The Plurality of Reception: Latitude and Longitude in Early Modern China, 1700–1900

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Abstract: Drawing on the social history of technology and the technological systems approach, this essay reconceptualizes latitude-longitude coordinates as part of an integrated sociocultural system. The latitude-longitude coordinate system was a technological innovation socially and culturally embedded in Europe. When the Jesuits brought this technology to early modern China, its reception, the author argues, was selective and did not follow a uniform pattern. Using maps and other materials, the essay chronicles the uneven reception of latitude-longitude coordinates across different strata of early modern China: various actors had their own reasons, from political to budgetary, to accept certain components of this technology while ignoring or even transforming other parts. Through the case of latitude-longitude coordinates, the essay reveals the complexity of technology transmission. Wider social milieus and specific agencies determine the many and various criteria for inclusion and exclusion.

"The areas that never built a relationship with China proper now are the subjects of our Great Qing. After searching past records, you would know that this is indeed an event of grandeur that did not exist before." Thus, in 1759, the Qianlong emperor (r. 1735–1796) proclaimed the annexation of Zungharia and the Tarim Basin.[1] The annexation not only sealed the Qing empire's (1644–1911) victory on the Eurasian steppes but also marked the completion of the final phase of its expansion. By the mid-eighteenth century, the Qing empire

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[1] *Qing shilu* 清實錄, 60 vols. (rpt.; Beijing: Zhonghua shuju, 1985), Vol. 16, pp. 702–703. (Here and throughout this essay, all translations into English are mine unless otherwise indicated.)

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had almost doubled the territory it had inherited from the Ming dynasty (1368–1644). For both ideological and utilitarian purposes, new maps had to be drawn to reflect these territorial changes. The Manchus had historically appreciated European missionaries' technological expertise and sought the help of the Jesuits in improving firearms amid the campaign to consolidate Qing control over China proper in the 1670s.[2] In the eighteenth century, the Manchu emperors commissioned the Jesuits to conduct on-site investigations across the country to produce new atlases. The Jesuits employed the technology of latitude-longitude coordinates in this specific mapmaking process.

The outcomes of the Jesuits' cartographic efforts were more than satisfying. The Manchu emperors and their ministers unanimously praised the superiority of the new atlases with latitude-longitude coordinates and readily consulted them when addressing military and diplomatic affairs. Despite the endorsement of policy makers, however, the reception of latitude-longitude coordinates in early modern China was a rocky process, which has been attributed to Chinese cartographers' reluctance to adopt the system. The broader social circumstances that conditioned mapmaking in early modern China thus have been mostly left out of consideration. The technological systems approach is a crucial feature in the historiography of the history of technology. The basis of this approach is Thomas Hughes's metaphor of a "seamless web." The term "system" could refer to a physical entity, such as the electrical grids that Hughes studied extensively. It could also be a less tangible structure, like cartels. On the macro level, any technology can be construed as an integrating part of a seamless web. Multiple interlocking factors contribute to the survival and development of a technology in a particular place and time.[3]

This essay takes such a holistic view in discussing the dissemination of latitude-longitude coordinates in China as a plural process. Historians have long noted that technologies are not value free and that systematic technology transfers were usually accompanied by sociocultural transformations. For example, Peter the Great created the Imperial Academy of Sciences in St. Petersburg not purely for the utilitarian purpose of importing Western European technologies. The academy was one element in his broader agenda to transform Russian society.[4] My study looks not only at the transregional dissemination of latitude-longitude coordinates but also at the dissemination of this technology within the social strata of the Qing empire, from the imperial court to common scholars. Different combinations of political, economic, and cultural factors determined that the reception of this technology in early modern China was uneven. Various strata of the empire were involved in the process in different ways, each selecting the part that best served its interests and ignoring or even transforming the rest.

Overall, there were manifold interlocking obstacles to the wide dissemination of latitude-longitude coordinates in early modern China. One was political. The archives of the Imperial Household Department (*Neiwu fu* 內務府) show that the Manchu emperors were fully aware of the utilitarian value of atlases with latitude-longitude coordinates and, before the mid-nineteenth

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[2] For the Jesuits' technological contributions to the consolidation of Manchu rule see Nicolas Di Cosmo, "Does the Gun Matter?" in *The Qing Formation in World-Historical Time*, ed. Lynn A. Struve (Cambridge, Mass.: Harvard Univ. Asia Center, 2004), pp. 151–161.

[3] For general discussions of the concept of technological systems and the metaphor of the "seamless web" see Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch, "General Introduction," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (rpt.; Cambridge, Mass.: MIT Press, 2012), pp. xli–xlii; and Hughes, "The Evolution of Large Technological Systems," *ibid.*, pp. 45–76. For a specific example of the use of the technological systems approach see Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (rpt.; Baltimore: Johns Hopkins Univ. Press, 1993).

[4] For the status of the St. Petersburg Academy of Sciences in Peter the Great's reformist vision see Michael D. Gordin, "The Importation of Being Earnest: The Early St. Petersburg Academy of Sciences," *Isis*, 2000, *1*:1–31.

century, cautiously restricted their circulation outside the imperial court. Meanwhile, Chinese society at large did not have a compelling need for more accurate maps with latitude-longitude coordinates. The dominant cosmological view of the flat Earth and dome-like heaven was another roadblock to accepting latitude-longitude coordinates, which are premised on the spherical Earth theory. There were a few exceptions, but the view of the flat Earth under the heavenly dome remained largely unchallenged in China until the second half of the nineteenth century. Pragmatically, cost was also an obstacle to the dissemination of latitude-longitude coordinates. In the late nineteenth century, with the growing popularity of the spherical Earth theory, a few scholars tried to use the technology of latitude-longitude coordinates to make maps. Although they were intellectually equipped to do the work, measuring latitudes and longitudes, which required enormous resources, was just a noble dream.

THE QUESTION OF SCALE

As Matthew Edney has argued, a series of universal concepts in mapping practice, including map scale, are modern inventions.[5] In early modern Europe and China, nonscale and scale maps coexisted. While the Europeans were navigating their overseas conquests through astronomical observation and marking locations with degrees of latitude and longitude, they did not stop producing nonscale maps. Indeed, until the eighteenth century, the Jesuits, who introduced latitude-longitude coordinates to China, were frustrated by the fact that European cartographers still relied on itinerary distances reported in travelogues to produce maps. This method, they claimed, would produce no map "with tolerable accuracy."[6]

There were Chinese cartographers who specialized in astronomical observation, but maps that indicated only the relative positions of places remained dominant until the late nineteenth century. These maps were widely used for urban planning, infrastructure building, long-distance travel, and so forth. Combining textual descriptions with graphical presentations, they could meet most of their readers' needs. *The Road Map of the Jiaxing Prefecture in Zhejiang Province* (*Zhejiang Jiaxing fu daoli tu* 浙江嘉興府道里圖) (see Figure 1) presents the Jiagxing prefecture and the counties in its jurisdiction in the late seventeenth or early eighteenth century. This administrative map uses travel distances to determine the location of one county in relation to its neighbors. For example, the location of Haiyan County 海鹽縣 is determined by the distances between its borders and the neighboring counties in the north, south, east, and west. The visual elements in this nonscale map are only indicative, but together with the mileages given in the bordered boxes they could give resident officials a good sense of their jurisdiction or help sojourning travelers to reconfirm their directions and estimate the time to their next stop.

Similarly, the lack of scale does not compromise the administrative utility of the *Maps of Wooden Dragons along the Yellow River in the Qingkou Area* (*Huanghe Qingkou mulong tu* 黃河清口木龍圖) (see Figure 2). The so-called wooden dragons are networks of wooden or bamboo stakes to safeguard dikes and dams. The maps accompany Gao Bin's (1683–1755) memorial on the construction of hydraulic facilities to minimize flood hazards in the Qingkou area, where the Huai River 淮河 flowed into the Yellow River. The *Maps of Wooden Dragons* visualizes the courses of the Yellow and Huai rivers and hydraulic facilities constructed between 1735 and 1749. The last sheet reflects the state of sediment deposition in 1749 and the newly built dams

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[5] For the myths regarding map scale see Matthew Edney, *Cartography: The Ideal and Its History* (Chicago: Univ. Chicago Press, 2019), pp. 166–227.

[6] Jean-Baptiste Du Halde, preface to *Description géographique, historique, chronologique, politique, et physique de l'empire de la Chine et de la Tartarie chinoise* (Pairs: Chez P. G. Le Mercier, 1735), 4 vols, Vol. 1, pp. xl–xlj. The English translation consulted is "P. Du Halde's Preface," in *A Description of the Empire of China and Chinese-Tartary: Together with the Kingdoms of Korea, and Tibet: Containing the Geography and History*, 2 vols., Vol. 1 (London: Printed by T. Gardner for E. Cave, 1738–1741), p. x.

Figure 1. *The Road Map of the Jiaxing Prefecture in Zhejiang Province* (*Zhejiang Jiaxing fu daoli tu*). Collection of Ming-Qing Maps (*Ming Qing yutu* 明清輿圖), Palace Museum, Taipei: 021509.

to which Gao Bin's memorial refers. The positions of rivers, dams, dikes, wooden dragons, and administrative units in the maps defy quantitative analysis, but between the visuals and the main body of Gao Bin's memorial the emperor and his ministers could garner sufficient information to give an overall assessment of the proposed hydraulic project.[7]

Both of these examples are coordinate-free. In fact, however, maps with rectangular-grid coordinates were not rare in early modern China. Chinese cartographers had a long history of "indicating distance by a network of squares" (*jili huafang* 計里畫方), mapping their subjects on grid-lined sheets. The ratio between the side of these grids and actual length is fixed, usually one side to 50 or 100 *li*.[8] Some modern scholars compare rectangular-grid coordinates with latitude-longitude coordinates. "Just as the scientific cartography of the Greeks was disappearing from the European scene," Joseph Needham claims, "the same science in different form began to be cultivated among the Chinese." Wang Yong 王庸, a founding figure in the field of Chinese historical geography, argues that the grid system heralded the development of scale maps before the arrival of latitude-longitude coordinates.[9]

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[7] Gao Bin's memorial and accompanying maps are in the Grand Council Archives (*Junji chu dang* 軍機處檔), Palace Museum, Taipei: 005027.

