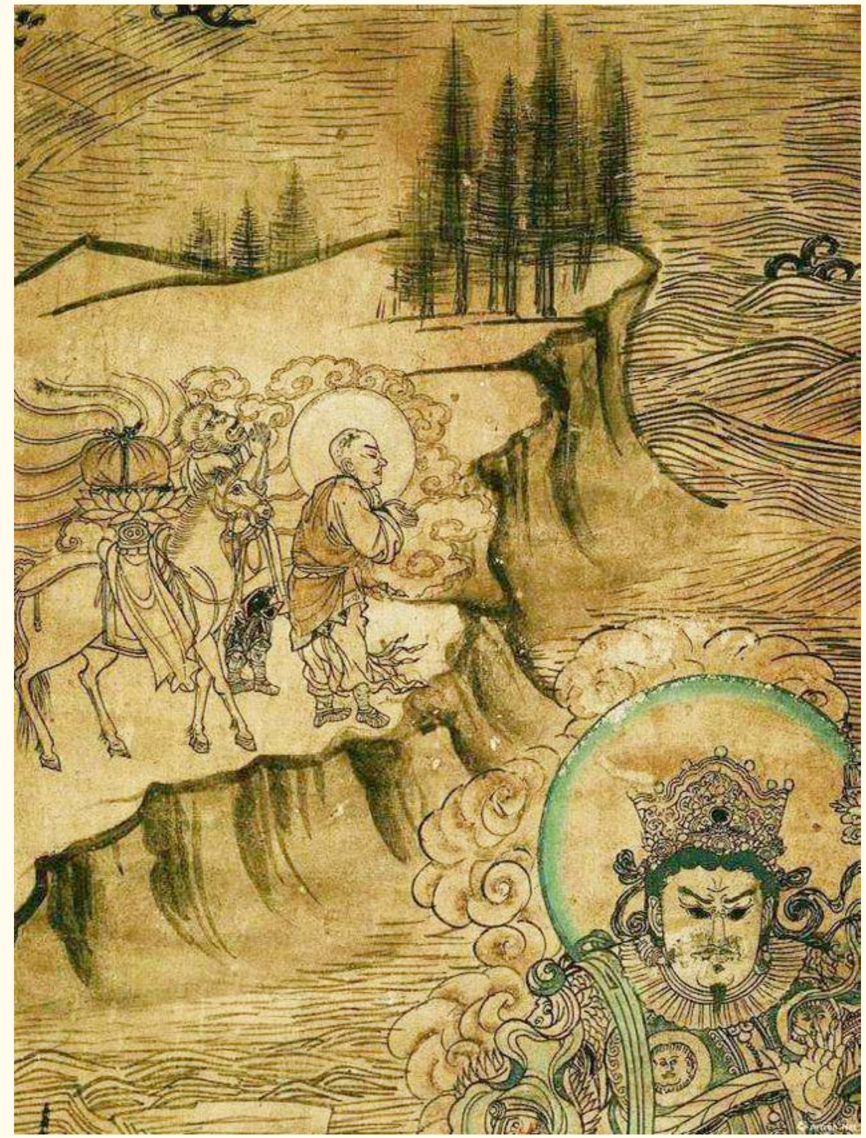
Image of Monk Xuan Zang (collection of Tokyo National Museum, Japan)



2016 年中国发行的《玄奘》特种邮票和小型张

A *Xuan Zang* special sheet and a minisheet issued by China in 2016

第 1 图是特种邮票（2-1）“西行求法”，衬景是印度那烂陀寺方塔的复原图。第 2 图是特种邮票（2-2）“东归译经”，衬景为西安兴教寺。第 3 图小型张为玄奘像。



甘肃瓜州榆林窟《玄奘取经图》壁画

A mural of *Monk Xuan Zang's Journey to the West to Obtain Buddhist Scriptures* in Yulin Caves, Guazhou County, Gansu Province

《大唐西域记》书影（局部）

Photoprint of *Great Tang Records on the Western Regions* (part)

《大唐西域记》记述的是唐玄奘法师自长安前往印度求取佛经的旅行见闻，它由玄奘法师在回到大唐后奉太宗旨意整理而成。全书共 12 卷，主要内容记述 7 世纪中亚各国及印度的佛教、历史、地理、文化、社会、风俗等状况。此绀纸金银交替写本，约书写于 12 世纪，现藏于日本东京国立博物馆。

玄奘西行往返路线图（示意）
Route map of Monk Xuan Zang's journey to the west and back

1980 年中国发行的鉴真大师像回国巡展邮票

Touring exhibition of statue of Jian Zhen paying a visit back to China sheet issued by China in 1980

鉴真东渡

Monk Jian Zhen's Eastbound Travel

鉴真（688—763）原姓淳于，唐代广陵江都（今江苏扬州）人，赴日传法名僧，著名的医学家。唐天宝元年（742），他应日本僧人邀请，先后 6 次东渡，历尽千辛万苦，经历了 5 次失败，终于在 754 年第 6 次沿着海上丝绸之路的东海航线到达日本。他留居日本 10 年，坚持不懈地传播唐朝多方面的文化成就。鉴真主持修建的唐招提寺是日本著名的佛教建筑。鉴真东渡主要通过白天看太阳、夜晚看星辰来确定方位。第 5 次东渡时他们遇到了飓风狂浪，顺水南漂十几天后，一群白鱼引领他们到达了陆地，来到了振州（现海南三亚）。第 6 次东渡他们也是历尽艰险，才终于到达日本。

Jian Zhen (688 A.D.–763 A.D.), secular surname Chunyu, a native of Guanglin Jiangdu (now Yangzhou City, Jiangsu Province) was a famous medical expert and an eminent monk who propagated Buddhism in Japan. Since the first year of the Tianbao Period of the Tang Dynasy (742 A.D.), he had attempted to visit Japan six times at the invitation of Japanese monks but had failed five times. He went through a lot of hardships and finally arrived in Japan in the year 754 A.D. along the East China Sea route of the maritime Silk Road on his sixth attempt. He had lived in Japan for ten years and worked tirelessly to spread the cultural achievements of the Tang Dynasty. Toshodai Temple which was set up by Jian Zhen is a famous Buddhist complex in Japan. Jian Zhen determined the direction by observing the sun by day and the stars by night. His fifth attempt to Japan encountered howling winds and roaring waves. After drifting southward for more than ten days, they were led by a group of white fish to Zhenzhou (now Sanya City, Hainan Province). He finally succeeded on his sixth attempt to Japan after going through hardships.

鉴真纪念堂
Jian Zhen Memorial Hall
（位于扬州市古大明寺内）

鉴真
Jian Zhen
（688—763）

鉴真和尚真像，位于日本奈良唐招提寺
Statue of Monk Jian Zhen in Toshodai Temple in Nara, Japan

《东征传绘卷》卷一 第一段：少年淳于出家（局部）
"The Ordination of Teenage Chunyu" in volume 1, passage 1 of *The Sea Journey to the East of a Great Bonze from the Tang Dynasty*

《东征传绘卷》卷二 第一段：第二次东渡失败（局部）
"The Failure of the Second Attempt to Japan" in volume 2, passage 1 of *The Sea Journey to the East of a Great Bonze from the Tang Dynasty*

《东征传绘卷》卷四 第三段：遣唐使拜会鉴真
"Japanese emissary's official visit to Jian Zhen" in volume 4, passage 3 of *The Sea Journey to the East of a Great Bonze from the Tang Dynasty*

东征传绘卷（高 37.3 厘米，现藏于日本奈良唐招提寺）

鉴真应遣唐僧荣睿、普照邀请，决意东渡日本传播戒律，后遇诸多困难，继而失明，却仍矢志不改。东渡日本后，鉴真于东大寺内创建戒坛院。东征传绘即描绘鉴真创建戒坛院初期之各种因缘。图绘系日本永仁六年（1298），由六郎兵卫入道莲行所作，颇受宋代画风之影响。

