5 · Taking the World's Measure: Chinese Maps between Observation and Text

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Historical scholarship has tended to measure the achievement of premodern Chinese cartography in terms of its application of numerical technique. Treated in this manner, Chinese cartography seems to parallel the course of European cartography. The modern form of the latter has often been regarded as the product of its alliance with number, so much so that modern maps are commonly viewed as scientific and value-free.[1] In the history of Chinese cartography, there is ample evidence of an alliance between number and map. There are, for example, attempts to formulate a coherent "code" specifying the methods to be used in translating empirical reality into quantitative terms. The quantitative techniques involved in mapmaking do not seem to have developed in response to cartographic needs per se; they were imported from established disciplines such as mathematical astronomy and water conservancy.[2] It is these codes and techniques that historians of Chinese cartography adduce to support their claims for a scientific tradition. The codes, however, do not seem to have been institutionalized or widely accepted. Part of the reason seems to have been a belief that the function of maps extended beyond the representation of nature knowledge to the transmission of cultural values and the preservation of political power. Contrary to the impression given in current accounts, in Chinese cartography there was no general tendency to eliminate human value from maps or to minimize its presence. As a result, cartography in China encompassed not only numerical techniques, but also what would now be considered humanistic concerns. The map allied itself with number and text. The two were not opposed—both were associated with value and power.

THE GOVERNMENT INTEREST IN MEASUREMENT

In *Oriental Despotism*, Wittfogel argues that the development of the Chinese bureaucracy could be linked to what he termed a "hydraulic" economy, one in which agriculture was supported by extensive irrigation projects requiring direction by an agromanagerial elite. The success of this economy depended on the making of accurate calendars to regulate agricultural activities, and this task also fell to the managerial elite. To the calendar measuring time, one could add the map for measuring and controlling space.

Wittfogel's analysis of the Chinese economy has been disputed, since the basic pattern of Chinese government, including the use of astrology, was created before rulers undertook extensive irrigation projects. Historians of Chinese science have also taken issue with him, since he proposes that hydraulic societies stifle creativity and are characterized by stagnation. According to Wittfogel, a centralized, bureaucratic political structure tended to "paralyze the search for scientific truth and social

1. One recent manifestation of this alliance is the use of digital computers for mapmaking. The literature on cartography is replete with references to its scientific character. In *Cartographical Innovations*, for example, maps are said to be scientific documents and works of art. The same work, however, suggests that this dual characterization does not apply to modern maps: "The 19th century mapmaker under his new name of cartographer belonged to the age of scientific communication in which cartography was establishing itself both as a science and as an industry." See Helen M. Wallis and Arthur H. Robinson, eds., *Cartographical Innovations: An International Handbook of Mapping Terms to 1900* (Tring, Hertfordshire: Map Collector Publications in association with the International Cartographic Association, 1987), XI and XVIII. John Keates, while reviewing a volume of essays exploring the relation between cartography and art, speaks of a "proper scientific and mathematical foundation for maps." See Keates's review of *Art and Cartography: Six Historical Essays*, ed. David Woodward (Chicago: University of Chicago Press, 1987), in *Cartographic Journal* 25 (1988): 179–80, esp. 179. For an exposition of cartography in terms of communication or information theory, see Arthur H. Robinson and Barbara Bartz Petchenik, *The Nature of Maps: Essays toward Understanding Maps and Mapping* (Chicago: University of Chicago Press, 1976). The authors of this work assert that "although cartography is often dubbed 'an art and science,' it is important to understand that it is also an exercise in engineering" (p. 108). This characterization again suggests the alliance of cartography and number—mapmaking as a kind of applied mathematics.

2. Here I use Stephen Toulmin's two-tiered definition of an intellectual discipline as having a well-defined subject matter and an explanatory (or procedural) ideal. See Toulmin's *Human Understanding* (Princeton: Princeton University Press, 1972–), vol. 1. In China, technical fields were defined according to subject matter and procedural ideal, though with epistemological bases different from those of European disciplines. See Nathan Sivin, "Science and Medicine in Imperial China—The State of the Field," *Journal of Asian Studies* 47 (1988): 41–90, esp. 43–44.

improvement."[3] Scholarship on Chinese science, however, has shown that Chinese civilization was capable of considerable innovation. Further weakening Wittfogel's interpretation of Chinese culture is the lack of evidence that the calendar served more than ritual purposes.

While admitting that some of Wittfogel's general conclusions do not withstand scrutiny, we can still recognize the aptness of at least one of his specific points: the masters of hydraulic civilization were "singularly well-equipped to lay the foundations for two major and interrelated sciences: astronomy and mathematics."[4] In large part, the mensurational and computational techniques that were applied to cartography do seem to have developed in response to bureaucratic or "managerial" needs, especially in the areas of astrology, water conservancy, and cadastral survey. Measurement, of course, was useful in other areas of government activity—for example, city planning and road construction. But given the agricultural basis of the Chinese economy and the importance of ritual to the ruling elite, a focus on astrology, water conservancy, and land measurement is perhaps justified.