[8] One *li* is roughly equivalent to 576 meters or 1,890 feet.

[9] Joseph Needham, *Science and Civilisation in China*, 7 vols., Vol. 3: *Mathematics and the Sciences of the Heavens and Earth* (Cambridge: Cambridge Univ. Press, 1954), p. 533; and Wang Yong, *Zhongguo ditu shi gang* 中國地圖史綱 (Beijing: Sanlian shudian, 1958), p. 21.

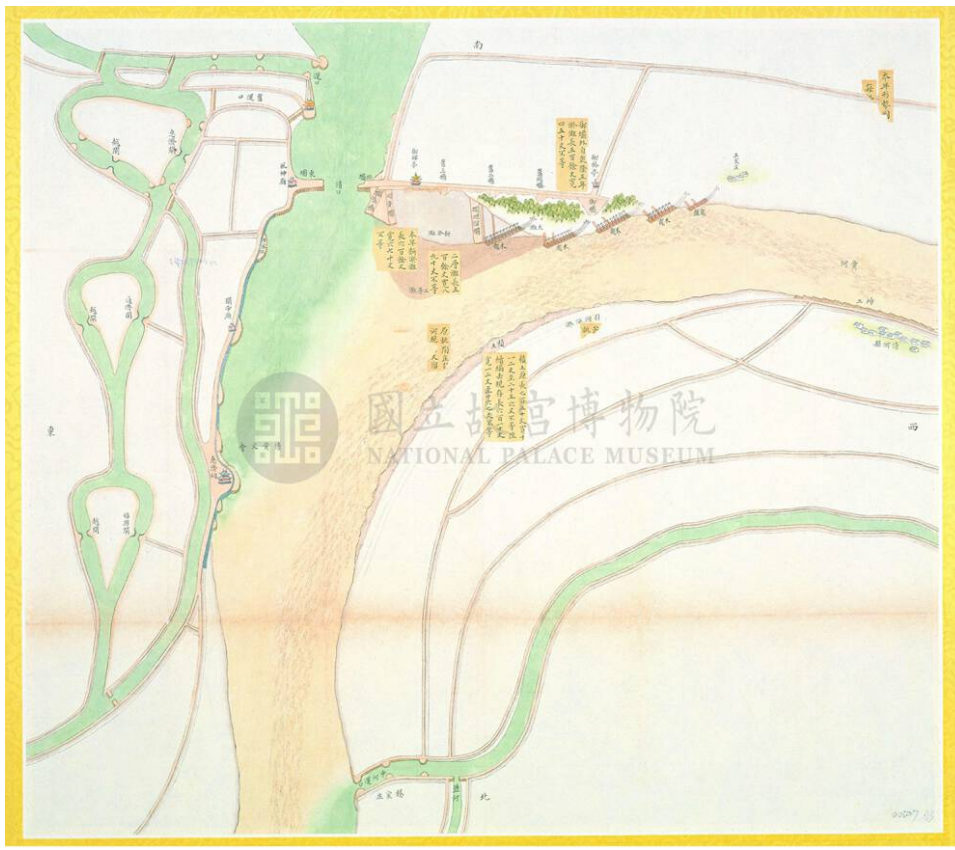

Figure 2. The third sheet in the *Maps of Wooden Dragons along the Yellow River in the Qingkou Area* (*Huanghe Qingkou mulong tu*). Collection of Ming-Qing Maps, Palace Museum, Taipei: 005027.

The latest scholarship questions the comparability between rectangular-grid coordinates and latitude-longitude coordinates. Wang Qianjin 汪前進 and Cheng Yinong 成一農 have shown that rectangular-grid coordinates, in essence, rely on relative positions between places rather than astronomical observation. The rectangular-grid maps normally set the capital as the point of origin for locating secondary-level administrative units, which in turn decide the locations of administrative units at the lowest level. The most important function of the rectangular grids is to help mapmakers and viewers conveniently estimate relative distances between geographical elements.[10]

Whether or not they were shown in terms of rectangular coordinates, relative positions proved sufficient for the needs of most Chinese viewers. This explains Chinese cartographers' lack of motivation to explore the astronomical method of determining locations while this method was prospering in Europe. The arrival of European missionaries with cartographical expertise brought latitude-longitude coordinates to the court of the nascent Qing dynasty (1644–1911),

[10] See Wang Qianjin, "Xiancun zui wanzheng de yifen Tangdai dili quantu shuju ji" 現存最完整的一份唐代地理全圖數據集, *Ziran kexue shi yanjiu* 自然科學史研究, 1998, 3:273–288; and Cheng Yinong, "Dui Jili huafang zai Zhongguo ditu huizhishi zhong diwei de chongxin pingjia" 對計里畫方在中國繪製史中地位的重新評價, *Mingshi yanjiu luncong* 明史研究論叢, 2014, *1*:24–26.

but until the late nineteenth century the impact of the new technology was almost unfelt beyond the palace walls.

THE THEORY OF THE SPHERICAL EARTH AND MAPS IN THE QING COURT

The Jesuits' latitude-longitude coordinates are premised on the sphericity of the Earth, while the theory of Heavenly Cover (*Gaitian shuo* 蓋天說), which claims that the Earth is flat underneath a dome-like heaven, dominated China until the late nineteenth century. The Kangxi emperor (r. 1661–1722) was an avid student of Western science and sympathetic to the spherical Earth theory. In fact, the spherical Earth theory would not have been unfamiliar to the Manchus. European missionaries brought the theory to East and Northeast Asia no later than the late sixteenth century. Matteo Ricci's (1552–1610) *Complete Map of the Myriad Kingdoms of the World* (*Kunyu wanguo quantu* 坤與萬國全圖) portrayed the Earth as a globe. Ricci's map was continuously published and even pirated in the seventeenth century. A Chinese-Manchu bilingual edition dated 1603 suggests that the Manchus were attentive to the spherical Earth theory before their conquest of China.[11] During the Kangxi reign, the emperor constantly received gifts of globes from missionaries and foreign envoys and used them to embellish the palace interiors.[12] However, Kangxi's descendants and their ministers did not share his interest in Western astronomy and were unable to detect the conflicting cosmological views embedded in different coordinate systems.

In the first years of the eighteenth century, impressed by "the accuracy of the European methods," the Kangxi emperor sponsored the Jesuits' empire-wide cartographic survey.[13] Since the early twentieth century, scholars have used multilingual sources to examine almost every aspect of this far-reaching project. The latest and most comprehensive account in any language is that of Mario Cams, published in 2017.[14] The data produced in the 1709–1717 survey formed the cornerstone of later imperial maps and compilations with latitudes and longitudes.[15] The Jesuits drafted regional maps on the road and had provincial administrators send them to the Kangxi emperor. The staff of the Imperial Household Department then pieced these regional maps together to make an atlas of the empire, commonly known as the Kangxi Atlas (*Huangyu quankan tu* 皇輿全覽圖) (see Figure 3).[16] The atlas adopts the sinusoidal projection. The horizontal parallels on the map indicate the lines of latitude, and the vertical curves (which appear as slanted lines in Figure 3) represent meridians.[17]

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[11] See Florin-Stefan Morar, "Relocating the Qing in the Global History of Science: The Manchu Translation of the 1603 World Map by Li Yingshi and Matteo Ricci," *Isis*, 2018, *4*:679–694, https://doi.org/10.1086/701475.

[12] For governmental records noting the presence of globes in the Qing court see Archives of the Imperial Household Department (*Neiwufu dang* 內務府檔), First Historical Archives, Beijing: 05-0184-043, 05-0184-045, 05-0186-012.

[13] Du Halde, preface to *Description géographique, historique, chronologique, politique, et physique de l'empire de la Chine et de la Tartarie chinoise* (cit. n. 6), Vol. 1, p. xxviij.

[14] Mario Cams, *Companions in Geography: East–West Collaboration in the Mapping of Qing China (c. 1685–1735)* (Leiden: Brill, 2017).

[15] In a letter to his fellow Jesuits in France, Joseph-Anne-Marie de Moyriac de Mailla claimed that the data were derived from on-site observation and geometrical measurement. See Joseph-Anne-Marie de Moyriac de Mailla and Jean-Baptiste Grosier, comps., *Histoire générale de la Chine: ou, Annales de cet empire; traduites du Tong-kien-kang*-mou, 13 vols., Vol. 1 (Paris: Ph.-D. Pierres . . . Clausier, 1777–1785), pp. clxxxj–clxxxiij. Cams argues that the list of longitudes and latitudes in du Halde's *Description . . . de la Chine* does not completely reflect the data that were collected by the Jesuits and informed the Kangxi Atlas. See Cams, *Companions in Geography*, p. 109.

[16] Cams, *Companions in Geography*, pp. 100–101, 128–129. For the various editions of the Kangxi Atlas see Li Xiaocong 李孝聰, "Ji Kangxi Huangyu quanlan tu de cehui jiqi banben" 記康熙皇輿全覽圖的測繪及其版本, *Gugong xueshu jikan* 故宮學術季刊, 2012, *1*:55–78, on pp. 66–78.

[17] On the type of projection adopted by the Kangxi Atlas see Wang Qianjin, "Kangxi tongban Huangyu quanlan tu touying zhonglei xintan" 康熙銅板皇輿全覽圖投影種類新探, *Ziran kexueshi yanjiu* 自然科學史研究, 1991, 2:186–194.