第五次东渡路线
Route of Jian Zhen's fifth attempt to Japan

第六次东渡路线
Route of Jian Zhen's sixth attempt to Japan

鉴真和尚东渡日本路线图（示意）
Route map of Monk Jian Zhen's attempts to Japan

元代西域天文学家扎马鲁丁
The Arab Astronomer Jamal ad-Din of the Yuan Dynasty

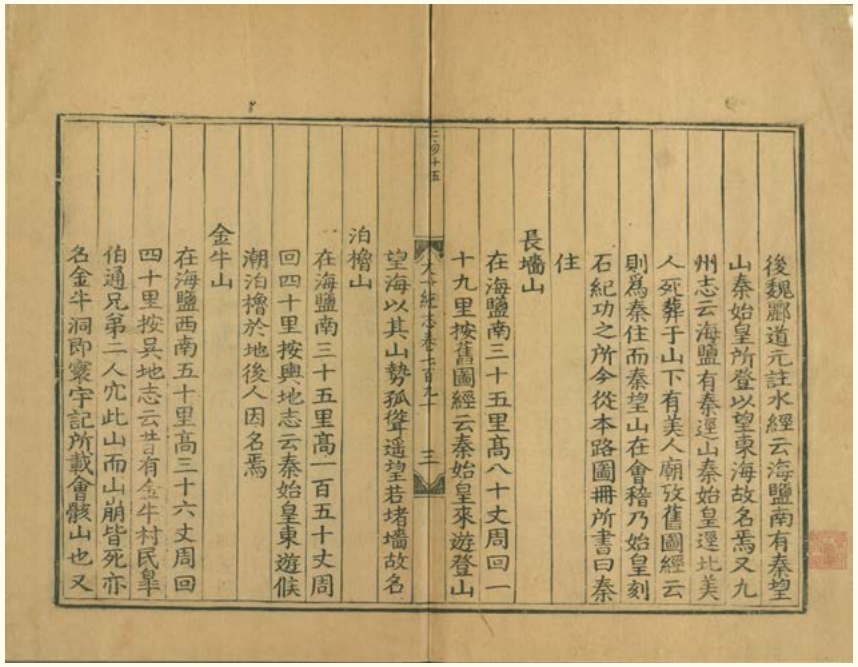
蒙古大帝国的建立促进了中亚阿拉伯文化与中原文化的交流。公元 1267 年，原供职于波斯马拉加天文台的西域天文学家扎马鲁丁来到元上都开平府，受到元世祖忽必烈的召见。同年，元世祖颁行扎马鲁丁编纂的回回历《万年历》。扎马鲁丁先后制造了黄道浑仪、地平纬仪（方位仪）、斜纬仪、平纬仪、天球仪、地球仪、星盘 7 件“西域仪象”（阿拉伯天文仪器）。1271 年，元朝在上都设回回司天台（后来称北司天台），任命扎马鲁丁为提点（相当于今天的国家天文台台长）。7 件“西域仪象”均安置在这里。

1286 年开始，在扎马鲁丁的领导下，经过 17 年的努力工作，编撰完成全国地理图志 1 300 卷，即著名的《大元大一统志》。该志扩充了当时中国版图的地理知识，增加了扎马鲁丁从西域带来的大量地图资料，并引进了阿拉伯制图技术。《大元大一统志》对元、明两代中国制图学产生了深远的影响。

The establishment of the Mongol Empire promoted the cultural exchanges between Arab in Central Asia and China. In 1267 A.D., Persian astronomer Jamal ad-Din who previously worked at Maragheh Observatory reached Kaiping city, the upper capital of the Yuan Dynasty and was summoned to the presence of Kublai Khan. In the same year, Kublai Khan issued the Islamic almanac known in China as *Eternal Calendar* compiled by Jamal ad-Din. He had made seven Islamic astronomical instruments including ecliptic sphere, organon parallacticon, an instrument for measuring the time of the two Equinoxes, a mural quadrant, cosmo-sphere, tellurion, Persian astrolabe. In 1271 A.D., the Islamic Observatory (later called the North Observatory) was set up in the upper capital of the Yuan Dynasty, where Jamal ad-Din was appointed as the director (equivalent to the director of present-day National Astronomy Observatory). The seven Islamic instruments were all placed there.

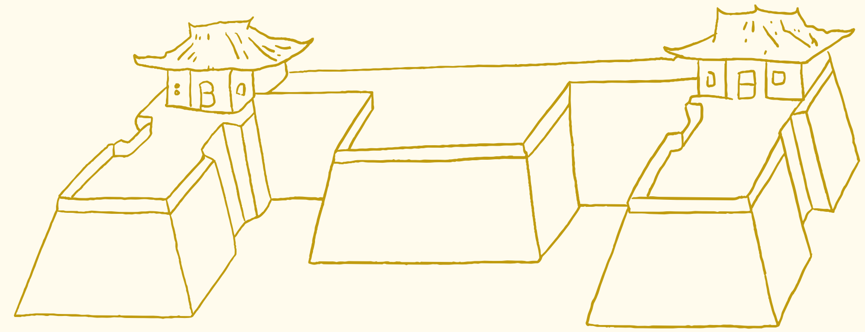
Under the leadership of Jamal ad-Din, the geographic records of the whole empire, that is, the famous *The Unified Domain of the Grand Yuan Dynasty* in 1,300 volumes had been completed after 17 years of effort beginning from the year 1286 A.D. This "Records" expanded the geographic knowledge of the Chinese territory at that time with a large amount of mapping information and Arabic mapping techniques introduced by Jamal ad-Din from the Western Regions, which had profound influence on Chinese cartography in Yuan and Ming Dynasties.

扎马鲁丁
Jamal ad-Din


後魏酈道元註水經云海鹽南有秦望
山秦始皇所登以望東海故名焉又九
州志云海鹽有秦逕山秦始皇逕此美
人死葬于山下有美人廟攷舊圖經云
則爲秦住而秦望山在會稽乃始皇刻
石紀功之所今從本路圖冊所書曰秦
住
長墻山
在海鹽南三十五里高八十丈周回一
十九里按舊圖經云秦始皇來遊登山
望海以其山勢孤聳遙望若堵墻故名
泊櫓山
在海鹽南三十五里高一百五十丈周
回四十里按輿地志云秦始皇東遊候
潮泊櫓於地後人因名焉
金牛山
在海鹽西南五十里高三十六丈周回
四十里按吳地志云昔有金牛村民皐
伯通兄弟二人究此山而山崩皆死亦
名金牛洞即寰宇記所載會骸山也又

《大元大一统志》（元刊本，19.5 厘米 ×25.5 厘米）
The Unified Domain of the Grand Yuan Dynasty (Yuan Dynasty edition, 19.5 cm*25.5 cm)

《大元大一统志》是为元代官修总志。元世祖至元二十三年（1286），天下统一，集贤大学士扎马鲁丁奏请编修总志，世祖许之，至元三十一年（1294）全书告成，凡 755 卷，题名《大一统志》。成宗大德初年，因得云南、甘肃、辽阳等地图志，由孛兰肹、岳铉等主持重修，成宗大德七年（1303）成书，较前书又多出 545 卷，为 1300 卷，定名《大元大一统志》。



元上都承应阙复原示意图
Schematic diagram of Chengyingque Palace in the upper capital of the Yuan Dynasty

至元八年（1271），天文台建在上都承应阙上，同时正式设置了官署。据记载，“至元八年，以上都承应阙官，增置行司天监”，“至元八年，始置（回回）司天台，秩从五品”，“至元八年七月，设回回司天台官属，以扎马鲁丁为提点”。回回司天台由 37 人组成：提点 1 员，司天监 3 员，少监 2 员，监丞 2 员，品秩分别为正四品、正五品、正六品；知事 1 员、令史 2 员，通事兼知印 1 人，奏差 1 人；属官：教授 1 员，天文科管勾 1 员，算历科管勾 1 员，三式科管勾 1 员，测验科管勾 1 员，漏刻科管勾 1 员，阴阳人 18 人。

从上都承应阙遗址的相关报道中我们可以知道，现在的遗址由东、中、西 3 组 5 个建筑面组成，东边的那一组有两个建筑面，南北排列，分别叫做东前台和东后台；中间那一组为一个建筑面；西边的那一组也有两个建筑面，与东台对称，分别叫西前台和西后台。这个遗址在上都内城的北墙正中内侧，向里凸出。在东后台和西后台上，各设有一个小房子，应当是当时的工作人员进行研究和工作的地方。

左图为梵蒂冈 1996 年 3 月 15 发行的《马可·波罗游记》纪念邮票小型张
右图为马可·波罗从忽必烈大汗手中接受金圣书的邮票
Left: *The Travels of Marco Polo* mini souvenir sheet issued by Vatican on March 15, 1996
Right: A stamp of Marco Polo receiving the golden holy book from Kublai Khan

马可·波罗游记
The Travels of Marco Polo

马可·波罗（1254—1324）是中世纪意大利旅行家。他 1271 年随父亲和叔叔由陆路东行，历时 4 年，于 1275 年到达元朝大都（今北京）。他在中国游历了 17 年，1291 年离华由海路返回威尼斯。由马可·波罗口述，好友鲁斯蒂谦诺（Rustichello）用法语记录整理，于 1299 年编撰的《马可·波罗游记》一经出版，又一次点燃了西方世界追逐东方黄金梦的激情。此书也随之变为了东方探险的“领航图”。马可·波罗从泉州乘船西行，经波斯返回威尼斯的这段海上游历，也为中世纪欧洲留下了重要的东方航海信息。马可·波罗当时是搭乘中国航海家驾驶的船舶回去的，在《马可·波罗游记》中记载了当时中国海船和航海的情况，海船由马六甲海峡进入广袤的印度洋后，便有了北极星高度的记录。此书记述马可·波罗到达印度西岸马里八儿（今马拉巴）时写有“在此国中，看见北极星更为清晰，可在水平面二肘上见之”，可见那时我国航海家已经掌握了牵星术。1887 年，其后人向美国国会图书馆捐赠的一箱 14 份 13 世纪的羊皮纸资料中有 5 幅据说是马可·波罗曾拥有的航海图。这些航海图为人们提供了非常难得的 13 世纪中欧海上丝绸之路的远航视野。

Marco Polo (1254 A.D.–1324 A.D.) was an Italian traveler in the middle Ages. In 1271 A.D., he traveled east by land with his father and uncle. Four years later, in 1275 A.D., they arrived in Dadu (present-day Beijing) of the Yuan Dynasty. He traveled around China for 17 years and returned to Venice by sea in 1291 A.D. Marco Polo dictated an account of his travels to his good friend Rustichello da Pisa who then wrote *The Travels of Marco Polo* in French in 1299 A.D. With the publication of this book, once again kindled the passion of the western world to pursue the oriental golden dream and the book became the "pilot chart" of oriental explorations. Marco Polo set sail west on a boat steered by Chinese navigators from Quanzhou to Venice via Persia, which also left important oriental navigational messages for the medieval Europe. *The Travels of Marco Polo* recorded the Chinese seacrafts and navigational situation at that time. After the seacraft entered the vast Indian Ocean through the Malacca Strait, there were records of the height of Polaris. When the seacraft arrived in Melibar (present-day Malabar), the western shoreline of India, he recorded "in this country you see more of the North Star, for it shows two cubits above the water". From this it can be inferred that Chinese navigators had mastered star-guided ocean crossing technique by then. In 1887 A.D., his descendants donated a box of 14 parchment documents in the 13th century to the U.S.Library of Congress, five of which were said to be Marco Polo's nautical charts, providing people with a very rare overview on an epic journey between Europe and China along the maritime Silk Road in the 13th century.