The political interests involved in astrology and water conservancy went beyond those Wittfogel suggests. The accurate prediction of celestial phenomena was linked to the fortunes of the state: according to the correlative cosmology that characterized much traditional Chinese thought, heavenly anomalies signified political malfeasance that could lead to loss of political authority (see pp. 88–89 and 209–10). Water conservancy was linked to the fortunes of the political establishment in a more literal way: canals served as a major means of transporting to the capital grain and other commodities collected as taxes, in addition to supporting the agriculture that generated those revenues. The *Shi ji* (Records of the grand historian) contains the following account of the uses of canals: "All the canals could be used for the passage of boats; if there was surplus water, then they were used for irrigation, so that the people could benefit from them. Wherever the canals passed, they drew water forth from them, using it to irrigate the ditches in their fields. There were tens and hundreds of thousands of these ditches—rather, an incalculable number of them."[5]

In state service, those involved in astrology and water conservancy employed a number of mensurational techniques that had cartographic applications. By the Han dynasty (206 B.C.–A.D. 220), properties of right triangles and circles and their applications in astronomy, especially for determining distances between celestial objects and the earth and calculating the periodicity of certain celestial phenomena, were already understood. One text, the *Huainanzi* ([Book of the] Master of Huainan), traces the origins of units of measurement to celestial phenomena: "The *cun* arises from the millet seed. The millet seed arises from the sun. The sun arises from form. Form arises from shadow. This is the root of measurement."[6] The relationships among sun, shadow, and measurement are more explicit in the *Huainanzi*'s description of the use of gnomons to determine the height of the sun (illustrated in fig. 5.1):

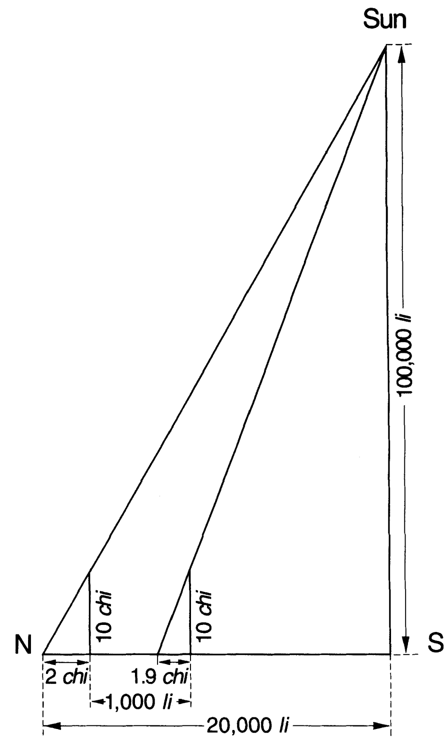


FIG. 5.1. CALCULATING THE HEIGHT OF THE SUN, ACCORDING TO THE *HUAINANZI* ([BOOK OF THE] MASTER OF HUAINAN).
After A. C. Graham, *Later Mohist Logic, Ethics and Science* (Hong Kong: Chinese University Press; London: School of Oriental and African Studies, University of London, 1978), 370.

> If you wish to know the height of the sky, plant gnomons 1 *zhang* [= 10 *chi*] tall directly north and south of one another, 1,000 *li* apart. Measure their shadows on the same day. If that of the northern gnomon is 2 *chi* long, and that of the southern gnomon 1 *chi* and 9 *cun* [10 *cun* = 1 *chi*], then every thousand *li* farther south the shadow shortens by a *cun*, and 20,000 *li* southward there is no shadow, since it is directly under the sun. Where the shadow is 2 *chi* and one obtains a height of 1 *zhang*, the height is five times the distance

3. Karl A. Wittfogel, *Oriental Despotism: A Comparative Study of Total Power* (New Haven: Yale University Press, 1957), 9.

4. Wittfogel, *Oriental Despotism*, 29 (note 3).

5. Sima Qian, *Shi ji* (completed ca. 91 B.C.), chap. 29; see the edition in 10 vols. (Beijing: Zhonghua Shuju, 1959), 4:1407.

6. *Huainanzi* (ca. 120 B.C.), attributed to Liu An (d. 122 B.C.), in *Huainanzi zhu* (Commentary on the *Huainanzi*, third century), ed. Gao You, chap. 9; see the modern edition (Taipei: Shijie Shuju, 1962), 141.