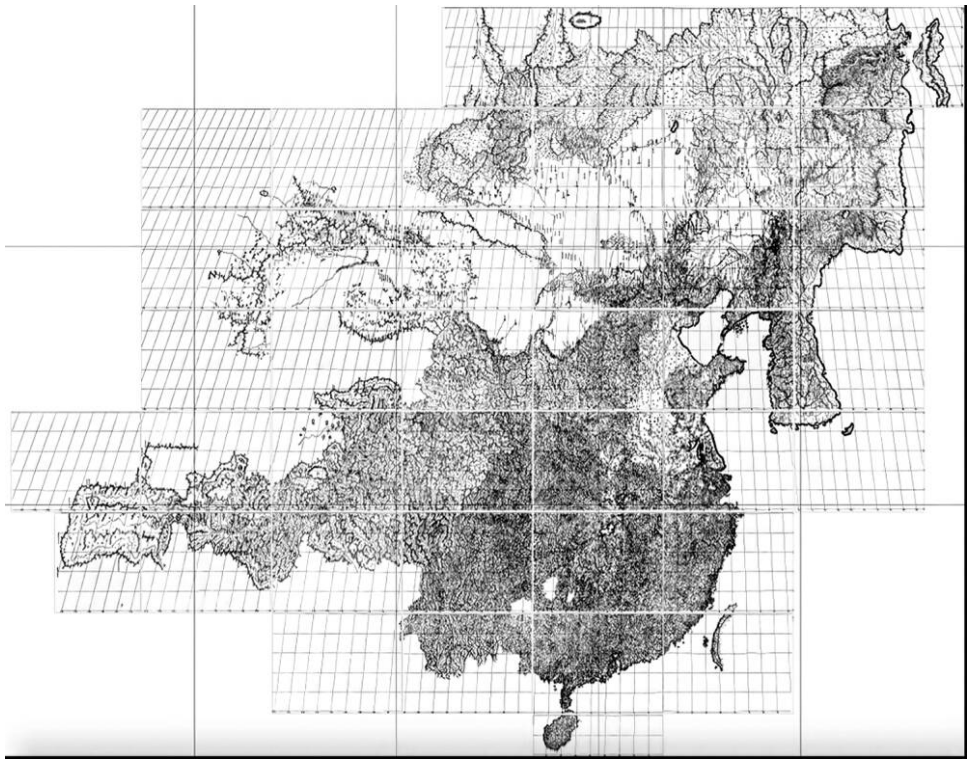

Figure 3. The copperplate edition of the Kangxi Atlas (1929 reprint edition). From *Qingting sanda shice quantu ji* 清廷三大實測全圖集 (Beijing: Waiwen chubanshe, 2007), via digital redesign on QingMaps.org (retrieved 23 Nov. 2021).

The Kangxi emperor's interpretation of latitude-longitude coordinates drew on traditional concepts in Chinese astronomy, such as the concept of field allocation (*fenye* 分野), but the framework was built on the sphericity of the Earth. In an edict dated 1721, the emperor said:

> This year, Russian envoys came to pay a tribute, presenting the map of their country for my review. They said that their country was more than twenty degrees away from the North Pole. . . . People in the past thought that China proper corresponded to the Heavenly Market enclosure. I initially doubted this view. Yet, by scrutinizing celestial globes and maps, [I confirmed that] China proper is twenty to forty degrees away from the Equator and that during the solar terms of Guyu, Lixia, and Xiaoman, the Heavenly Market enclosure is also twenty degrees away from the Equator, corresponding to China proper. Then I came to realize that the theory of field allocation is not groundless.

The theory of field allocation, which took shape in the fifth to third centuries B.C.E., correlates terrestrial domains with celestial regions. Historically, there is no unanimous view on the specifics of such correspondences, but an implicit assumption of the theory of field allocation is that the Earth is an immobile plane.[18] Kangxi affirmed the validity of the concept of field allocation

[18] *Qing shilu* (cit. n. 1), Vol. 6, pp. 831–832. For the development of the theory of field allocation in Chinese history see Qiu Jingjia 邱嘉靖, *Tiandi zhijian tianwen fenye de lishixue yanjiu* 天地之間: 天文分野的歷史學研究 (Beijing: Zhonghua shuju, 2020).

but also implied the movement of the Earth. The Heavenly Market enclosure (*tianshi yuan* 天市垣) is an asterism in Chinese astronomy. According to Kangxi, the relative position between the asterism and Earth changed constantly throughout the year. It was only during the solar terms (*jieqi* 節氣) of Guyu 谷雨, Lixia 立夏, and Xiaoman 小滿—that is, from late April to late May—that the angle between the Heavenly Market enclosure and the plane of the Celestial Equator was twenty degrees, in agreement with that between China proper and the equator of Earth.

The Kangxi emperor's comments on the Kangxi Atlas further suggested the spherical shape of the Earth. He said:

> One degree in the heavens roughly corresponded to a certain distance on the earth. If measured with the unit of *chi* in the Zhou dynasty, one degree in the heavens corresponds to two hundred and fifty *li* on the earth. If measured with contemporary *chi*, one degree in the heavens corresponds to two hundred *li* on the earth. No mapmaker in the past has used the degrees of the heavens to calculate distances between places, and thus [their works] abounded with flaws. I particularly sent people excelling in calculation and drawing to the northeast, having them calculate the locations of mountains and rivers according to their degrees in the heavens and map these items at length.[19]

The emperor's assertion that "one degree in the heavens corresponds to two hundred *li* on the earth" (天上一度, 即有地下二百里) is riddled with vagueness and ambiguity. The crux lies in the meaning of "degree in the heavens" 天上度數. It is tempting to interpret it as the degree of the curvature of the heavenly dome that covers the flat Earth. In fact, Chinese scholars in the nineteenth century did so interpret it. However, a letter from the Kangxi emperor to his crown prince clarifies that what he called the "degree in the heavens" refers to the angle between Polaris and the ground. In 1796 Kangxi traveled to the Mongol steppe on the expedition to pursue the fleeing Junghar Mongols. The crown prince was left in Beijing to take care of everyday administration. In a Manchu-language letter, Kangxi told him: "[I] had people measure the height of Polaris with instruments. Compared with that in Beijing, it is five degrees higher. The corresponding distance thus is 1250 *li*."[20]

The Kangxi emperor's solid grasp of the spherical Earth theory was exceptional in the Qing court. His successors, the Yongzheng (r. 1723–1735) and Qianlong (r. 1735–1796) emperors, did not inherit his interest in Western astronomy. They had probably learned about the spherical Earth theory, but neither the emperors nor their ministers were able to detect the chasm between the latitude-longitude coordinates of the Kangxi and Qianlong Atlases and the square grids of the Yongzheng Atlas. Their reigns thus witnessed the coexistence of the two coordinate systems, with their contradictory cosmological views, in imperial atlases. The former, characterized by its vertical curves, postulates the sphericity of the Earth, while the latter uses straight lines to indicate the flatness of the Earth.

The Yongzheng Atlas (*Yongzheng shipai tu* 雍正十排圖) was a multiyear project, extending from the late Kangxi reign to the early Yongzheng reign. In 1728 the Yongzheng emperor bestowed copies of the atlas on at least eight territorial officials, who customarily replied with memorials of gratitude. Yongzheng's vermillion rescripts on the memorial of Tian Wenjing 田文鏡

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[19] *Qing shilu*, Vol. 6, pp. 756–766. One *chi* is roughly equivalent to 0.32 meters or 1.05 feet.

[20] Palace Memorial Archives (*Gongzhong dang* 宮中檔), Palace Museum, Taipei: 411000611. For my translation I consulted Okada Hidehiro 岡田英弘, *Daishin teikoku ryūseiki no jitsuzō: daiyondai Kōkitei no tegami kara 1661–1722* 大清帝国隆盛期の実像: 第四代康熙帝の手紙から1661–1722 (Tokyo: Fujiwara shoten, 2016), pp. 126–127; and First Historical Archives in Beijing, comp. and trans., *Kangxi manwen zhupi zouzhe quanyi* 康熙朝滿文朱批奏摺全譯 (Beijing: Zhongguo shehui kexue chubanshe, 1996), p. 78.

(1662–1733), the emperor's confidant and the governor of Henan province, indicated the provenance of the map: "This map is what my late father, the Shengzu [Kangxi] emperor, spent several decades to accomplish. It is truly a treasure that has never before been seen. You must cherish."[21] The Yongzheng Atlas comprises ten rolls, extending the imperial gaze to Inner and West Asia, well beyond Qing control, but its sheets regarding China proper basically reproduce the Kangxi Atlas. For example, the coastlines of the Shandong Peninsula and the toponyms along the coastlines in the two atlases are strikingly similar. In the northwest, not only did the Great Wall wind the same way, but the names of Qing garrisons in Chinese and the non-Han toponyms noted in Manchu are identical.

Although it recycles geographical elements of the Kangxi Atlas, the Yongzheng Atlas replaced its latitude-longitude coordinates. The coordinate system it uses is not the conventional rectangular-grid coordinate, which is completely degree-free. The horizontal lines of the Yongzheng Atlas are not numbered, but there are indicators at the bottom of its vertical lines, from "east one" to "east thirty-two" and from "west one" to "west eighty-two." The central line crosses Shuntian prefecture 順天府, the capital area of the empire. However, these vertical lines also distinguish the coordinates of the Yongzheng Atlas from the latitude-longitude coordinates of the Kangxi Atlas. The archives of the Imperial Household Department refer to the Yongzheng Atlas as the "square-grid map" (*fangge ditu* 方格地圖) for the straight lines of its coordinates: the Yongzheng Atlas contains 77 horizontal lines and 125 vertical lines, all of which are straight. The Kangxi Atlas is known as the "oblique-grid map" (*xiege titu* 斜格地圖) in Qing archives for its meridian curves.