马可·波罗
Marco Polo
(1254—1324)

《马可·波罗游记》插图

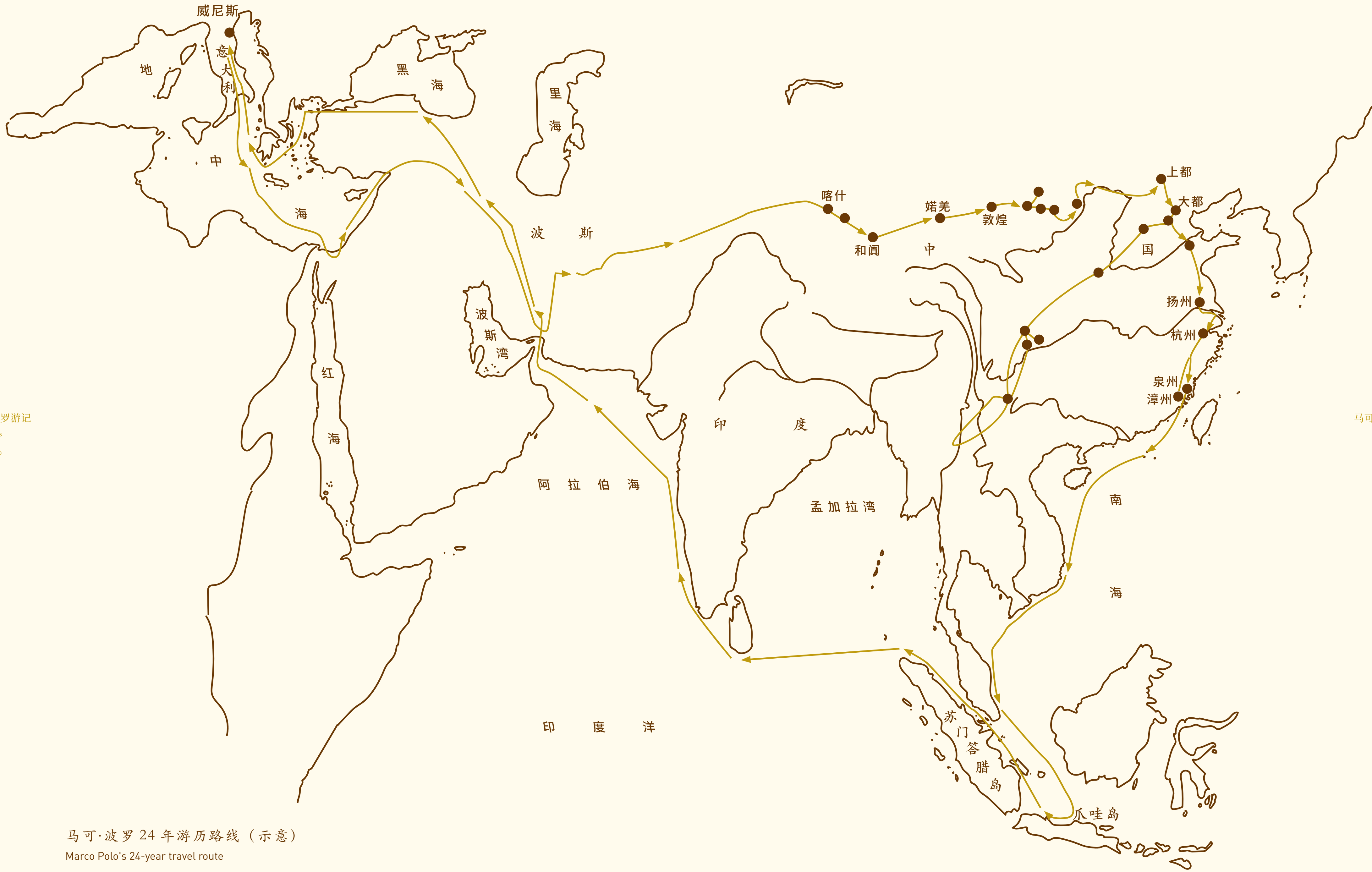
An illustration from *The Travels of Marco Polo*

马可·波罗与父亲尼科洛·波罗、叔叔马泰奥·波罗来中国时，向忽必烈大汗献上一本书和一个十字架。

《马可·波罗游记》插图

An illustration from *The Travels of Marco Polo*

忽必烈给马可·波罗的父亲和叔叔两兄弟颁发金牌。



马可·波罗 24 年游历路线（示意）

Marco Polo's 24-year travel route

郑和下西洋
Zheng He's Expeditionary Voyages

郑和（1371—1433），别称“三保太监”，昆阳（今云南晋宁）人，世奉伊斯兰教。郑和远航，史称“郑和下西洋”。明永乐三年（1405）至明宣德八年（1433）28 年间，受明朝皇帝派遣，郑和率 200 多艘船、27 000 人的庞大船队七下西洋，经过中国南海、西南太平洋、印度洋，到达东南亚、红海和非洲东海岸，访问了亚洲、非洲 30 多个国家和地区，促进了明朝同东南亚以及非洲各国的海上贸易和文化交流。

船队能够顺利完成航行目标体现了中国古代航海技术的高超成就。郑和大航海综合应用了天文导航（过洋牵星术）、罗盘导航、陆标导航、地文导航等多种导航手段。当时在海船上使用水罗盘来指认方向，后来又引入了旱罗盘。郑和的船队使用过洋牵星术，即利用牵星板观测太阳或北极星和其他星辰的高度来确定航位。因为他们主要是沿岸行驶，在有地貌特征处他们采用陆标观测（沿途岛屿地貌特征），在无地貌特征的海域他们就采用过洋牵星术确定航位，再加上通过水文测量（水深和海底泥沙），对照以往的航海日志和针路图，来确定船队的具体位置。

郑和下西洋开辟了亚非的洲际航线，对西太平洋和印度洋进行了海洋考察，搜集和掌握了大量海洋科学数据。《郑和航海图》就是根据大量海洋调查结果绘制而成的。《郑和航海图》的精髓在于其“不拘比例”，收放得宜，能在尺幅之间，蕴藏几万里之航程。英国著名科技史学家李约瑟在《中国科技史》中对《郑和航海图》作了高度评价，认为“它是世界上最早的一幅真正科学的海图”。

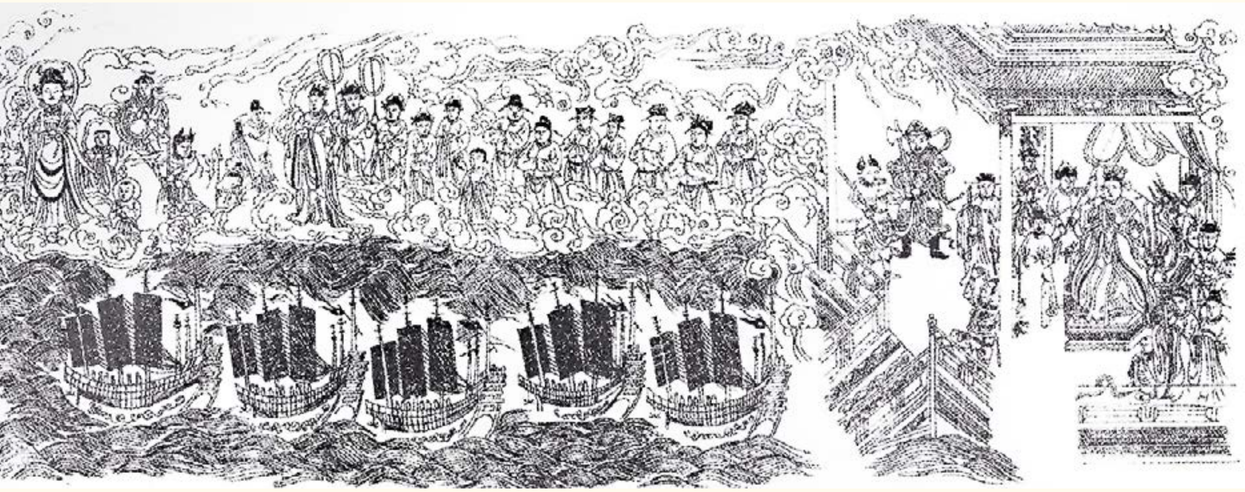
Zheng He (1371 A.D.–1433 A.D.), also known as "Triratna Eunuch", was a native of Kunyang (present-day Jinning, Yunnan province). He was born in a Muslim family. Zheng He's voyages, historically known as "Zheng He's expeditionary voyages to the western ocean" reached Southeast Asia, the Red Sea and East Africa via the South China Sea, the Southwest Pacific and Indian Ocean from the 3rd year of the Yongle Period of Ming (1405 A.D.) to the 8th year of the Xuande Period of Ming (1433 A.D.). Sent by the Ming Emperors, Zheng He conducted seven voyages to the western ocean and visited more than 30 countries and regions in Asia and Africa over 28 years with a large fleet of more than 200 vessels and 27,000 people, which promoted the maritime trade and cultural exchanges between the Ming Dynasty, Southeast Asia and African countries.