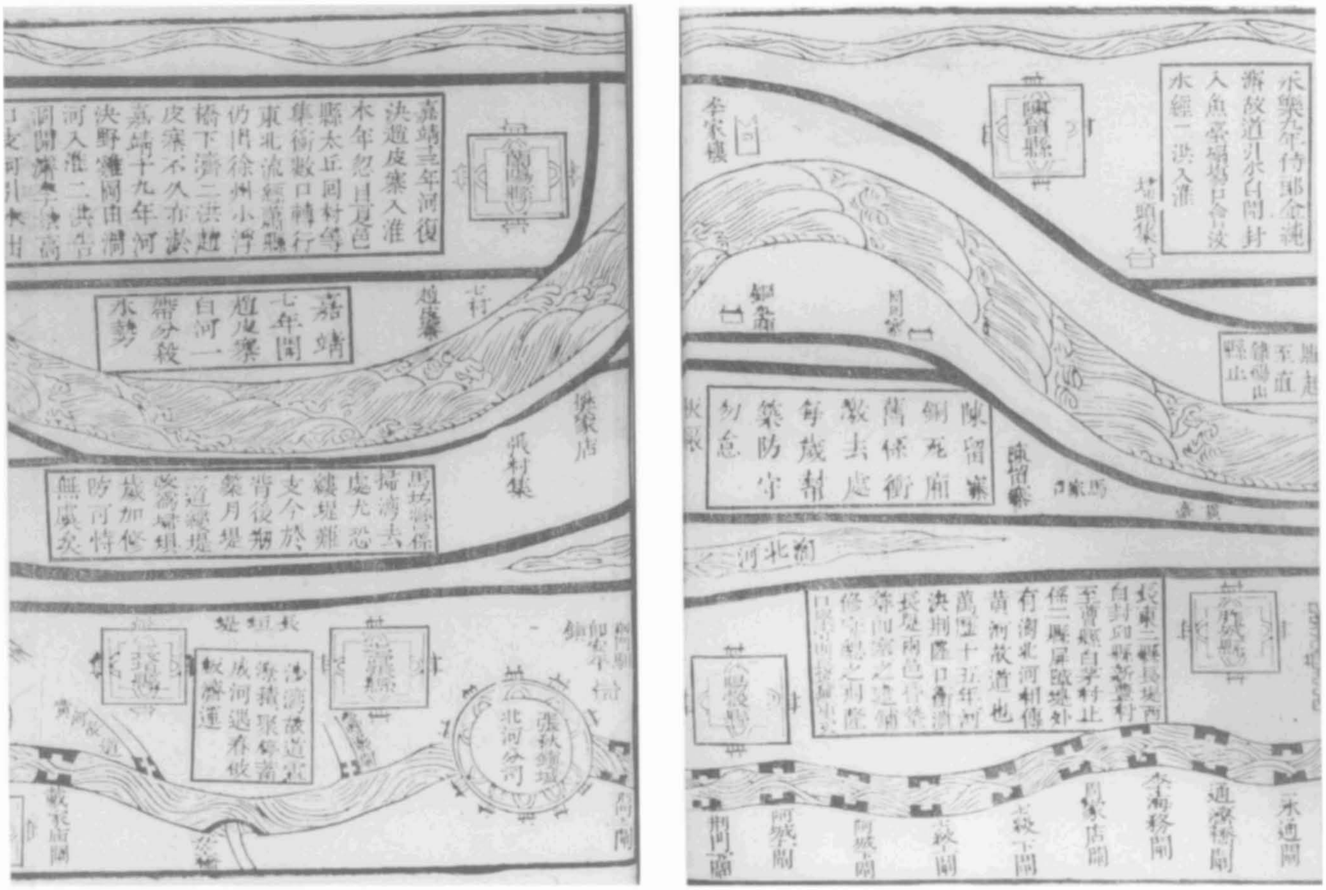


FIG. 5.2. PLANIMETRIC HYDROLOGIC MAP. Portion of a map of the Huanghe, or Yellow River (compare this with fig. 5.3 and plate 5). Size of each page: 19.5 × 14 cm. From Pan Jixun, *Hefang yilan* (General view of river control, 1590), 1748 edition, chap. 1, unpaginated. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

> southward. If you take the number of *li* from this point to the place under the sun [20,000 *li*] and multiply it by five, you get 100,000 *li*: this is the height of the sky.[7]

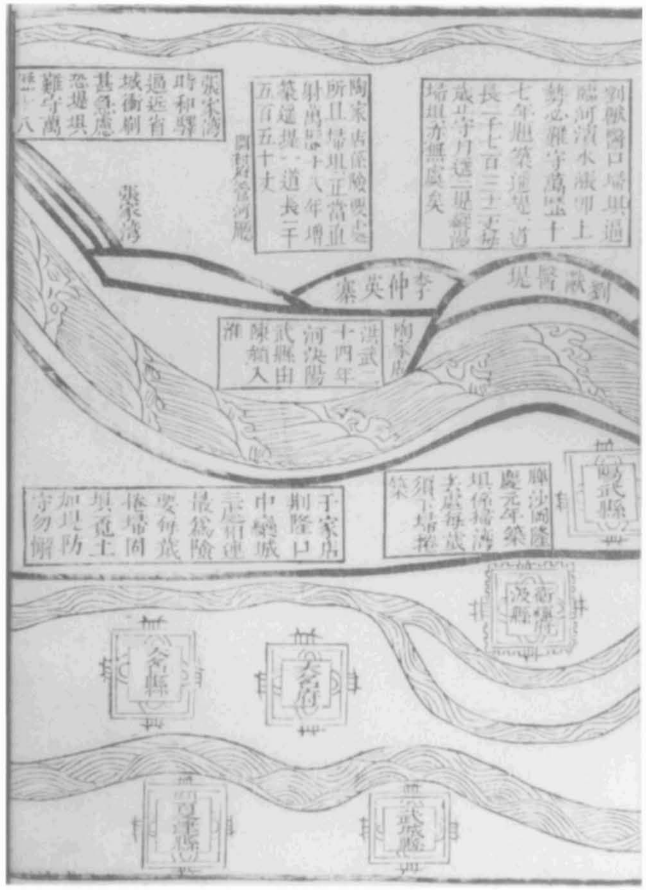
The properties of similar triangles used for indirect measurement in this example were also applied in cartography, as we will see below.