The Qing empire's westward expansion in the Qianlong reign prompted the imperial court to commission new maps and update old ones. In 1760 the Qianlong emperor, who was the son of the Yongzheng emperor and the grandson of the Kangxi emperor, commissioned a new atlas that would include the newly annexed territories in Inner Asia. Modern scholars generally refer to the new atlas as the Qianlong Atlas (*Qianlong shisan pai* 乾隆十三排). The French Jesuit Michel Benoist (1715–1774) supervised the engraving of the 104 copper plates of the Qianlong Atlas, which cost five thousand copper *liang*. The initial print run of the copperplate edition reached a hundred, and each copy had 103 sheets, divided into twenty-four foldable booklets.[22] The Qianlong Atlas, like the Kangxi Atlas, is an "oblique-grid map": its coordinate system, like that of the Kangxi Atlas, is made up of straight latitude lines and the curves of longitude.

For the Qianlong emperor and his ministers, making a new atlas with the latitude-longitude coordinates did not indicate denigration of the Yongzheng Atlas, with its square grids. In 1760 the Qianlong emperor approved Prince Zhuang's 莊親王 request to add new Inner Asian territories to old atlases. Prince Zhuang was the brother of Yongzheng and the uncle of Qianlong. He discovered a xylographic edition of the Yongzheng Atlas in the imperial collection and then had the Portuguese Jesuit Felix da Rocha (1713–1781) and ministers in the Grand Council (*Junji chu* 軍機處) oversee the revision process and the Imperial Printing Office take charge of printing matters.[23]

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[21] Grand Council Archives, Palace Museum, Taipei: 402007070. For the extant editions of the Yongzheng Atlas in China see Yu Fushun 於福順, "Qing Yongzheng shipai Huangyutu de chubu yanjiu" 清雍正十排《皇輿圖》的初步研究, *Wenwu* 文物, 1983, *12*:71–83; and Feng Baolin 馮寶琳, "Ji Jizhong butong banben de Huangyu shipai quantu" 記幾種版本不同的皇輿十排全圖, *Gugong bowu yuan yuankan* 故宮博物院院刊, 1986, *4*:73–78.

[22] Charles Le Gobien *et al.*, comp., *Lettres édifiantes et curieuses, écrites des missions étrangères, par quelques missionaires de la Compagnie de Jèsus*, 34 vols., Vol. 24 (Paris: Chez J. G. Merigot, 1717–1777), pp. 381–383; and *Qinggong Neiwu fu zaoban chu dang'an zonghui* 清宮內務府造辦處檔案總匯, 55 vols., Vol. 31 (Beijing: Renmin chubanshe, 2005), pp. 62–63, Vol. 34 (Beijing: Renmin chubanshe, 2005), pp. 611–612. For the foldable booklets see Weng Lianxi 翁連溪, *Neifu keshu yanjiu* 內府刻書研究 (Beijing: Zijin cheng chubanshe, 2013), pp. 239–420.

[23] Archives of the Imperial Household Department, First Historical Archives, Beijing: 05-0186-012.

The Yongzheng Atlas in the British Library (I henceforth refer to this as the BL edition) is likely the edition revised under the oversight of Prince Zhuang. The catalogue of the British Library refers to it in generic terms as a "Chinese roll map" (IOR/X/3265). Its entry in a late nineteenth-century catalogue of the India Office reads "A Chinese map of the greater part of Asia and part of European Russia."[24] The Qianlong emperor's two poems at the upper right corner of the BL edition, dated 1756 and 1760, respectively, state explicitly that the map incorporates the results of the Qing's land surveys of Inner Asia in the 1750s. These poems also appear in the Qianlong Atlas. Some scholars identify the map in the British Library as a woodblock edition of the Qianlong Atlas, but the straight meridians attest to its ties to the Yongzheng Atlas. Moreover, its square grids, which are 2.5 inches in length, agree with Prince Zhuang's descriptions: each side of the grids in the revised edition of the Yongzheng Atlas is two *cun*, which equals exactly 2.5 inches (see Figure 4).

The Kangxi emperor's exceptional interest in astronomy did not inspire his successors to consider the differences between "oblique-grid maps" and "square-grid maps" and the contradictory cosmological views they embodied. The Yongzheng and Qianlong emperors and their ministers did not necessarily believe in the flat Earth, but they were not adamant proponents of the spherical Earth theory either. They acknowledged the symbolic and practical value of maps but showed little interest in exploring the mechanisms of mapmaking. The emperor's formula "one degree in the heavens corresponds to two hundred *li* on the earth" was largely forgotten until Chinese scholars reinterpreted it in the nineteenth century.

TRICKLING DOWN TO SCHOLARS: THE DISSEMINATION OF LONGITUDE AND LATITUDE BEFORE THE 1830s

Until the 1830s, more than a century after the Jesuits' first empire-wide investigation, the concepts of longitude and latitude remained alien to most Qing scholars, but a select few came across imperial maps with latitude-longitude coordinates when compiling voluminous works for the Qing court. They reproduced the longitude and latitude degrees in their own works, but not the images. For them, the out-of-context numbers were more a token of imperial authority than practically useful indicators of locations.

The Qing court was extremely discreet about the data that the Jesuits gathered. On a few rare occasions, the Qing emperors bestowed maps with latitude-longitude coordinates on officials. The recipients were confined to a handful of the monarchs' most trusted ministers. Owing to the military sensitivity of these maps, even the emperor's confidants could be given only the sheets relevant to their jurisdiction, not the entire map.[25]

Nevertheless, stringent rules and regulations could not stop the knowledge of latitude-longitude coordinates from trickling down to scholarly communities outside the Forbidden City. A small coterie of scholars benefiting from their editorship roles in the Qing court were able to access maps with latitude-longitude coordinates. Qi Shaonan 齊召南 (1703–1768) and Xu Song 徐松 (1781–1848) were among the privileged few.

In the 1730s Qi Shaonan, who had just passed the metropolitan civil service examination, was recruited into the Office of *The Gazetteer of the Great Qing* (*Da Qing yitongzhi* 大清一統志) as a junior editor. In the eighteenth century the Qing, as a conquest dynasty eager to consolidate its

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[24] *A Catalogue of Manuscript and Printed Reports, Field Books, Memoirs, Maps, etc. of the Indian Surveys Deposited in the Map Room of the India Office* (London: W. H. Allen, 1878), pp. 504–506.

[25] In a memorial dated to 1717, the provincial governor Nian Gengyao 年羹堯 (1679–1726) expressed his gratitude to Kangxi, stating that the map of Sichuan rendered him "fully aware of the topographical features [of the province]" (*xiaoran yu xingshi xianyi* 曉然於形勢險易). At that time, the entire Kangxi Atlas had been completed, but the emperor bestowed on Nian only the sheets concerning his jurisdiction. See Palace Memorial Archives, First Historical Archives, Beijing: 04-01-30-0147-005.

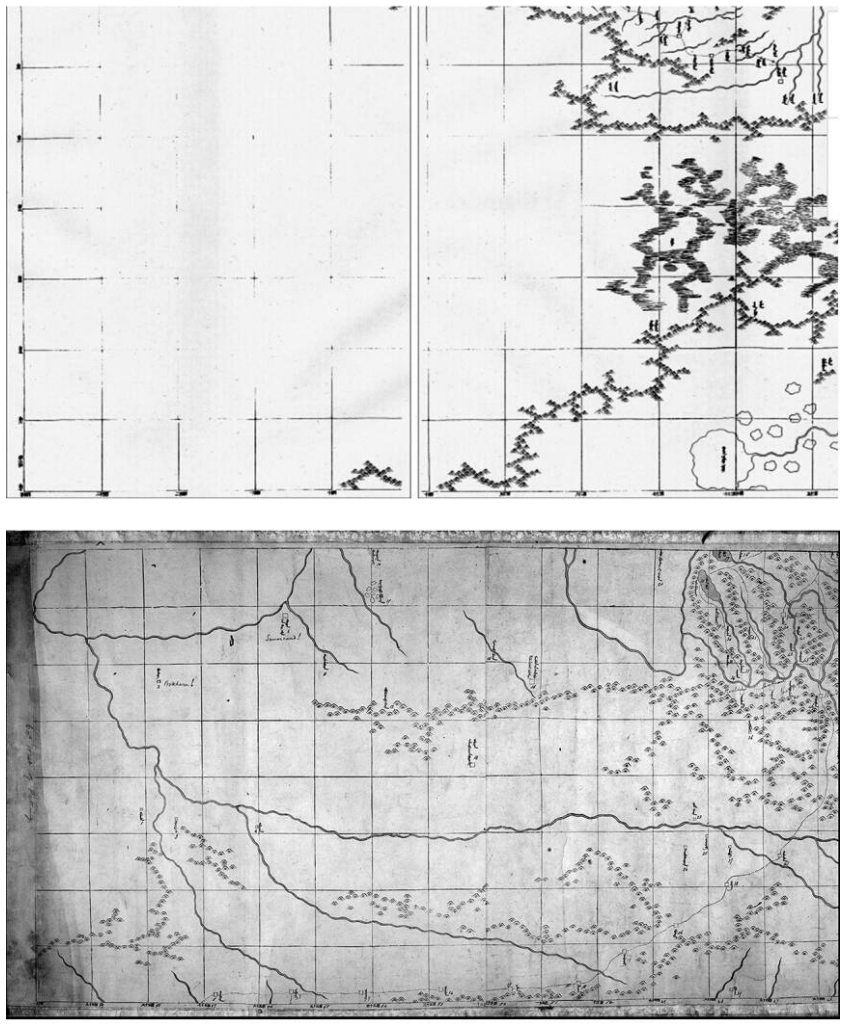

Figure 4. Top: The Yongzheng Atlas in the Chinese Academy of Sciences. From *Qingting sanda shice quantu*, via digital redesign on QingMaps.org (retrieved 23 Nov. 2021). The sixth row of the Yongzheng Atlas in the Chinese Academy of Sciences ends with the meridian of west forty-four. Bottom: In the British Library edition of the Yongzheng Atlas (© British Library Board IOR/X/3265), the sixth row extends to west sixty.

intellectual authority, commissioned a series of massive encyclopedias and dictionaries, including *The Gazetteer of the Great Qing*.[26] The Office of *The Gazetteer* formally opened in 1686 and operated without interruption until 1743, when the first edition was finalized.[27]

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[26] For the Qing government's intellectual projects, Kent Guy's *The Emperor's Four Treasuries: Scholars and the State in the Late Ch'ien-lung Era* (Cambridge, Mass.: Council on East Asian Studies, Harvard Univ., 1987) provides a comprehensive account of the *Siku quanshu* 四庫全書 project, undertaken in the 1770s, as well as its sociopolitical context and legacy.