The accomplishment of the voyages embodied the superb achievements of the ancient Chinese navigation techniques. Zheng He comprehensively applied various navigation methods such as astronomical navigation (star-guided ocean crossing technique), compass navigation and landmark navigation to his great voyages. The water compass was then used on the sea vessels to determine the direction and the dry compass was later introduced. Zheng He's fleet employed star-guided ocean crossing technique, that is, the Chinese latitude hook to determine the latitude by observing the sun or Polaris, etc. As they mainly traveled along the coast, they adopted the landmark navigation where there were geomorphic features, while they adopted star-guided ocean crossing technique to determine the location where there were not. Together with the hydrological survey (water depth and seabed sediment), specific position of the fleet could be confirmed in comparison with the previous log and needle chart.

Zheng He's voyages opened up the intercontinental routes between Asia and Africa. He conducted ocean expeditions to the Western Pacific and India Ocean where he collected a large number of data on marine science. *Zheng He's Nautical Chart* was drawn on the basis of a large number of ocean surveys. The essence of *Zheng He's Nautical Chart* is that it's "not stick to the scale", which means it varies properly in scale. It can be scaled down to hold tens of thousands of miles in one of a set of the chart. Joseph Needham, a famous British historian of science, spoke highly of *Zheng He's nautical chart* in *The History of Chinese Science and Technology*: "it is the world's first true scientific nautical chart."

郑和宝船复原图
Image of a restored Zheng He's treasure vessel

郑和
Zheng He
(1371—1433)



▲《天妃经》卷首郑和下西洋插图描摹复原图（局部）
Illustration of Zheng He's expeditionary voyages, as a prelude to the *Taoist Canon of the Princess of Heaven* (part)
成书于 1420 年的《天妃经》卷首郑和下西洋插图描摹复原图，是迄今发现最早的郑和下西洋船队的图像资料。

▶ 四川大学张箭教授《郑和航海图的复原》
Zheng He's Nautical Chart restored by Prof. Zhang Jian of Sichuan University

敕封护国庇民妙灵昭应弘仁普济天妃之神，威灵布于钜海，功德著于太常，尚矣。和等自永乐初奉使诸番，今经七次。每统领官兵数万人，海船百余艘，自太仓开洋，由占城国、暹罗国、爪哇国、柯枝国、古里国，抵于西域忽鲁谟斯等三十余国，涉沧溟十万余里。观夫鲸波接天，浩浩无涯，或烟雾之溟濛，或风浪之崔嵬。海洋之状，变态无时，而我之云帆高张，昼夜星驰，非仗神功，曷克康济？直有险阻，一称神号，感应如响，即有神灯烛于帆樯。灵光一临，则变险为夷，舟师恬然，咸保无虞，此神功之大概也。

——郑和太仓《通番事迹之记》碑

《郑和航海图》现存于明代茅元仪编辑的《武备志》，图的原名是《自宝船厂开船从龙江关出水直抵外国诸番图》，包括普通的航海图 40 页，专用的过洋牵星图 4 页。

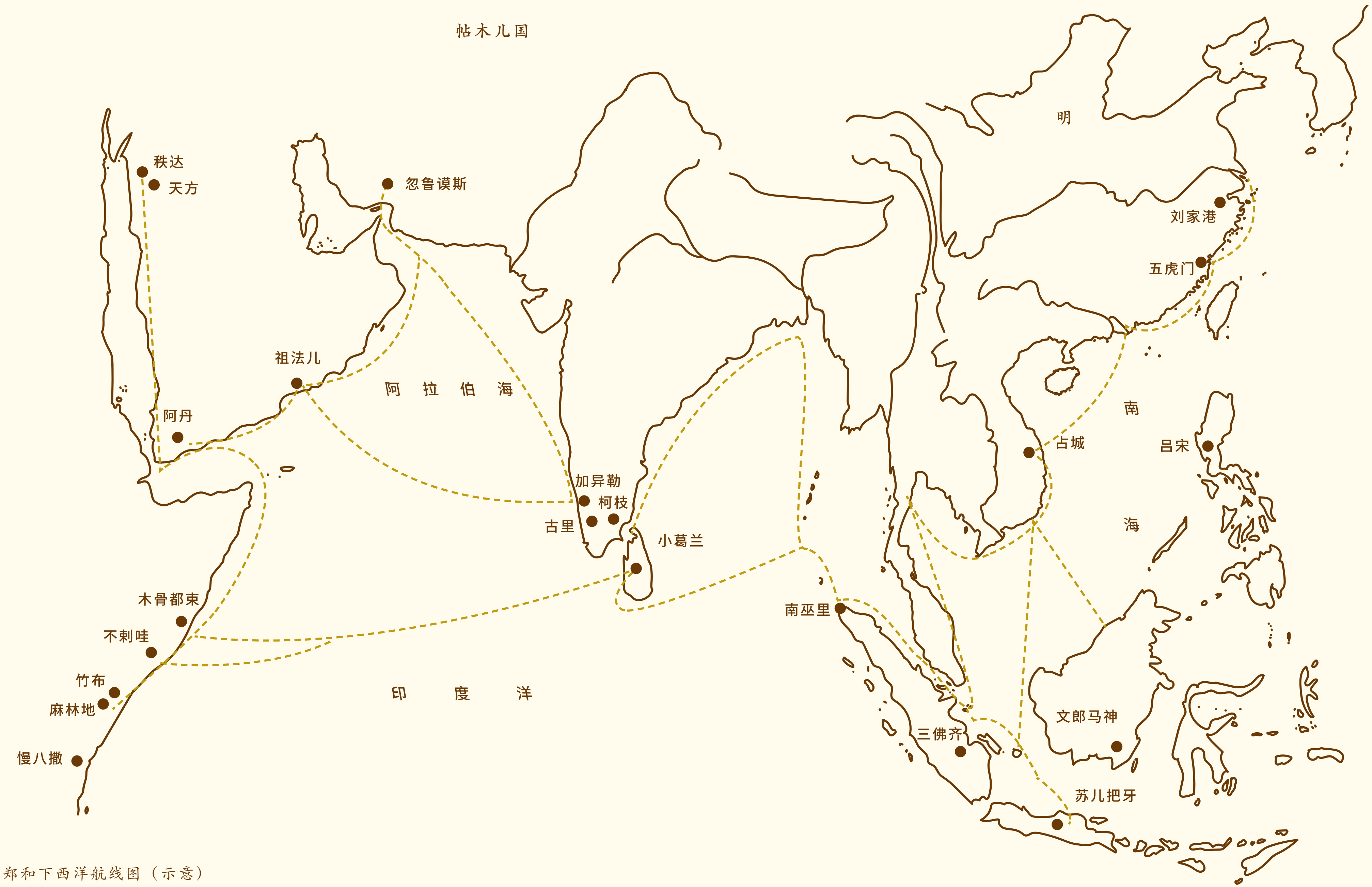
普通航海图主要内容有：大陆海岸线、岛屿、浅滩、礁石、港口、江河入海口，沿海城镇、山峰，作为陆标的宝塔、寺庙、桥梁、旗杆等各种地理名称及地物名称的标识注记。

《郑和航海图》展示的航线相当完整。它以今江苏南京为起点，出长江口沿海岸向南，绕过中南半岛、马来半岛，穿过今马六甲海峡，经锡兰山（今斯里兰卡）到印度洋的溜山国（今马尔代夫群岛），从溜山国开始航线分为两支：一支是横跨印度洋到非洲东岸的木骨都束（今索马里的摩加迪沙）；另一支是穿过阿拉伯海至忽鲁谟斯（位于今霍尔木兹海峡北部）。航海图的最后一页是忽鲁谟斯，图中标示的最远点是非洲东岸的麻林地（今肯尼亚共和国的马林迪）。

《郑和航海图》有详细的针路注记。航线上的针位注记，一般包括从某地什么针位多少航程到某地，如“船平大甘，小甘外过，用丹艮针，四更，船平大武山。”这里“丹艮”是针位，“四更”是航程。有的针路注记还有航道深度、礁石分布及其他航行说明等，如“船取孝顺洋，一路打水九托，平九山，对九山，西南边有一沉礁，打浪”。在印度洋的航海图图幅中，还注有牵星数据，如“丁得把昔开到忽鲁谟斯，看北辰星，十四指”。