From textual sources, it appears that water conservancy projects, as well as land allocation schemes, were stimuli for techniques of direct measurement. During the Han, water conservancy was believed to have had a long association with mensuration: in the *Shi ji*, the emperor Yu is described as holding a plumb line, a carpenter's square (*ju*), and a pair of compasses (*gui*) while surveying for his work in flood control.[8] The *Zhou li* (Ritual forms of Zhou) purports to describe a Zhou dynasty (ca. 1027–256 B.C.) bureaucracy that had already standardized the depths and widths of canals—an action that presupposes the existence of mensurational techniques. Since at least the late Zhanguo (Warring States) period (403–221 B.C.), mensuration itself was regarded as linked to the well-being of the state. According to an account in the *Zuozhuan* (Zuo's tradition [of interpreting the *Chunqiu*, or Spring and autumn annals]), a text dating from about 300 B.C., mensuration served as an instrument of fiscal policy:

> Wei Yan was made marshal of Chu, and Zimu [the chief minister] commissioned him to regulate the gov-

7. *Huainanzi zhu*, chap. 3 (54) (note 6). The ancient Greeks also noticed that gnomon shadows shorten as one proceeds southward toward the tropic. Eratosthenes (ca. 275–194 B.C.) attributed this decrease to the curvature of the earth and used it to calculate the earth's circumference (see Germaine Aujac and the editors, "The Growth of an Empirical Cartography in Hellenistic Greece," in *The History of Cartography*, ed. J. B. Harley and David Woodward [Chicago: University of Chicago Press, 1987–], 1:148–60, esp. 154–56). In contrast, the *Huainanzi* ascribes the decrease in shadow length to the decrease in angle as one gets closer to the place directly under the sun. The calculation of the sun's altitude presupposes that the earth's surface is essentially level. The *Huainanzi* does give dimensions for the earth: "28,000 *li* east to west and 26,000 *li* north to south" (chap. 4 [56]), but how these dimensions were derived is not stated. Chinese notions of the shape of the earth are discussed later in this chapter.

8. *Shi ji*, chap. 2 (1:51) (note 5).



> ernment levies and count the number of cuirasses and weapons each fief had to contribute. . . . Wei Yan made a register of arable lands, measured the mountains and forests, calculated the area of marshlands, distinguished the highlands and the downs, listed salt tracts, enumerated the borders of flooded areas, measured the area of diked reservoirs, regularized balks to divide the plains between embankments, assigned low wetlands for pasturage, divided fertile land into units shaped like the graph *jing* [well; that is, into grids]. He determined the levies due, fixing the number of chariots and horses to be contributed, and assessing the numbers of chariot drivers, foot soldiers, and armored soldiers with shields that had to be mustered. He presented the results to Zimu. They were all proper.[9]

As this last example suggests, in China as elsewhere, government support for numerical techniques had as its primary purpose not the representation of nature, or reality, for its own sake, but the perpetuation of political power. The understanding of nature was secondary to the practical matter of maintaining the government. Land, for example, was measured as a means of calculating taxes owed. Information on ownership, extent of holdings, and boundaries was recorded in land registers. Those that survive from the Tang (618–907) consist entirely of text, but from the Song (960–1279) onward such registers were often accompanied by maps. The maps in the registers gave a sense of the configuration of the fields measured, while annotations and accompanying text provided the measurements and other information.

This dual form of record keeping could also be used to help prevent tax evasion, as has been mentioned elsewhere (p. 86). The Qing scholar Gu Yanwu (1613–82) transcribes this account of the situation under the Ming: "Local governments kept records of the number of male

9. *Zuozhuan* (ca. 300 B.C.), *Xiang* 25, in *Chunqiu jingzhuan yinde* (Concordance to the *Chunqiu* [Spring and autumn annals] and its commentaries), 4 vols. (1937; reprinted Taipei: Chengwen Chubanshe, 1966), 1:307. The translation here is based on that of James Legge in *The Chinese Classics*, 5 vols. (1893–95 editions; reprinted Hong Kong: Hong Kong University Press, 1960), vol. 5, *The Ch'un Ts'ew with the Tso Chuen*, 517.