[27] For the establishment of the Office of the *National Gazetteer* see Wang Dawen 王大文, "Da Qing yitong zhi guan chutan" 大清一統志館初探, *Lishi dangan* 歷史檔案, 2018, 3:92–98.

The editors of *The Gazetteer of the Great Qing* were allowed access to all kinds of government records, including maps. A document from the Imperial Printing Office dated to 1730 shows that the editors referred to the map collections in the central government to determine boundaries.[28] Despite the sensitive information it conveyed, the Kangxi Atlas was among the works available to Qi Shaonan and his peers. Qi recollected that he spent much time "examining and collating books and maps" at the Office of *The Gazetteer of the Great Qing* and that he "crouched down to see the atlas commissioned by the Kangxi emperor." The Kangxi Atlas immediately captured his attention for its longitude and latitude lines, respectively indicating "the sequence of the solar terms" and "the height of Polaris."[29] A colleague once asked Qi if it was possible to identify "the Black Water" mentioned in the Confucian canon *The Book of Documents* (*Shangshu* 尚書). Qi replied with information that he found in the Kangxi Atlas: it was likely to be the Lu River, because the flow of the river was black. The Lu River originated from the Buka lake in Tibet, whose longitude was 25° W.[30]

After resigning from the central government in 1749, Qi began work on *The Outline of Waterways* (*Shuidao tigang* 水道提綱), which was based on his earlier notes. In the preface he said:

> I worked in the Office of *The National Gazetteer* for a long time, examining and collating books and maps. . . . After I was allowed to go back to Taishan at Your Majesty's mercy, I closed my gate [to stop socializing with others] and led a life of leisure. When I was recovering from my illness, I went through the drafts in my cases and then edited and transcribed them in order. In the end, I accomplished twenty-eight volumes in total.[31]

The Outline of Waterways presents the latitudes and longitudes of over 180 sites, and they are basically consistent with the numbers in the Kangxi Atlas. For instance, in *The Outline of Waterways* the mouth of Heilongjiang 黑龍江 (the Amur River) was 25.5° E, 53° N and the mountain south of it known as Aotuoke aofoluo 敖托科敖佛洛 (Ma. Otoko Oforo) was 25.8° E, 52° N (see Figure 5). Both sets of longitudes and latitudes roughly agree with the Kangxi Atlas. *The Outline of Waterways* occasionally refers to "the map," which should be understood as the Kangxi Atlas. Following the lengthy description of the origin of the Kemu 客木 (Ma. Kema) River, Qi Shaonan's commentary, in a smaller font, reads: "[According to] the map, [the river runs] from forty-nine degree five minutes to fifty-five degrees." The description and latitude are congruent with the Kangxi Atlas.[32]

The Kangxi Atlas provided Qi Shaonan with sufficient credentials to claim to be the leading authority on geography. The map's aura of imperial power convinced Qi's fellow scholars that *The Outline of Waterways* was an indisputable masterpiece. Qi invited his friend and colleague Ruan Xuejun to write a preface to his volume. Ruan first lauded the sophistication of the Kangxi Atlas. The oversized map, which could be unfolded completely only on the floor, was so informative that it "eluded the viewers." Then he turned to Qi and praised his absolute mastery of the map. The editors of the annotated catalogue of the imperial collection emphasized his experience in the Office of *The Gazetteer of the Great Qing*: thanks to this experience in serving the

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[28] Grand Secretariat Archives (*Neige daku dang* 內閣大庫檔), Academia Sinica, Taiwan: 186233, 174191, 175504.

[29] Qi Shaonan, preface to *Shuidao tigang* 水道提綱 (1776 ed.).

[30] Qi Shaonan, *Baolun tang wenchao* 寶綸堂文鈔 (1808 ed.), rpt. in *Qingdai shiwen ji huibian* 清代詩文集彙編 (Shanghai: Shanghai guji chubanshe, 2010), Vol. 300, pp. 267–268.

[31] Qi Shaonan, preface to *Shuidao tigang* (cit. n. 29).

[32] Qi Shaonan, *Shuidao tigang*, Vol. 26, pp. 1a–b (latitude and longitude for the mouth of Heilongjiang and Aotuoke aofoluo), Vol. 23, p. 11b (quotation).

Figure 5. The mouth of the Amur River and Otoko Oforo in the copperplate edition of the Kangxi Atlas. From *Qingting sanda shice quantu ji*, via digital redesign on QingMaps.org (retrieved 23 Nov. 2021).

court, Qi was able to view "all the maps under the heaven." He thus learned about areas that previous scholars had never touched on and knew them as well as his own palms.[33]

Despite the wide recognition that his familiarity with the Kangxi Atlas earned him, Qi Shaonan never explained the concepts of longitude and latitude that characterize the map. At times the longitudes and latitudes inserted in *The Outline of Waterways* are redundant information that interrupts the flow of the narrative. For instance, the text describes the location of the Poyang lake 鄱陽湖 relative to nearby administrative units:

> It is a huge lake across the prefectures of Nanchang, Raozhou, Nankang, and Jiujiang, and the counties of Xinjian, Jianchang, De'an, Xingzi, Dehua, Hukou, Duchang, Poyang, and Yugan. Its width, from east to west, is from forty or fifty *li* to one hundred *li*. Its length, from south to north, is three hundred *li*. The shape of the lake is like a gourd. The central part of the lake is the "slim waist" of the gourd. The lake lies southeast of the Nankang and Xingzi counties, northwest of the Duchang county.

Qi Shaonan's commentary between lines notes that the latitude and longitude of the so-called "mouth of the lake," through which the Yangzi River flowed, are 0.1° W, 28.8° N. The numbers are meaningless in the context, in which the location of the Poyang lake is defined by its position relative to other places.[34]

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[33] Ruan Xuejun 阮學濬, preface to *Shuidao tigang*, Vol. 26, pp. 1a–b.
[34] Qi Shaonan, *Shuidao tigang*, Vol. 14, pp. 25a–b.

Qi's readers, from his friend who prefaced *The Outline of Waterways* to the editors of the imperial catalogue, were invariably silent about the longitudes and latitudes presented in the work. After all, without explanatory texts or images, they were nothing other than incomprehensible numbers. This indifference may imply a universal lack of understanding of the use of latitude and longitude, but it did not compromise the authority of the Kangxi Atlas. For Qi Shaonan and his contemporaries, the authority of the map derived primarily, if not solely, from the emperor's supreme power rather than anything else.

Half a century after the publication of *The Outline of Waterways*, another geographical work that incorporates longitudes and latitudes came out. Like *The Outline of Waterways*, Xu Song's (1781–1848) *The Waterways in the Western Regions* (*Xiyu shuidao ji* 西域水道記) focuses on rivers, but it narrows the scope to Xinjiang. In 1805 Xu Song entered the prestigious Hanlin academy in the central government as a top finisher in the civil service examination. After three years' training, he became a full-time editor and subsequently undertook the compilation of multiple court-sponsored works. In 1812 Xu was banished to Xinjiang for misconduct during his tenure as the educational commissioner of Hunan province. In the following eight years, he wrote extensively about the geography of Xinjiang, and *The Waterways in the Western Regions* was his most important work. Xu Song completed the initial draft of the text before he was pardoned and allowed to return to Beijing in 1820. There he spent the rest of his life polishing this work.[35]

The Qing government had a long tradition of sending convicts to frontier areas. After it conquered the Zunghar khanate in the 1750s, the Qing continued to send exiles to other borderlands, such as Manchuria and Mongolia, but many more went to Xinjiang, the former territory of the Zunghars. In Xinjiang, former bureaucrats and degree holders were usually exempted from toil and drafted to fill the lower echelons of the local government. Soon after Xu Song arrived in the seat of Xinjiang, he was recruited to compile the gazetteer of Xinjiang. While serving the military governor of Xinjiang, Xu Song began to work on his geographical texts, including *The Waterways in the Western Regions*.[36]

The Waterways has two main editions: one is Xu Song's manuscript, produced in his exile, and the other is the xylographic edition published in the 1830s. The manuscript contains fifty-one sets of latitudes and longitudes, while the xylographic edition contains the latitudes and longitudes of fifty-nine places in Xinjiang. The latitudes and longitudes of specific locations in the two editions are also incongruent. According to Zhu Yuqi 朱玉麒, the discrepancies result from the different sources available to Xu Song in Xinjiang and in Beijing. The latitudes and longitudes in Xu Song's manuscript come primarily from Qi Shaonan's *The Outline of Waterways* and court-commissioned compendiums that included longitude and latitude information. The xylographic edition, however, incorporates latitude and longitude numbers taken from the Qianlong Atlas.[37]

Although far away at the Qing empire's periphery, Xu Song managed to obtain necessary reference books. One privilege of being a clerk in the military governor's office was access to its book collection. Qi Yunshi 祁韻士 (1751–1815), who worked for the military governor of Xinjiang from 1805 to 1808, mentioned this privilege enjoyed by the clerical staff.[38] In his years of exile, Xu

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[35] For the biography of Xu Song see Miao Quansun 繆荃孫, "Xu Xingbo xiansheng shiji" 徐星伯先生事輯, in *Yifeng tang wenji* 藝風堂文集 (1901 ed.), Vol. 1, pp. 42a–48b; and Zhu Yuqi, *Xiyu shuidaoji yanjiu* 西域水道記研究 (Beijing: Beijing daxue chubanshe, 2015).