从航海史方面来说，《郑和航海图》有详细的针路图和过洋牵星图等资料，是反映明代早期海上导航的宝贵资料，也是研究当时航海技术水平的重要资料。航海图详细注记了五百多个地名，其地理范围之广、地名之多，是当时其他图籍所不及的。故据此还可以研究明代早期我国对东南亚、印度洋沿岸的地理认识。从海图发展史方面及制图学方面来说，《郑和航海图》的意义也是十分重要的。

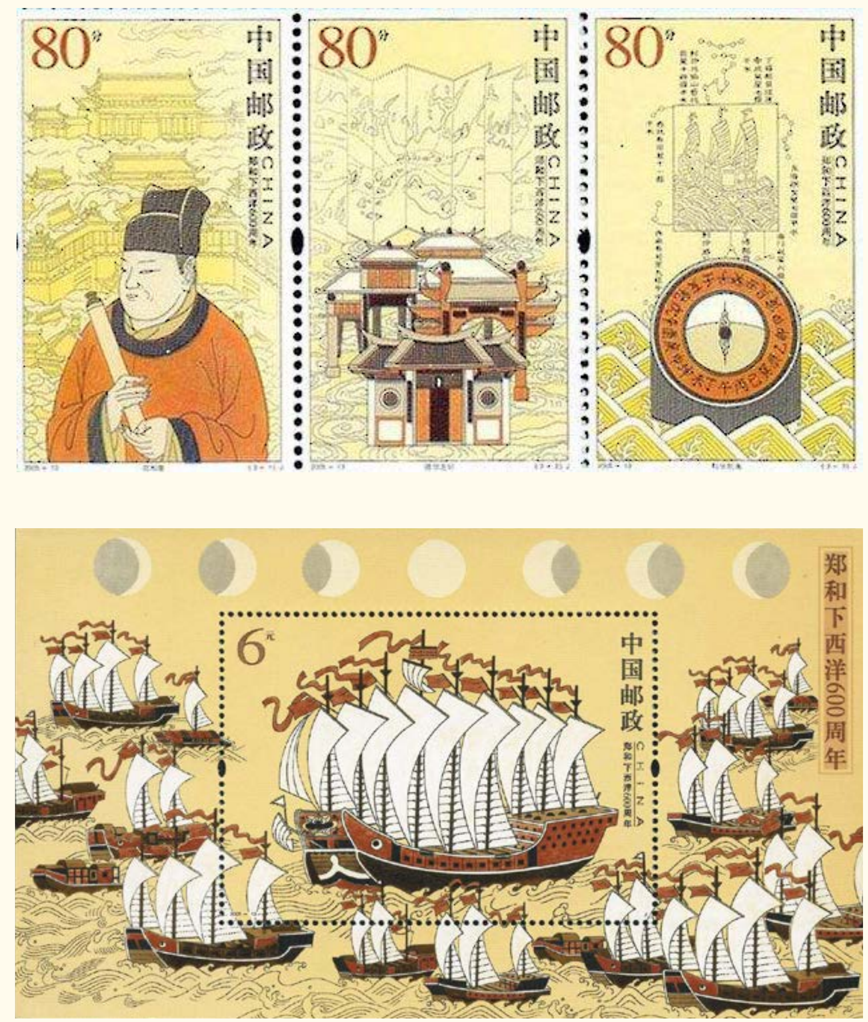
中国古代导航技术
ANCIENT CHINESE
NAVIGATION TECHNOLOGY



郑和下西洋航线图（示意）
Route map of Zheng He's expeditionary voyages

1985 年中国发行的《郑和下西洋 580 周年》纪念邮票

The 580th Anniversary of Zheng He's Expeditionary Voyages souvenir sheet issued by China in 1985



2005 年中国发行的《郑和下西洋 600 周年》纪念邮票和小型张

The 600th Anniversary of Zheng He's Expeditionary Voyages souvenir sheet and minisheet issued by China in 2005

▼ 郑和下西洋和西方三次大航海活动比较

The comparison of Zheng He's expeditionary voyages and the three major voyages by Europeans

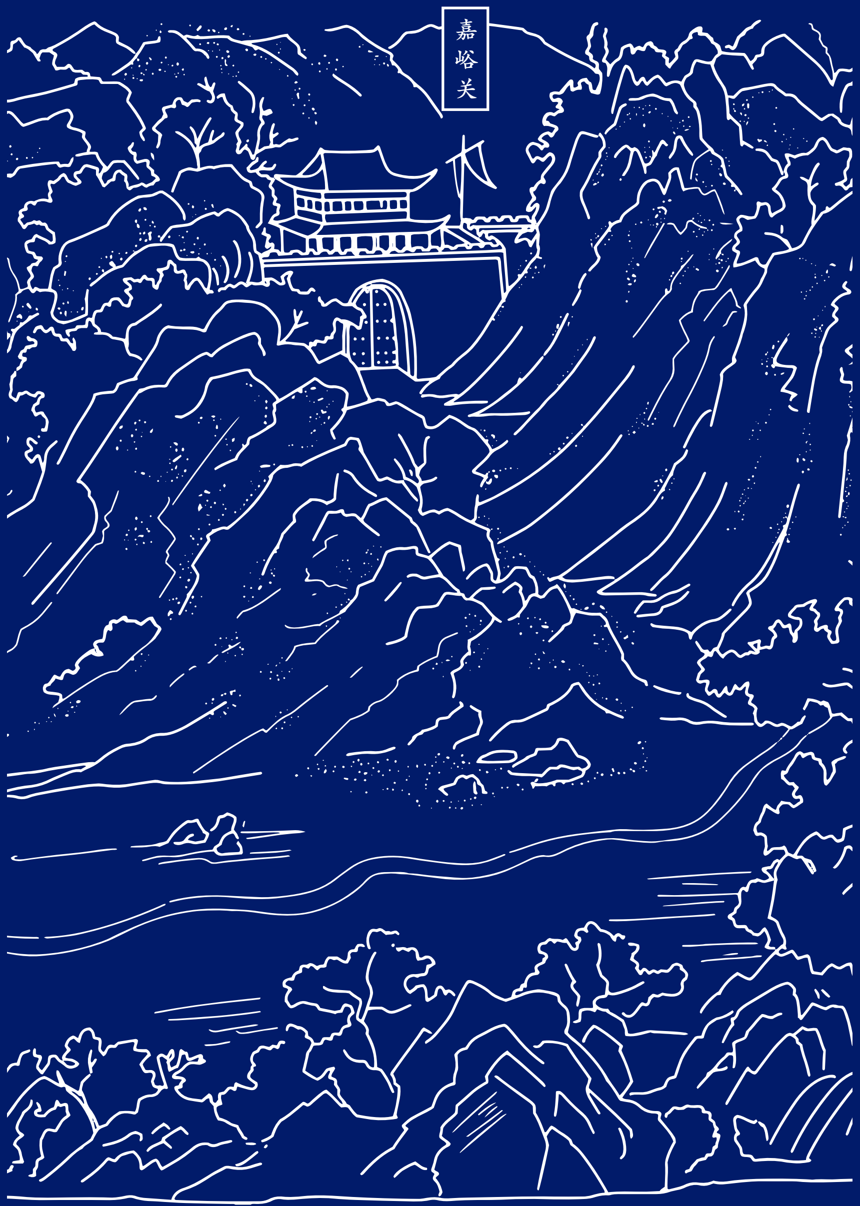
航海家、探险家	国　家	时　间	目　的	航　线	船队规模	人　数	造船技术	航海技术
郑和	中国（明）	1405—1433年，七次下西洋	主要是政治目的：宣扬国威，播撒友谊	从中国东南沿海出发，沿海岸线南行，穿越东南亚群岛西行，一路向西斜穿印度洋，最远抵非洲东海岸，另一路穿过阿拉伯海至霍尔木兹海峡北部。再原路返回	每次大小船200多艘。其中超百米长的宝船超50艘，大宝船排水量达数千吨	首次27 800人，每次都在27 000人左右	多桅多杆，便于使风，平底吃水浅，快航敏捷，水密隔舱壁，稳定安全	牵星术，罗盘，针路，郑和航海图，燃香计时计程，天文测时，测深，水文，陆标导航，流木法计程
哥伦布	意大利人，航海活动获西班牙王室支持	1492—1504年，四次西航美洲	主要是经济目的：殖民掠夺，攫取暴利。麦哲伦环球航行除了寻找绕过南美去亚洲香料群岛的新航线，还有一个目的是验证“地圆说”	从西班牙出发，向西横渡大西洋，抵达美洲。再向东横渡大西洋返回	首次3只小船，最大船长约25米，排水量达百十来吨。四次总计30多艘船，大船排水量达二三百吨	首次88人，四次总计1 700多人	三桅四角帆，体积小，轻巧灵活。配备火炮火枪	等纬航行法，罗盘，象限仪，沙漏计时，天文测时，星盘，指向标，测深，发现磁偏角并用于航迹推算，水文，海图
达·伽马	葡萄牙人，受葡萄牙王室派遣远航印度	1497—1524年，三次东航印度		从葡萄牙出发，沿非洲西海岸线南行，绕过非洲南端好望角，再沿非洲东海岸线北行至莫桑比克，向东横穿印度洋，抵达印度。再原路返回	首次4艘小型船，第二次23艘，大船排水量达二三百吨	首次170人		海图，罗盘，象限仪，沙漏计时，天文测时，星盘，指向标，测深，水文
麦哲伦	葡萄牙人，后入西班牙籍，航海活动获得西班牙王室的支持	1519—1522年，首次环球航行（1521年4月麦哲伦死于菲律宾）		从西班牙出发，向西横渡大西洋，绕过南美洲，向西横渡太平洋，穿过马来群岛，向西横渡印度洋，绕过非洲好望角，回到欧洲。首次环球航行，一路向西	5艘小型船，旗舰“特里尼达”号排水量为110吨	256人（一说234人）	多层甲板，3根以上桅杆。配备火炮火枪	海图，象限仪、指南针，沙漏计时，天文测时，星盘，指向标，测深，水文