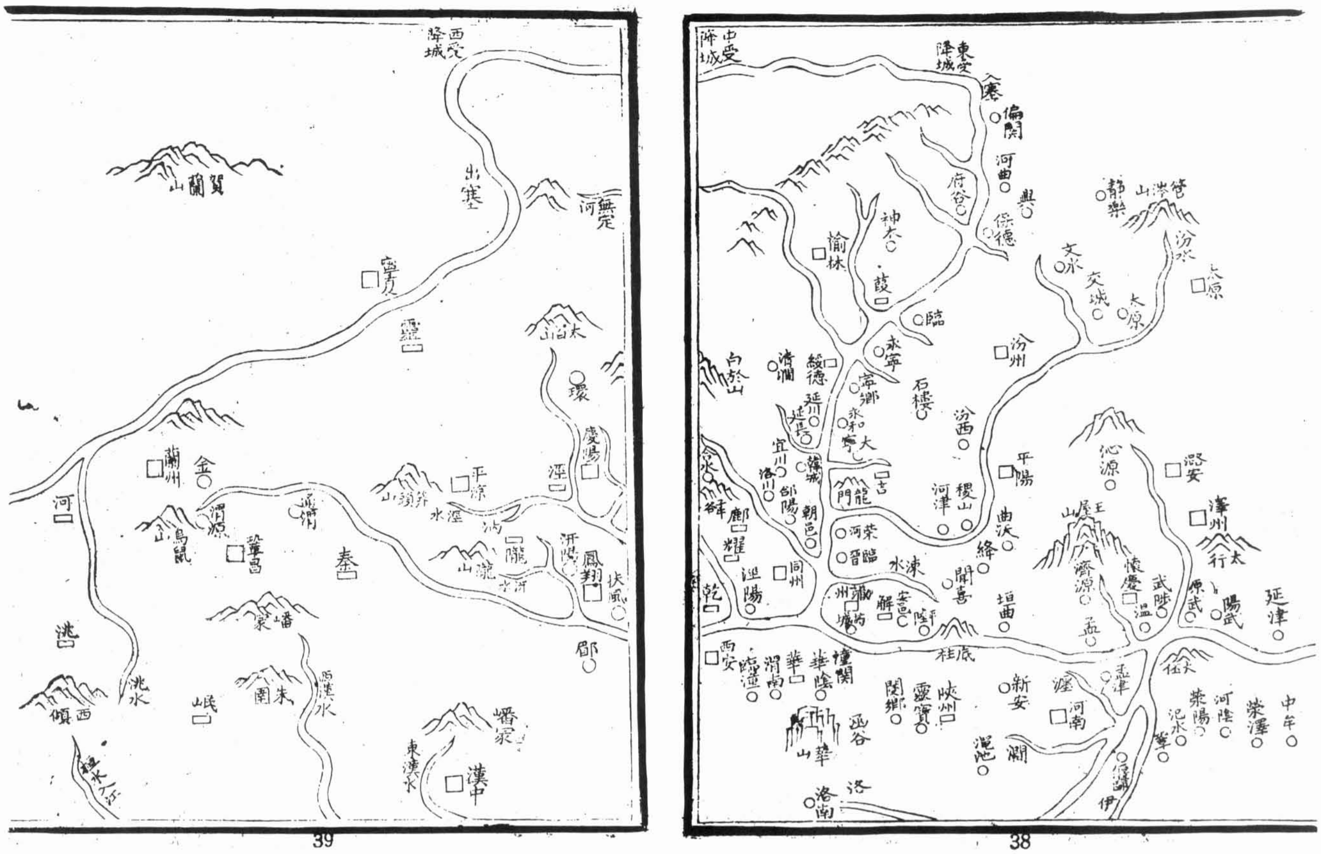


FIG. 5.3. PORTION OF A MAP OF THE YELLOW RIVER. The rivers are represented planimetrically and the mountains in a more pictorial form. Size of each page: ca. 14 × 11 cm. From Jin Fu, *Zhihe fanglüe* (Summary of river-control methods), ed. Cui Yingjie (1767; photo-reprinted Taipei: Guangwen Shuju, 1969), 38–39.

members and the property of each household. Each village kept maps of fields that were close together. [The imperial government] could check the maps to see whether fields were desolate or cultivated, and there was no covering up of the owner of each field."[10] Under the Ming, four sets of population records were made by local officials, one each for county, prefectural, and provincial governments. The fourth copy was sent to the imperial government and had a yellow cover to signify this, thus the generic term for these registers: *huangce*, or yellow books. The registers were often accompanied by cadastral maps, which depicted the boundaries of contiguous landholdings in a manner that resembled the scales of a fish. These maps were thus known as *yulin tu*, or fish-scale maps (see fig. 4.10 above).[11]

For presenting the results of cadastral surveys, both forms of representation, the textual and the cartographic, were regarded as essential. Gu Yanwu records this statement: "One can see that maps and registers complement each other, and neither is dispensable. Maps link people to the land, so they are the foundation of taxation. Registers list the farmland of each household, so that [the

10. *Zhenjiang fu zhi* (Gazetteer of Zhenjiang Prefecture [in present-day Jiangsu Province], date not given but presumably the 1596 edition), quoted in Gu Yanwu, *Tianxia junguo libing shu* (Treatise on the advantages and disadvantages of the commanderies and states of the empire, preface written in 1662) (1811; reprinted Taipei: Taiwan Shangwu Yinshuguan, 1981), 7.80a. As Gu recognizes, however, the system seldom worked to perfection. Local officials and clerks were susceptible to corruption and could be bribed to falsify records. In many instances the central government had to intervene: "In the twelfth year of the Hongwu reign period [1379], there was an investigation of the farmland all over the empire. [The government] sent students from the imperial academy to measure the fields, make maps, and number them" (*Zhenjiang fu zhi*, quoted in Gu, *Tianxia junguo libing shu*, 7.80a).