[36] Regarding the lives of disgraced officials in Xinjiang see Joanna Waley-Cohen, *Exile in Mid-Qing China: Banishment to Xinjiang, 1758–1820* (New Haven, Conn.: Yale Univ. Press, 1991), pp. 138–162.

[37] Zhu Yuqi, "Xiyu shuidao ji: Gaoben, jiaoben, bu jiaoben" 西域水道記: 稿本、校本、補校本, in *Zhongwai guanxi shi: Xin shiliao yu xin wenti* 中外關係史: 新史料與新問題, ed. Rong Xinjiang and Li Xiaocong (Beijing: Kexue chuban she, 2004), pp. 391–396.

[38] Qi Yunshi, *Xichui zongtong shilue* 西陲總統事略 (1809 ed.), Vol. 8, pp. 16a–18b.

exhaustively browsed "ancient histories, the court-commissioned military histories known as *fanglue* 方略, and other records regarding the geography of [Xinjiang]."[39] His manuscript was sometimes explicit about his sources, but more commonly it quoted latitude and longitude numbers without giving any references.

As a confidential document, however, the Qianlong Atlas might not have been available to Xu Song until he returned from exile. In Beijing Xu Song was awarded a low-ranking position in the Grand Secretariat for his contribution to the newly finished gazetteer of Xinjiang. Despite its humble pay and low status, the position gave him access to all kinds of records in the central government. Xu Song may have seized the chance and secretly made a copy of the Qianlong Atlas. His close friend Zhang Mu 張穆 (1805–1849) mentioned that Xu had "an imperial map with thirteen rows." Shen Yao 沈垚 (1798–1840), Xu Song's protégé, confirmed that the imperial map was the Qianlong Atlas: "[I] once saw the Qianlong Atlas with thirteen rows in the possession of master [Xu Song]."[40]

Like Qi Shaonan, Xu Song never tried to clarify the implications of the latitudes and longitudes given in his work. Despite their pervasive presence, neither the manuscript nor the xylographic edition provides any explanation. The illustrative maps in the two editions do not reflect latitude and longitude degrees at all. These south-oriented maps either have no coordinates or place elements proportionally on squared sheets. Each side of a rectangular grid represents one hundred miles, and readers thus can calculate relative distances between places (see Figure 6). As I noted above, indicating relative distances by a network of rectangular grids is a conventional practice in Chinese cartography that can be traced back to the twelfth century.

Qi Shaonan and Xu Song were among the lucky few who had the chance to view imperial maps with latitude-longitude coordinates, the secret treasures in the emperor's vault. These leading scholars might have been amazed by the unprecedented sophistication of the Kangxi and Qianlong Atlases, but the imperial aura was a more decisive reason for their eagerness to integrate longitude and latitude degrees into their studies indiscriminately. The numbers testified to their ties to the center of political power, which they relied on to build their scholarly authority. Qi Shaonan and Xu Song needed longitude and latitude degrees for the imperial power that they symbolized; but, on the other hand, they consciously or unconsciously ignored their revolutionary aspect. Just like their predecessors in earlier centuries, Qi Shaonan and Xu Song were comfortable with using relative positions on the ground to describe locations and were unmotivated to explore new approaches. Longitudes and latitudes were a welcome addition to their texts, but the established methodology remained unchallenged.

MERIDIANS IN DISPUTE: THE DISSEMINATION OF LONGITUDE AND LATITUDE AFTER 1832

With the dissemination of the Kangxi and the Qianlong Atlases in the nineteenth century, their curved meridians ignited a debate between scholars who insisted on using relative positions on the ground to determination location and the proponents of the spherical Earth theory and astronomy-based cartography. Until the late nineteenth century, the latter were in the minority.

Dong Youcheng 董佑誠 (1791–1823) and Li Zhaoluo 李兆洛 (1769–1841) were the two key figures in disseminating imperial maps with latitude-longitude coordinates. Around 1812, Dong Youcheng traveled to Beijing, where he earned a living as the tutor of Qian Yiji's 錢儀吉 (1783–1850) sons. Qian was a midlevel bureaucrat who was drafted to revise a legal compendium of the

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[39] Long Wanyu 龍萬育, preface to *Xiyu shuidao ji* (Daoguang ed.; rpt., Yangzhou: Jiangsu Guangling guji keyinshe, 1991).

[40] Zhang Mu, *Menggu youmu ji* 蒙古遊牧記 (1867 ed.), rpt. in *Xuxiu siku quanshu* 續修四庫全書 (Shanghai: Shanghai guji chubanshe, 2002), Vol. 731, p. 146; and Shen Yao, *Luofan lou wenji* 落颿樓文稿 (1918 ed.), rpt. *ibid.*, Vol. 1525, p. 430.

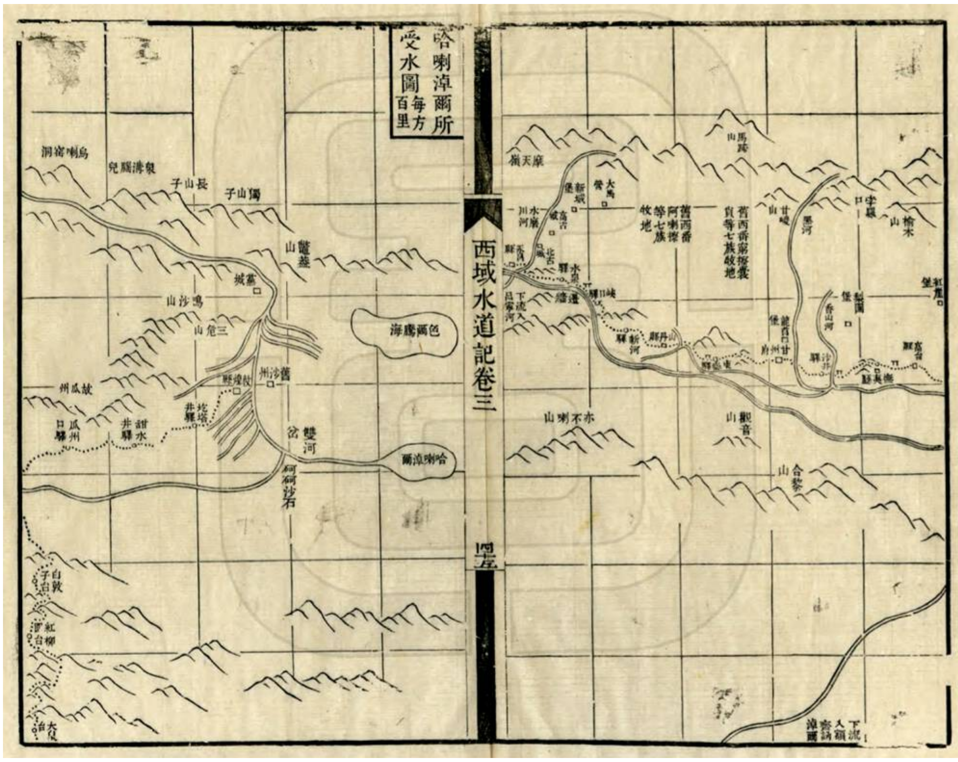

Figure 6. A map with rectangular grids in the xylographic edition of *The Waterways in the Western Regions* preserved in the National Library of China (地 716.3/156). The text in the box says: "Each grid presents one hundred *li*."

Qing state. Thanks to Qian, Dong had the chance to scrutinize the Kangxi and Qianlong Atlases in the central government's holdings and finished a map with latitude-longitude coordinates. Dong's map draws on the two atlases and makes only a few minor revisions to reflect the latest changes in administrative boundaries and waterways up to 1822.[41]

In 1832, almost a decade after Dong's death, his friend Li Zhaoluo reedited his works and published the map under the title *The Complete Map of the Unified Empire* (*Huangchao yitong yudi quantu* 皇朝一統輿地全圖). Li Zhaoluo delegated the printing of *The Complete Map* to family-hired workers and may not have intended it to be widely disseminated. The map was surprisingly popular, however. In 1842 Li Zhaoluo's disciple Liu Yan 六嚴 had to publish a revised edition to meet growing demand. In the following years, commercial printing houses across the country began to publish maps patterned on *The Complete Map of the Unified Empire*.[42]

A crucial change that Li Zhaoluo made to Dong Youcheng's map was the addition of new meridians. Dong had reproduced the meridians of the Kangxi and Qianlong Atlases, in which

[41] Chen Li, *Dongshu ji* 東塾集 (1892 ed.), rpt. in *Qingdai shiwen ji huibian* (cit. n. 30), Vol. 637, pp. 192–193; and Li Zhaoluo, *Yangyi zhai wenji* 養一齋文集 (1878 ed.), Vol. 19, pp. 4b–5b.

[42] Chen Yanen 陳延恩, postscript to *Huangchao yitong yudi quantu* 皇朝輿地全圖 (1842 ed.). The digitized copy of the 1842 edition can be found on the website of the Library of Congress: https://www.loc.gov/item/gm71005054/. The most common editions include the ones published by Hu Xiyan 胡錫燕 in 1856 and by Yu Shouyi 俞守義 in 1871.

all the meridians except the central meridian are curves. Meridians parallel each other at the equator but converge toward the poles. To these curves, Li Zhaoluo added straight lines. In *The Complete Map of the Unified Empire*, curves are shown as dashed lines and the straight lines are solid (see Figure 7).