▶ 丝路山水地图
Silk Road Landscape Map

丝路山水地图
Silk Road Landscape Map

丝路山水地图是一幅明朝宫廷的皇家地图，大约绘制于明嘉靖三年至十八年（1524—1539）之间，现收藏于北京故宫博物院。藏品尺寸为宽 0.59 米、长 30.12 米。它是一幅供明朝内府使用的青绿山水手卷。它描绘了东起嘉峪关西至天方城（今沙特麦加）的辽阔地域范围。这幅地图蕴含了大量的地理信息，共绘制了 211 个西域地名，包括了丝路上的许多重要城市，如中国的敦煌（沙州城）、乌兹别克斯坦的撒马尔罕（撒马儿罕城，其中“望星楼”，就是今乌兹别克斯坦的“兀鲁伯天文台”）、阿富汗的赫拉特（黑楼城）、伊朗的伊斯法罕（牙思城）、叙利亚的大马士革（哈密）、沙特阿拉伯的麦加（天方国）等都有清晰的标注。该地图全面反映了延续千年的丝绸之路在明代中期的辉煌场景。

It is a royal map in the Ming Dynasty's court, approximately drawn between the third year to the eighteenth year of the Jiajing Period (1524 A.D. –1539 A.D.) of the Ming Dynasty. It is now housed in the Palace Museum in Beijing. The green-colored landscape scroll used within the Ming Imperial Household Department is 30.12 meters long and 0.59 meters wide. It depicts a vast geographic range from Jiayuguan Pass in the east to Tianfang City (present-day the holy city of Mecca in Saudi Arabia) in the west. This map is filled with a large amount of geographical information with the clear marks of as many as 211 western toponyms including many important cities along the Silk Road such as Dunhuang (Shazhou City) in China, Samarkand ("Stargazing Pavilion", present-day "Ulugh Beg Astronomy Observatory") in Uzbekistan, Herat (Heilou City) in Afghanistan, Isfahan (Yasi City) in Iran, Damascus (Hami) in Syrian and Mecca (the Kingdom of Tianfang) in Saudi Arabia. This scroll comprehensively reflects the glorious scenes during the mid-Ming Dynasty along the Silk Road which lasted for more than a thousand years.



丝路山水地图（局部）
Silk Road Landscape Map (part)

利玛窦在中国
Matteo Ricci in China

利玛窦（1552—1610），意大利耶稣会传教士、学者，明朝万历十年（1582）来到中国传教，在中国生活了 28 年直至去世。其原名 Matteo Ricci，中文直译为玛提欧·利奇，利玛窦是他的中文名字。在中国，利玛窦广交官员和社会名流，传播西方天文、数学、地理等科学技术知识。他将西方地图投影方法传入了中国，绘制了 10 多种世界地图。他测定了中国许多城市的经纬度坐标，将世界各地的许多地名译为中文，有的甚至沿用至今，比如“大西洋”“地中海”“古巴”“加拿大”等。

万历二十九年（1601），利玛窦到京师进献自制的《山海舆地全图》。万历三十年（1602），太仆寺少卿李之藻和利玛窦绘制成《坤舆万国全图》，木版刻印出版。

该地图原图已佚，现仅存 6 幅副本，这 6 幅副本是根据李之藻 1602 年单色六条屏刻印的版本。现藏于美国明尼苏达大学的《坤舆万国全图》是六幅副本中保存较为完好的两幅之一，它由六条屏装裱为一大幅，无着色。它是中国第一幅采用西方绘图技术的世界地图，也是现存最早出现美洲的中文地图。它将亚洲东部居于世界地图的中央，开创了中国绘制世界地图的先例。另有彩色摹绘版存于南京博物院。

Matteo Ricci (1552 A.D.–1610 A.D.) was an Italian Jesuit missionary and a scholar. He began his missionary work in China in the 10th year of the Wanli Period in the Ming Dynasty (1582 A.D.), where he had lived for 28 years until his death. Li Madou was his Chinese name. Matteo Ricci made extensive contacts with officials and elites to spread western scientific and technological knowledge of astronomy, mathematics and geography. He introduced the western map projection to China and drew more than 10 world maps. He also measured the longitude and latitude coordinates of many cities in China and translated many foreign toponyms into Chinese. Some of the toponyms he translated such as "Atlantic" "Mediterranean" "Cuba" and "Canada" are still in use today.

In the 29th year of the Wanli Period (1601 A.D.), Matteo Ricci went to the capital Beijing to offer his self-made *Shanhai Yudi Quantu* map. In the 30th year of the Wanli Period, he collaborated with official Li Zhizao to create *Kunyu Wanguo Quantu* (*The Great Universal Geographic Map*) which was woodblock printed.

The original map now is lost, only six copies of which are known to exit. They are the copies of Li Zhizao's map printed in 1602 in brownish ink on six paper panels. *Kunyu Wanguo Quantu* now housed in the University of Minnesota is one of the two well-preserved maps of these six original copies. Mounted on one large paper, the pigment-free map is the first world map in China that uses western mapping techniques as well as the earliest extant map in Chinese to show the Americas. It also shows East Asia at the center of the world map, setting a precedent for the world map drawn in Chinese. There is also a colored copy in Nanjing Museum.

利玛窦
Matteo Ricci
（1552 —1610）

利玛窦像，新加坡国家文物局藏

Portrait of Matteo Ricci, a collection of National Heritage Board of Singapore

意大利和梵蒂冈发行的利玛窦纪念邮票

Matteo Ricci souvenir sheet issued by Italy and Vatican

左 1 图为意大利 2002 年 4 月 20 日发行的“传教士利玛窦诞生 450 周年”邮票 1 枚，图案为身着明朝士人服装的利玛窦，背景为他送给万历皇帝的《山海舆地全图》。右 2 图为梵蒂冈 2010 年 6 月 22 日发行的利玛窦神父逝世 400 周年纪念邮票 2 枚。图案分别为“利玛窦神父与徐光启在一起”和“利玛窦像”。

《坤舆万国全图》是中国第一幅完整的世界地图。它在地理学和制图学界具有重要位置。该地图经多次翻印摹抄，影响深远。

《坤舆万国全图》其内容大致分作三部分：主图是椭圆形的世界地图、四个角的天文图和地理图以及题跋解释说明的文字。

主图为世界地图，显示了五大洲的相对位置，中国居于图的中心；山脉以立体形象表示，海洋用密密的波纹表示；南极洲画得很大。在该图的空隙处填写了与地名有关的附注性说明，其中两篇为利玛窦署名，介绍地球知识与西洋绘图法。主图采用的是等积投影，经线为对称的弧线，纬线为平行直线。

右上角有九重天图，右下角有天地仪图，左上角有赤道北地半球之图和日、月食图，左下角有赤道南地半球之图和中气图，另有量天尺图附于主图内左下方。全图的文字，大约可以分为五类：

一是地名，有 1 114 个地名；

二是题识，有利玛窦、李之藻、吴中明、陈民志、杨景淳、祁光宗共 6 篇；

三是说明，包括全图、九重天、四行论、昼夜长短、天地仪、量天尺、日月蚀、中气、南北二半球等的说明；

四是表，有总论横度里分表、太阳出入赤道纬度表；

五是附注，对各洲的自然地理和人文地理进行解说。

《坤舆万国全图》[明万历年间绘制；整幅（六屏）约 167.5 厘米 ×371.2 厘米，每幅约 167 厘米 ×61.5 厘米或更小；比例尺约为 1:12 500 000]

Kunyu Wanguo Quantu [drew during the Wanli Period in the Ming Dynasty; the map (six paper panels) is about 167.5 cm × 371.2 cm with each panel about 167 cm × 61.5 cm or smaller; the scale is about 1:12500000.]