11. Sometimes such maps were included in the yellow books, and sometimes they made up registers of their own, *yulin ce* or *yulin tuce* (fish-scale registers or fish-scale map registers).

Previous scholarship has tended to use the fish-scale maps as a means of gauging the efficiency or inefficiency of the imperial tax collection process, while slighting their cartographic interest. As a result, there are no catalogs of fish-scale maps, though visitors to China have noted their existence in various libraries and museums. See Frederic Wakeman, Jr., ed., *Ming and Qing Historical Studies in the People's Republic of China* (Berkeley: Institute of East Asian Studies, University of California, Berkeley, Center for Chinese Studies, 1980). A useful survey of land tenure systems in Ming China is Chao Kang and Ch'en Chung-i (Zhao Gang and Chen Zhongyi), *Zhongguo tudi zhidu shi* (History of Chinese

FIG. 5.4. WATER CONSERVANCY WORKERS PERFORMING MEASUREMENTS FOR CUTTING A CANAL. This is a detail from a Qing illustration.
Size of the full page: 29 × 28 cm. From Linqing, *Hongxue yinyuan tuji* (Illustrated record of my life experiences—[traces of] a goose [treading on] snow, 1847), vol. 11, unpaginated. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

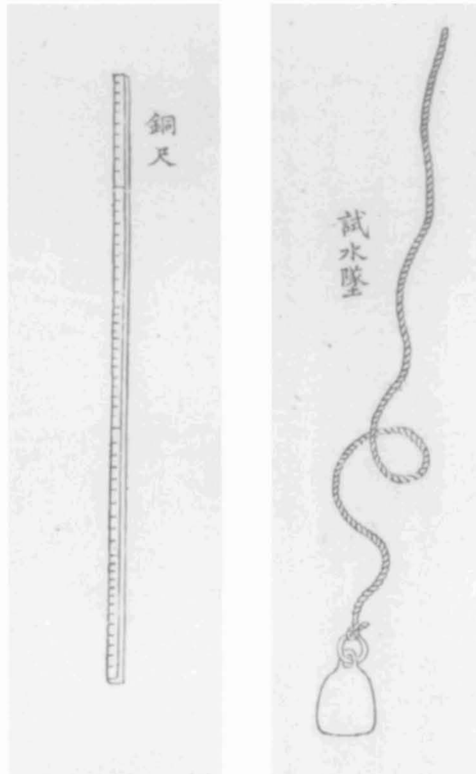


FIG. 5.5. EXAMPLES OF MEASURING TOOLS USED IN WATER CONSERVANCY. On the left is a graduated rod and on the right a plumb line.
Length of the originals: both ca. 16 cm. From Linqing, *Hegong qiju tushuo* (Illustrated explanation of the tools used in river works, 1836), 1.6a and 1.4a. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

government] can collect taxes and assign civic duties."[12] The dual system of record keeping described here was not unique to cadastral surveys. Similar systems in which text complemented map were also employed in other areas of government concern—for example, water conservancy.

Water Conservancy and Cartography

The state interest in water conservancy projects was accompanied by an interest in specialized hydrological maps representing rivers, canals, and their immediate surroundings. One might expect that mensuration in water conservancy projects would be transferred to maps—that water conservancy projects fostered the production of maps and plans reflective of careful measurement. In this case, however, history does not conform to expectations. Like the surviving corpus of geographic maps, hydrological maps manifest a wide range of representational modes (see figs. 5.2 and 5.3 and plate 5). Some of them are almost purely planimetric, making them suitable for the presentation of quantitative information, except that in some cases such maps lack scalar indications. More often, however, hydrological maps are eclectic in their manner of representation, some showing a mix of planimetric and pictorial modes and others almost completely pictorial. Like geographic maps, hydrological maps were often not intended to stand alone—they were usually accompanied by texts. In many cases, maps or diagrams were drawn to accompany memorials to the throne reporting on water conservancy projects.[13]

land-tenure systems) (Taipei: Lianjing Chuban Shiye Gongsi, 1982). On the yellow book system, one may consult Wei Qingyuan, *Mingdai huangce zhidu* (Yellow book system of the Ming period) (Beijing: Zhonghua Shuju, 1961).

12. *Zhenjiang fu zhi*, quoted in Gu, *Tianxia junguo libing shu*, 7.80b–81a (note 10).