This revision was inspired by the Kangxi emperor's remark about the Kangxi Atlas that "one degree in the heavens corresponds to two hundred *li* on the earth," but Li reintegrated it with the theory of Heavenly Cover. Li Zhaoluo's preface to *The Complete Map* says:

> [Dong Youcheng's] original map follows [the practice of] the inner court, using the degrees of the heavenly arcs to draw longitude and latitude lines. One degree in the heavens corresponds to two hundred *li* on the earth. While latitude lines remain the same, longitude lines converge from the equator northwards. We cannot use [curved longitude lines] to decide distances on the ground. If one degree of the heaven corresponds to two hundred *li* on the earth, one minute in the heavens should correspond to three *li* and one-third. One second in the heavens should correspond to twenty *bu*. The degrees of the [heavenly] dome may be slightly uneven, but [the corresponding relations] are roughly the same. Based on the outcome of on-site surveys in *The Treatise on Astronomical Instruments at the Imperial Observatory* (*Lingtai yixiang zhi* 靈台儀象志), I draw [solid] lines in the north–south direction, which form square grids with latitude lines. Each side of these square grids represents one hundred *li*. Distances on the earth thus can be easily

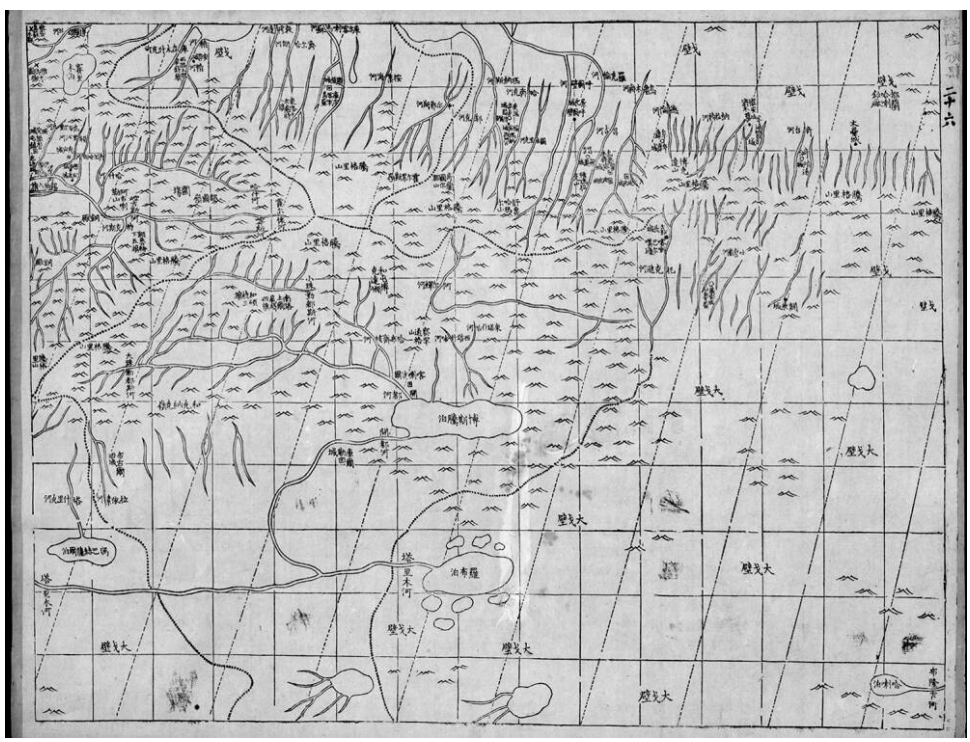

Figure 7. The coexistence of curves and straight lines in the north–south direction in Li Zhaoluo's *The Complete Map of the Unified Empire* (1832 ed.). National Library of Australia (2055303), http://nla.gov.au/nla.obj-230562425 (retrieved 23 Nov. 2021).

> calculated. I use dashed lines to record the degrees of the heaven, which could be references for observers of the heaven.[43]

Li unequivocally used the term "dome" (*qiong* 穹) to refer to the heavens. Given that the heavens formed a hemispheric dome covering the flat Earth, "degree in the heavens" must be the degree of the heavenly arc. Li then read Kangxi's comments as the emperor's recognition of the quantitative correlation between heavenly arcs and distances on the ground. *The Treatise on Astronomical Instruments at the Imperial Observatory* is a compendium that the Flemish Jesuit Ferdinand Verbiest (1623–1688) put together to promulgate his astronomical scholarship. In 1670 Verbiest won the calendar debate with Chinese astronomers and was appointed to reequip the Imperial Observatory. The conversion chart between the degrees and lengths of meridian arcs—that is, "the outcome of on-site surveys"—comes toward the end of the third fascicle of the treatise. Meridian arcs, to Li's understanding, were the curves of the heaven. The lengths were the lengths not of the curves of the heavenly arcs but of the corresponding straight lines on the ground.[44]

Li Zhaoluo's addition of straight vertical lines transforms the original latitude-longitude coordinate system into a dual-tiered system. Given the correspondence between heavenly arcs and ground distances, the meridian curves and the lines of latitude constitute a composite coordinate of the heaven and the Earth. The added straight lines and the original latitude lines form the other coordinate, which follows the conventional practice of indicating relative distances by a network of rectangular grids.

Most map viewers in nineteenth-century China did not much care about the arcs of the heaven, which were of little use in their daily lives. Thus most maps modeled on *The Complete Map of the Unified Empire* dropped the curved meridians. The 1842 edition was an exception. Liu Yan, as Li Zhaoluo's student, was well informed as to Li's intentions of keeping the curved meridians. When Liu reedited *The Complete Map*, he even changed the dashed black lines into more conspicuous solid vermillion ones. Nevertheless, Liu Yan removed all the curves from his own compilation, *The Outline of the Geography of the August Dynasty* (*Huangchao yudi lue* 皇朝輿地略), a collection of provincial maps of China proper. The straightforward format and portable size made it one of the most popular atlases adapted from *The Complete Map*. From 1841 to 1884, government-owned and private printing houses in the provinces of Jiangsu, Hunan, Hubei, Guangdong, and beyond published multiple editions of *The Outline of the Geography of the August Dynasty*. Weng Tonghe 翁同龢 (1830–1904) purchased an abridged edition that deleted the explanatory texts following each map. In the 1880s, he consulted the abridged edition to prepare classes on borderland management for the teenaged Guangxu emperor (r. 1875–1908).[45]

While many mapmakers chose Li Zhaoluo's *The Complete Map* as their prototype, proponents of the spherical Earth theory questioned its dual-tiered coordinates, premised on the flat Earth belief. The Qing emperors believed in the theory of Heavenly Cover but were tolerant of alternative cosmological views. Numerous high-profile scholar-officials were well versed in the spherical

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[43] Li Zhaoluo's preface to *The Complete Map of the Unified Empire* has two editions: one is in the 1832 edition of *The Complete Map of the Unified Empire* and one in his *Yangyi zhai wenji*. The quotations above are identical in the two editions.

[44] For Ferdinand Verbiest's contribution to the circulation of Western technological knowledge in China see Nicole Halsberghe, "Introduction and Development of the Screw in Seventeenth-Century China: Theoretical Explanations and Practical Applications by Ferdinand Verbiest," *East Asian Science, Technology, and Medicine*, 2011, 34:163–193, https://doi.org/10.1163/26669323-03401006

[45] Weng purchased at least three copies of the abridged edition of *The Outline of the Geography of the August Dynasty*. The three copies, entitled *Huangchao neifu yudi tu suomo ben* 皇朝内府輿地縮摹本, are all in the National Central Library in Taiwan. Weng's handwritten notes can be seen in the margins of these copies. On the blank page of one copy he wrote: "[The notes on] the copy was what I transcribed by hand when I worked in the Hanlin Academy. In the eighth year of the Guangxu reign (1884), I transcribed [these] for tutoring the emperor. [These notes] were intended for border management and thus were detailed in diplomatic treaties."

Earth theory and sympathetic to it. Ji Yun 紀昀 (1724–1805) was the chief editor of *The Complete Library of the Four Treasuries* (*Siku quanshu* 四庫全書), the most ambitious intellectual project of the Qing government. In private, however, Ji recognized that the Earth was a spheroid, with a diameter of thirty thousand *li*. Qian Daxin 錢大昕 (1728–1804) and Ruan Yuan 阮元 (1764–1849) had successful bureaucratic careers. They were also the indisputable leaders of the scholarly world. Qian helped to finalize the translation of the French Jesuit Michel Benoist's *The Illustrated Explanation of the Earth as a Globe* (*Diqiu tushuo* 地球圖說). Ruan sponsored its publication.[46]

The wave of the Western Learning (*Xixue* 西學) in the post–Opium War period further promulgated the spherical Earth theory. In light of the new cosmological view, scholars began to doubt the validity of Li Zhaoluo's transformation of latitude-longitude coordinates. Chen Li 陳澧 (1810–1882) was a scholar based in Guangdong province, where one of the first treaty ports was opened to foreign trade in accordance with the Sino-British Treaty of Nanking. Li was vocal in his criticism of Li Zhaoluo's *The Complete Map*. He said:

> No one ever heard of maps with longitude and latitude lines until the Kangxi Atlas. Latitude lines are horizonal. [In the Kangxi Atlas], the central longitude line is straight, but the rest are oblique. The copy of Dong Youcheng from the Yanghu county is faithful to the Kangxi Atlas. When Li Zhaoluo published it, he added straight lines all over the map, which is wrong. Liu Yan from the Jiangyin county compiled *The Outline of the Geography of the August Dynasty*, which keeps straight lines but removes curves. That is more wrong. Oblique lines are not truly oblique. Oblique lines are just to display that the areas near the equator are wide, and the polar regions are narrow. This is because the earth is spherical.[47]

Chen Li astutely detected Li Zhaoluo and Liu Yan's problem. On the assumption that the Earth was a spheroid, the authors of the Kangxi Atlas used curves to simulate the Earth's surface. Li Zhaoluo and Liu Yan did not share this assumption—indeed, they may even have been unaware of it—but they unhesitatingly reproduced the features of the emperor-endorsed map. Misinterpretations thus were inevitable.