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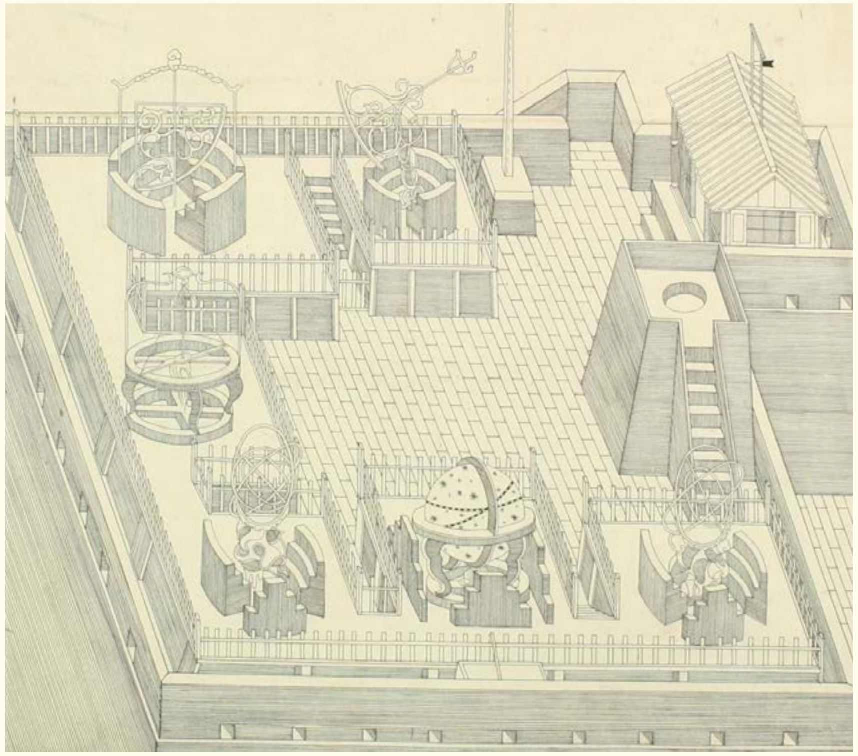
北京古观象台
Beijing Ancient Observatory

北京古观象台建于明正统七年（1442），当时被称为“观星台”，平台上设置有简仪、浑仪和浑象等大型天文仪器，平台下陈设有计时工具圭表和漏壶等。清代时观星台改称“观象台”，康熙和乾隆年间，先后由西方传教士南怀仁、纪理安和戴进贤等制作了8件铜制的大型天文仪器：赤道经纬仪、黄道经纬仪、天体仪、纪限仪、象限仪、地平经仪、地平经纬仪和玑衡抚辰仪。1911年辛亥革命后，观象台改名为中央观象台，1929年改为国立天文陈列馆。从明正统七年到1929年止，古观象台从事天文观测488年，是现存古观象台中连续观测年代最长的。古观象台还以建筑完整和仪器配套齐全，在国际上久负盛名。清制8件铜制仪器除了造型、花饰、工艺等方面具有中国传统外，在刻度、游表、结构等方面，还反映了西方文艺复兴时期以后世界大型天文仪器的进展和成就。这些天文仪器成为东西方科学文化交流的历史见证。

Beijing Ancient Observatory was built in the 7th year of the Zhengtong Period of the Ming Dynasty (1442 A.D.). It was then called "Guanxing Tai" ("Stargazing Observatory"). Several large astronomical instruments were placed on the platform, such as the Abridged Armilla, the Armillary Sphere, and the Celestial Sphere, whereas the timing instruments, such as the gnomon and clepsydra were placed below. In the Qing Dynasty, "Guanxing Tai" was renamed "Guanxiang Tai" ("Astronomy Observatory"). During the reign of Emperor Kangxi and Emperor Qianlong of Qing, the western missionaries Ferdinand Verbiest, Kilian Stumpf and Ignaz Kōgle successively designed eight large bronze astronomical instruments which were the Equatorial Armillary Sphere, the Ecliptic Armillary Sphere, the Celestial Instrument, Sextant, Quadrant Muralis, the Horizon Circle, the Altazimuth, and the Elaborate Equatorial Armillary Sphere. After the Revolution of 1911, "Guanxiang Tai" was renamed "Central Guanxiang Tai" and later "National Museum of Astronomy" in 1929. From the 7th year of the Zhengtong Period of Ming to 1929, the Ancient Observatory had been engaged in astronomical observation for 488 years, the longest standing record for continuous observation among the extant ancient observatories. The Ancient Observatory has long been enjoying a good reputation worldwide for its completeness in structure and instrumental equipment. In addition to the Chinese tradition in the aspects of modelling, pattern and fabrication, the eight bronze instruments made in the Qing Dynasty also reflect the post-Renaissance achievements in the large astronomical instruments in aspects of scale, table and structure. These astronomical instruments are historical testimony to the scientific and cultural exchanges between the East and the West.



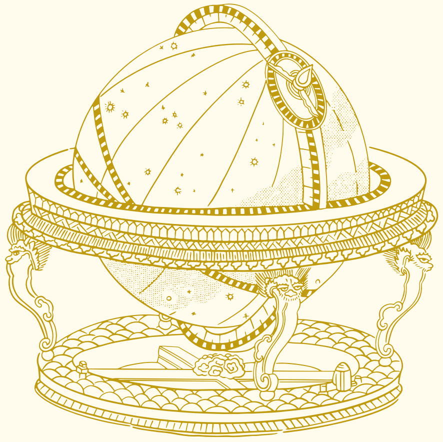
南怀仁《仪象图》
Illustration of Astronomical Instruments by Ferdinand Verbiest

南怀仁（Ferdinand Verbiest，1623—1688），比利时人，1658年来华。他是康熙皇帝的科学启蒙老师，精通天文历法。1674年，南怀仁由康熙皇帝授命，设计并监造完成了6架天文仪器，替换了观星台上的明制诸仪。南怀仁为配合新仪器，绘制《仪象图》115幅，第一幅即此陈列布置图。

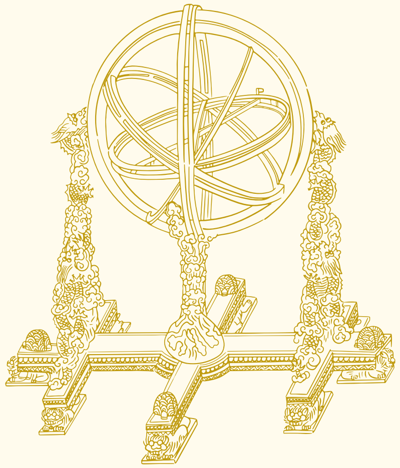
此图中6件大型仪器，从前排右到左，顺时针依序为：赤道经纬仪、天体仪、黄道经纬仪、地平经仪、象限仪（地平纬仪）、纪限仪（距度仪）。

康熙五十二年至五十四年（1713—1715），法国耶稣会传教士纪理安设计并制造了地平经纬仪。乾隆九年，皇帝下令仿照古代浑仪制造新仪，由钦天监监正戴进贤和刘松龄监造，历经十年于乾隆十九年（1754）完成。乾隆亲自命名为“玑衡抚辰仪”。它是清代铸造的最后一件大型天文仪器。

《日月合璧五星联珠图》纸本设色，纵 48.9 厘米，横 1342.6 厘米
Fine brushwork painting of *the Assembly of the Sun, the Moon and Five Planets* with 48.9 cm in length and 1342.6 cm in width



天体仪
The Celestial Instrument



玑衡抚辰仪
The Elaborate Equatorial Armillary Sphere

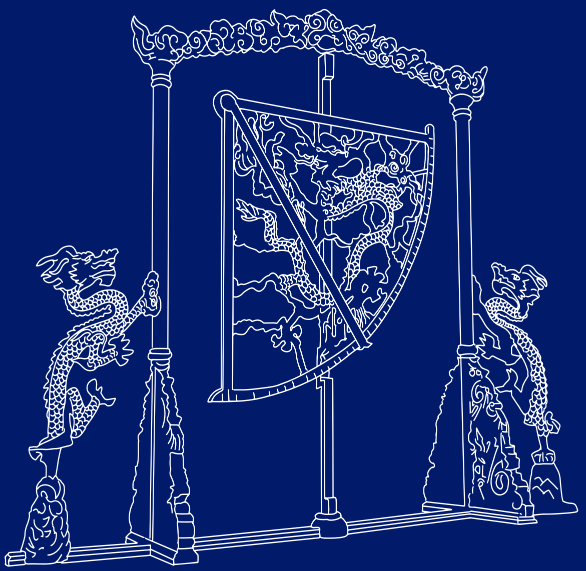
乾隆二十五年（1760）底，观象台钦天监勒尔森预测隔年正月初一（1761年 2 月 5 日）将出现"日月合璧，五星联珠"的祥瑞天象，徐扬奉命绘图记录而作此画。

画作里的观象台，即北京古观象台。乾隆二十六年（1761），观象台上应该有八件仪器，即南怀仁六仪、地平经纬仪、玑衡抚辰仪等，不知为何徐扬仅画了其中两件。

徐扬所绘的这两件仪器，在《皇朝礼器图式》里有详细的图文记载。天体仪，康熙十二年（1673）制成，是南怀仁六仪之一。玑衡抚辰仪，也叫精密赤道浑仪，乾隆十九年（1754）制成。