13. The practice of appending maps or diagrams (*tu*) to memorials pertaining to water conservancy goes back at least to the Song. The *Song shi* (History of the Song, 1346) preserves at least one memorial stating that it is accompanied by a map or illustration (Tuotuo et al., *Song shi*, chap. 94; see the edition in 40 vols. [Beijing: Zhonghua Shuju, 1977], 7:2332). The map, however, is not reproduced. In addition, at least 200 memorials from the Qianlong reign period (1736–95), out of the roughly 34,000 reproduced by the National Palace Museum in

These memorials reported on such matters as the condition of embankments, the progress of construction and repair work, the expenses incurred for particular projects, and changes in flood conditions. In some cases officials seem to have carried out volumetric calculations to estimate the acreage that certain canals would be able to irrigate.[14] More often, they performed and recorded linear measurements of rivers, canals, and embankments (fig. 5.4). For these measurements, the officials could have used the graduated rods and plumb lines illustrated in a Qing text on hydraulics (fig. 5.5).

The attention officials paid to measurement is evident in these excerpts from memorials of the Qianlong period (1736–95):

> The east embankment of the Feng River should be subdivided again and raised up 2 or 3 *chi* in order to avoid overflowing. Moreover, within the 20 *li* at the southern embankment where the floodwaters collect in the lower reaches, reinforcement should be made to block river sediments.[15]

> Together we measured below the city of Xuzhou [in present-day Jiangsu Province]. The surface of the river was 20 or 30 *zhang* wide and the water 5 or 6 *chi* deep. We also measured the original flooding at Sunjiaji. The surface of the river was 203 *zhang* wide where two dams had already been built in the north and south. These works were 87 *zhang* long. Where dams were as yet unbuilt, the surface of the water was 116 *zhang*, and the water's depth varied from 3 or 4 *chi* to 1 *zhang* and 8 or 9 *chi*.[16]

> From the lakeshore to the base of the dam, there was originally a diversion canal. It measured 35 *li* in length. Beyond the dam, the diversion canal reached to the cliffs of the Yellow River. We measured the course to be 14 *li*. This time, though the lake's water was overflowing for 13 *li* around, we measured the water at lakeside to be 1 *zhang* and 8 or 9 *chi* deep. The water at the head of the diversion canal was only 2 or 3 *chi* deep.[17]

The memorials these passages were taken from all state that a map was appended for the emperor's reference. The Qianlong emperor seems to have attached great importance to the maps presented with memorials. He implicitly criticized officials for not submitting maps with memorials reporting on water conservancy projects, and in some cases he asked for explanation of things that were unclear on the maps submitted.[18] The emperor's orders for the execution of water conservancy work were often based on maps. One official, for example, memorialized that the emperor had used a map to direct work on the expansion of a waterway and thus averted danger.[19]

The maps that accompanied the memorials quoted above apparently have not been preserved, so we do not know what modes of representation were employed in them. What evidence there is suggests that pictorial representation was used to some extent. In the memorials, the verb most often used to describe their manufacture is *hui*, meaning "to paint," especially using color. In fact, one official describes the color symbolism employed on maps presented with memorials: "Within the dikes, [a map submitted previously] used a deep green. Within deep waters, it used a deep blue. For hidden sandbars, it used black ink. Each color was painted in a clear and distinct manner. The map presented this time uses only light colors to give a simple sketch and does not distinguish between shallow and deep water. It thus cannot be understood at a glance, and that being so, your highness ordered that maps presented subsequently by this governor should—according to the former style—be painted so as to distinguish the colors."[20] This memorial dates from 1778, well after the court had been introduced to the European style of cartography. The discrepancy between the two styles of painting described in the memorial suggests a lack of standardized practice within the bureaucracy. In addition, it seems that pictorial technique for the easy recognition of geographic features of interest was just as important as the quantitative information presented in the memorials. This is corroborated by maps now separated from the memorials they once illustrated: these maps are characterized by the use of color and pictorial elements (plates 6 and 7).[21]

The same pictorial representation can be found in maps included in hydrological treatises, where the division of labor is similar to that proposed for map and memorial. In hydrological treatises from the Qing (1644–1911), quantitative information, as well as historical facts, is found in verbal text, and maps provide a sense of the

Taiwan, say that they are presented together with maps or diagrams. These memorials appear in *Gongzhongdang Qianlong chao zouzhe* (Palace memorials from the Qianlong reign period in the palace archives), 69 vols. (Taipei: Guoli Gugong Bowuyuan, 1982–88).

14. See, for example, *Qianlong chao zouzhe*, 1:385–387 (note 13).

15. *Qianlong chao zouzhe*, 2:109 (note 13).

16. *Qianlong chao zouzhe*, 15:656 (note 13).

17. *Qianlong chao zouzhe*, 48:617 (note 13).

18. See, for example, *Qianlong chao zouzhe*, 37:863, 45:662, 6:10 (note 13). We do not have the emperor's exact words, but the officials' responses to them note that the emperor commented that maps were lacking in previous memorials. The officials also promise to attach maps to future memorials on water conservancy projects.

19. *Qianlong chao zouzhe*, 27:156 (note 13).

20. *Qianlong chao zouzhe*, 43:552 (note 13).

21. Under the Qing palace memorial system, memorials and maps were preserved separately, thus the difficulty in matching maps with their corresponding memorials. For further discussion of the relation between map and picture, see chap. 6 below, esp. pp. 139–53.