Chen Li's friend Zou Boqi 鄒伯奇 (1819–1869) had a similar criticism of Li Zhaoluo and Liu Yan. He said: "Drawing a map whose rectangular grids are based on the arcs of the heaven is not an easy task. However, the earth is a globe. Longitude and latitude lines intersect and form right angles. If they are drawn as unbent lines on a plane, they will constitute oblique grids." His own map, he claimed, "uses curves to portray the globe" (*yiyuan huiyuan* 以圓繪圓), and in that feature it is distinctively different from those published by commercial printing houses.[48]

Feng Guifen 馮桂芬 (1809–1874), a reformist active from the 1840s to the 1860s, put cartography on his sociopolitical agenda. Feng softened the tone but still expressed his disapproval of the changes Li Zhaoluo had made. He said:

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[46] Ji Yun, *Yuewei caotang biji* 閱微草堂筆記 (1800 ed.), rpt. in *Xuxiu siku quanshu* (cit. n. 40), Vol. 1269, p. 89. For the scholarship of Qian Daxin and Ruan Yuan see Ori Sela, *China's Philological Turn: Scholars, Textualism, and the Dao in the Eighteenth Century* (New York: Columbia Univ. Press, 2018); Betty Peh-T'i Wei, *Ruan Yuan, 1764–1849: The Life and Work of a Major Scholar-Official in Nineteenth-Century China before the Opium War* (Hong Kong: Hong Kong Univ. Press, 2006); and Steven B. Miles, *The Sea of Learning: Mobility and Identity in Nineteenth-Century Guangzhou* (Cambridge, Mass.: Harvard Univ. Asia Center, 2006).

[47] Chen Li, *Dongshu ji* (cit. n. 41), Vol. 637, pp. 201–202.

[48] *Zou Boqi yigao* 鄒伯奇遺稿, p. 31. Zou Boqi's unpublished manuscripts are preserved in the Guangdong Provincial Museum. Zou's descendants transcribed them. The unpublished transcriptions, entitled *Zou Boqi yigao* (*Surviving Drafts of Zou Boqi*), can be found in the Guangzhou Library: http://opac.gzlib.gov.cn/opac/m/book/1441462.

> Li Zhaoluo's *The Complete Map* is the best map nowadays. It indicates relative distances through a network of grids, and, meanwhile, uses dashed lines to record the longitude degrees of the heavenly body. The map is sophisticated. However, there is an issue that requires clarification. The north pole has a fixed location, but the south–north lines vary from place from place. So do the east–west lines. Therefore, there must be minor discrepancies between directions in Li Zhaoluo's map and those in reality. The more eastwards or westwards, the south–north line leans more heavily. With the east–west lines increasingly winding, the south–north lines converge. . . . [Viewers] need to know that the dashed lines [in Li Zhaoluo's map] are the true south–north lines. The horizontal lines perpendicular to the dashed lines are the latitude lines, that is, the true east–west lines. When we republish [Li Zhaoluo's map] someday, we could change all the longitude and latitude line curves. If so, that is the best of the best.[49]

Given that the Earth is a spheroid, Feng Guifen, without considering the specific map projection, naturally assumed that the "true" longitude and latitude lines must be curves. The meridian curves of the Kangxi Atlas—that is, the dashed lines in *The Complete Map of the Unified Empire*—should thus be retained and used as references for drawing longitude lines, which were supposed to be perpendicular to meridians.

Since all existing maps were flawed, the advocates of the spherical Earth theory called for a thorough reform of cartographic practice. Feng Guifen's famous *Petitions from the Jiaobin Studio* (*Jiaobin lu kangyi* 校邠廬抗議) itemizes forty sociopolitical fields to be overhauled. Cartography is one of them.[50] However, in the second half of the nineteenth century, determining accurate latitudes and longitudes was an almost impossible mission—not only for individual scholars but also for an empire in its twilight.

In 1864 Chen Li and Zou Boqi accepted the provincial governor's invitation to contribute to *The Illustrated Introduction to Guangdong Province* (*Guangdong tushuo* 廣東圖說). Zou shared Chen's belief in the spherical Earth theory, whose maps were "wide at the bottom and narrow at the top."[51] *The Illustrated Introduction to Guangdong Province* is a ninety-two-volume gazetteer. Following the overview of Guangdong province and Canton, the provincial capital, are the sections on county-level units. The gazetteer has 106 maps in total: in addition to the maps for each administrative unit, the appendix offers a seven-folio atlas of Guangdong province.

These maps adopted latitude-longitude coordinates, but only a small portion of the longitude and latitude degrees were determined through astronomical observation. While the provincial government initiated the project, the burden of on-site measurement fell mainly to county magistrates, who were ill-equipped for the task and had limited knowledge of mapmaking. Zou Boqi wrote the manual *Treatise on Map-Drawing* (*Hui ditu shuo* 繪地圖說) to help local bureaucrats undertake this daunting task.[52] The provincial government soon distributed an abridged edition, *The Principles for Map-Drawing from the Office of Cartography in Guangdong* (*Guangdong Quansheng yutuju chifa Huitu zhangcheng* 廣東全省輿圖局飭發繪圖章程).[53]

However, *The Principles for Map-Drawing* is an instruction manual for measuring relative distances on the ground rather than determining latitudes and longitudes through astronomical

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[49] Feng Guifen, *Xianzhi tang ji* 顯志堂集 (1876 ed.), rpt. in *Xuxiu siku quanshu* (cit. n. 40), Vol. 1536, p. 37.

[50] Feng Guifen, *Jiaobin lu kangyi* 校邠廬抗議 (1884 ed.), rpt. in *Xuxiu siku quanshu*, Vol. 952, pp. 510–511.

[51] Chen Li, *Dongshu ji* (cit. n. 41), Vol. 637, p. 201.

[52] The transcription of *Hui ditu shuo* can be found in *Zou Boqi yigao* (cit. n. 48).

[53] Zhou Xin 周鑫, "Xuantong yuannian shiyin ben Guangdong yudi quantu zhi Guangdong sheng jingwei du tu kao: Wanqing nanhai ditu yanjiu zhiy" 宣統元年石印本《廣東輿地全圖》之《廣東省經緯度圖》考: 晚清南海地圖 研究之一, in *Haiyang shi yanjiu diwu ji* 海洋史研究第五輯, ed. Li Qingxin (Beijing: Shehui kexue wenxian chubanshe, 2013), pp. 219–222.

observation. The reason is simple: county administrators did not have sufficient measuring instruments at their disposal and in any case lacked the necessary training to operate them. *The Principles for Map-Drawing* admits that employing instruments such as theodolites to determine longitude and latitude degrees is "the most precise method," but "the instruments are not readily available." Moreover, using these instruments requires "specialized knowledge that not everyone is able to master."[54] To Zou Boqi's disappointment, even with the help of *The Principles for Map-Drawing* many officials were unable to perform the assigned tasks. In a letter, Zou confided his frustration to his friend:

> In the first month of last year, Governor Guo invited me to join the office [of *The Illustrated Introduction to Guangdong Province*] to prepare the atlas of Guandong. I have not yet finished the draft. At the beginning, I gladly accepted the invitation, and anticipated guiding people in conducting measurement. I purchased various instruments and collected dozens of Western-language maps of coastal areas, which extend from Southeast Asia to the estuary of the Amur river. I also obtained the Western-language records on the degrees of the sun, the moon, and other heavenly bodies. The measurements were taken on voyages and are the most accurate and reliable. However, no one has ever bothered to ask me about them. I am too tired to endure long-distance travel. Day by day, I just idle the time away. To finish the atlas, I have to patch up incongruous maps from counties, where no one knows about determining direction and distance.[55]

The paucity of measuring instruments and professional surveyors continued to plague the Qing government's cartographic projects until its final years. In 1889 the central government demanded maps from provincial, prefectural, and county administrators to prepare for a new atlas of the empire. The 1891 guide instructed the provincial governors to submit maps with latitude-longitude coordinates. Although its map's format complies with the central government's instruction, Guangdong province officials gathered latitude and longitude data only in Canton and coastal ports and on provincial borders. The rest are added to the map proportionally.[56]

CONCLUSION

The latitude-longitude coordinate system, like any other technology, is not an airtight, objective entity. Instead, its meaning-loaded existence is snared in a seamless social web. The reception of a technology is thus contingent on the reception of a set of norms and values ingrained in it. In the transcultural context, full reception is rare; selective appropriation is more common. Various actors in early modern China, from the Manchu emperors to commercial publishers, readily accepted the visual form of latitude-longitude coordinates, but few were able to accept or even understand the cosmological view embedded in the technology. In fact, most actors just strategically selected the components that best suited their interests and gave the technology new meanings. The emperors' and their courtiers' appreciation of the accuracy of the maps with latitude-longitude coordinates did not stop them from quietly overriding their cosmological foundation. For some scholars, what mattered most was the ties of these maps to the imperial court, while commercial publishers cared chiefly about the prospect of profit. From this vantage point, technology reception

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[54] *Guangdong Quansheng yutuju chifa Huitu zhangcheng* 廣東全省輿圖局飭發繪圖章程, pp. 1a–b (edition in the National Library of China, Beijing).

[55] Zou Boqi, *Zou Zhengjun cungao* 鄒徵君存稿 (1874 ed.), pp. 26a–b.

[56] Zhou Xin, "Xuantong yuannian shiyin ben Guangdong yudi quantu zhi Guangdong sheng jingwei du tu kao" (cit. n. 52). For the cartographic project in 1891 see Wang Yifan 王一帆, "Qingmo dili da cehui: Yi Guangxu Huidian yutu wei zhongxin" 清末地理大測繪: 以光緒會典輿圖為中心 (Ph.D. diss., Fudan Univ., 2011).

is indeed a plural process. In addition to cultural factors, the reception of a technology is conditioned by social circumstances. The characteristics of a technology that conduce to its survival and prosperity in one society could be obstacles to its dissemination in other societies. The new mode of mapmaking, like many other Western technologies, could not take hold in China before a social transformation took place. Here we can return to and affirm the vision of Peter the Great: before it could harness Western European technologies, Russian society had to be overhauled. Only in properly fertilized soil will crops grow.