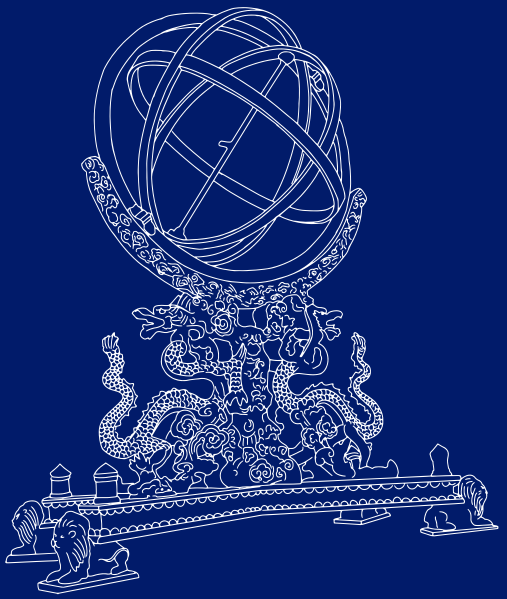
象限仪
The Quadrant Muralis

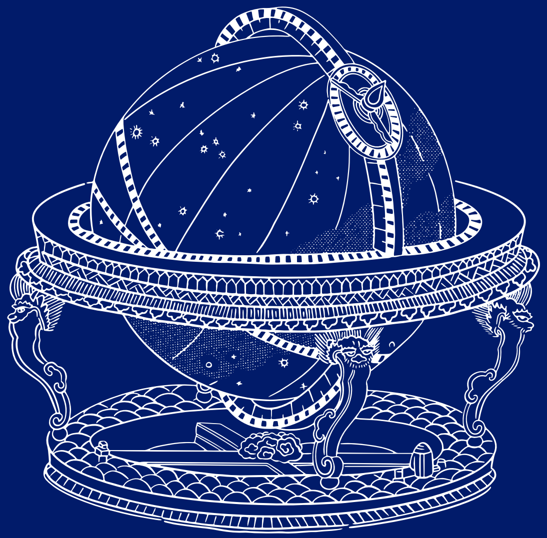
象限仪又称地平纬仪，主要由象限环、横表、竖轴、窥衡等部分组成。用来测量恒星的地平高度和天顶距。



黄道经纬仪
The Ecliptic Armillary Sphere

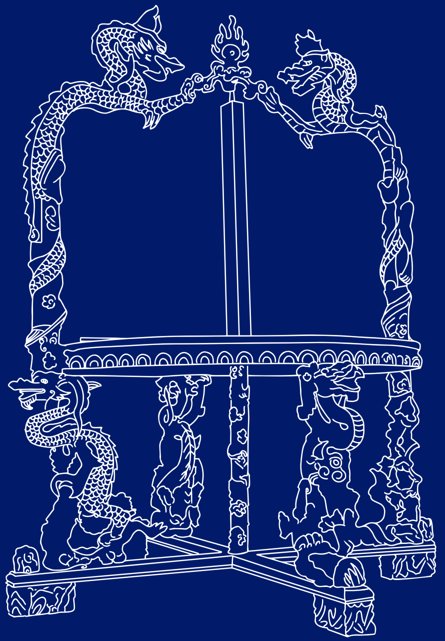
黄道经纬仪由子午圈、黄道圈、黄道经圈、极至圈等部分组成，主要是测定天体黄道经纬度和节气，对太阳和行星观测较为方便。





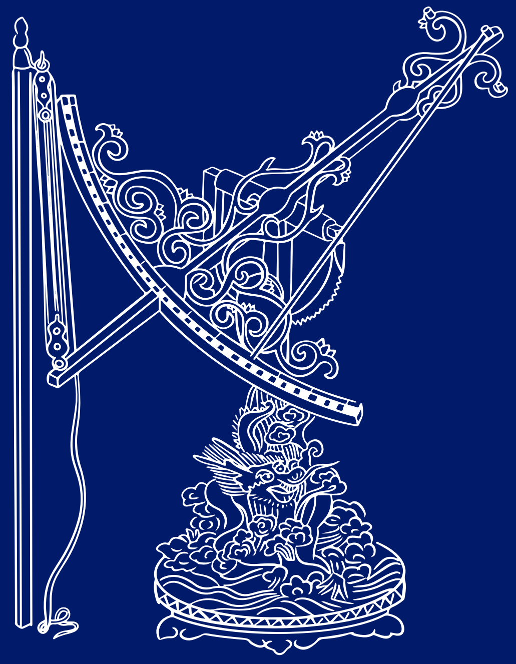
天体仪
The Celestial Instrument

天体仪即天球仪。直径六尺铜球，镶 1 888 颗大小不同的镀金铜星。子午圈连接齿弧，可调整北天极高度。通过转动时盘上的游标，可演示任意时刻天象及星体不同坐标的变换。



地平经仪
The Horizon Circle

地平经仪由地平圈、龙柱、铜柱支、立表、横表等组成。立表上端到横表两段有线，用以标准目标恒星。主要用于测量恒星地平经度。

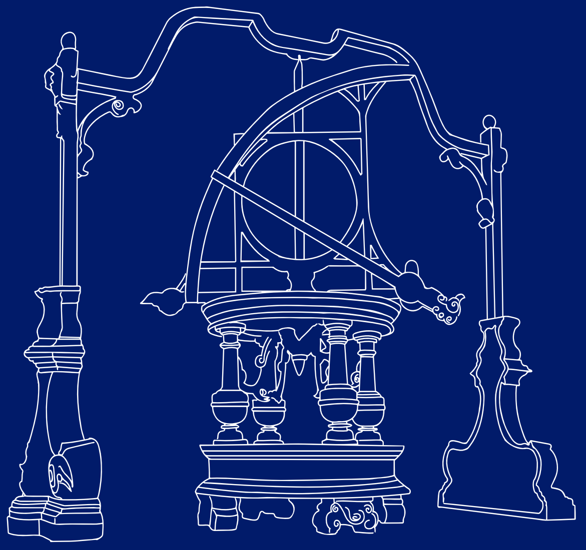


纪限仪
The Sextant

纪限仪又叫距度仪。由一可做三维运动的机械装置、滑车、手轮、半圆齿轮、窥衡和游表（已散失）等部分组成。用于测定任意两星之间（60度以内）的角距离。

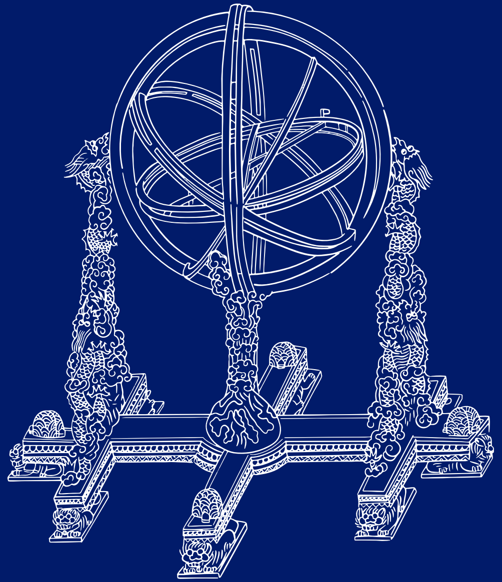
地平经纬仪
The Altazimuth

地平经纬仪由地平经仪和象限仪组合而成，减少了由于两架仪器测量所带来的误差。它的制造工艺比较特殊，表尺用黄铜做，嵌入仪面，而不是直接刻在仪器面上；立柱、横梁、仪身都无游云、升龙等装饰。主要用于测量天体的地平坐标。



赤道经纬仪
The Equatorial Armillary Sphere

赤道经纬仪由子午圈、赤经圈、赤道圈、象限弧和支架等部分组成。子午圈刻有去极度，从南极伸出两个象限弧支撑赤道圈（不能转）。主要为测量真太阳时和恒星的赤经赤纬。



玑衡抚辰仪
The Elaborate Equatorial Armillary Sphere

玑衡抚辰仪又称清代浑仪，实际是西法改造的浑仪。分为三重，最外重是子午圈（双环）和天常赤道，第二重是赤道经圈（双环），最里一重是四游圈（双环）。主要用来测天体的赤道坐标。

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结束语

Conclusion

悠久灿烂的中华文明创造了中国古代导航技术的辉煌成就：发明指南针，发展天文测向导航的“牵星术”，制造令世人惊叹的“水运仪象台”，总结出“制图六体”和“计里画方”的地图绘制方法，为世界导航技术的发展做出了重要贡献。同时，中国和世界各国的先贤们基于导航技术开辟了古丝绸之路和海上丝绸之路，促进了世界各国经济文化交流和人类进步发展。

回顾历史是为了更好地面向未来。当今，全球卫星导航定位技术蓬勃发展，北斗卫星导航系统助力“一带一路”互联互通，为促进世界各国贸易畅通和民心相通，构建人类命运共同体，推动全人类走向共同繁荣，发挥着越来越重要的作用。

The long-standing and splendid Chinese civilization has created the brilliant achievements in ancient Chinese navigation techniques. The invention of the compass, the development of astronavigation of "star-guided ocean crossing technique", the manufacture of the spectacular "water-driven astronomical clock tower" and the summarization of cartographic methods of "six principles of cartography" and "squared map with grid system and scale" made important contributions to the development of world's navigation technologies. At the same time, forerunners at home and abroad opened up the ancient Silk Road and the Maritime Silk Road by navigation techniques, which promoted economic and cultural exchanges and the progress of human beings around the world.

The review of history is to better face the future. Today, the global satellite navigation and positioning technology is flourishing. The Beidou Navigation Satellite System is dedicated to serve "One Belt One Road" initiative. It is playing an increasingly important role in boosting unimpeded global trade, building a community of shared future and promoting the common prosperity for all mankind.

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