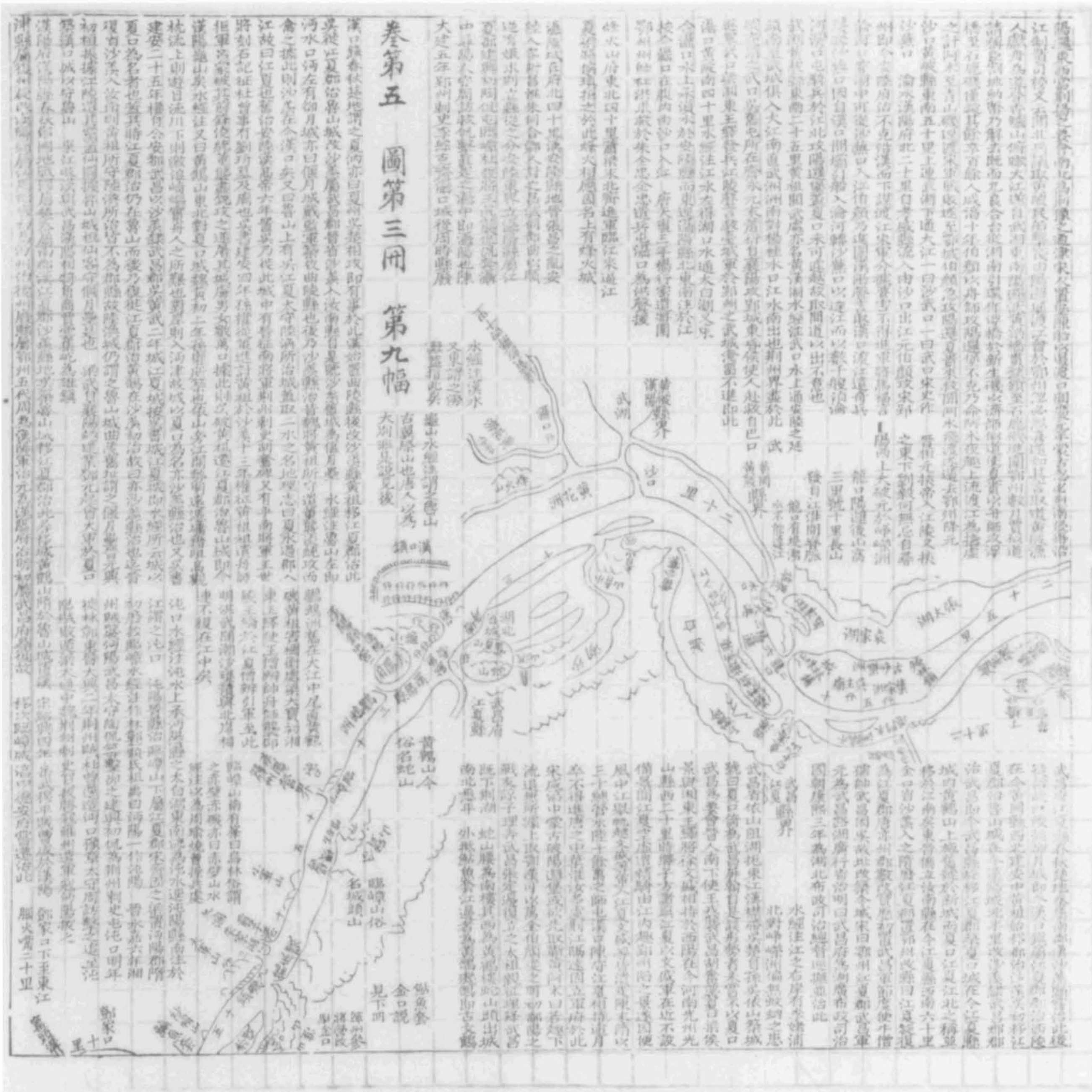


FIG. 5.6. TEXT AND IMAGE ON A QING MAP OF THE CHANGJIANG, OR YANGTZE RIVER. The text on the map gives historical and geographic information, referring to previous scholarship. Size of the original: 26.5 × 27 cm. From Ma Zhenglin, *Changjiang tushuo* (Illustrated account of the Yangtze, 1871), chap. 5, map 9. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

physical appearance of the area of interest.[22] In some cases the cartographic image is almost overwhelmed by text (fig. 5.6). More typical is a division of map and text, as in the *Xingshui jinjian* (Golden mirror of flowing waters), a hydrological work dating from 1725. It opens with a section of maps predominantly pictorial in their mode of presentation (fig. 5.7). The work is predominantly text, however, and the author's reverence for text is made clear in the narrative. The main descriptions are taken from classic texts such as the "Yu gong" (Tribute

22. A similar situation obtains in the use of maps in legal cases in Europe since the late medieval period. The map does not serve as the final authority. Even in present-day international boundary legislation, lawyers prefer to verbalize, not map.

FIG. 5.7. SECTION OF A QING MAP OF THE YELLOW RIVER.
Size of each page: 18 × 13.5 cm. From Fu Zehong, *Xingshui jinjian* (Golden mirror of flowing waters, 1725), 1.55a–56b. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

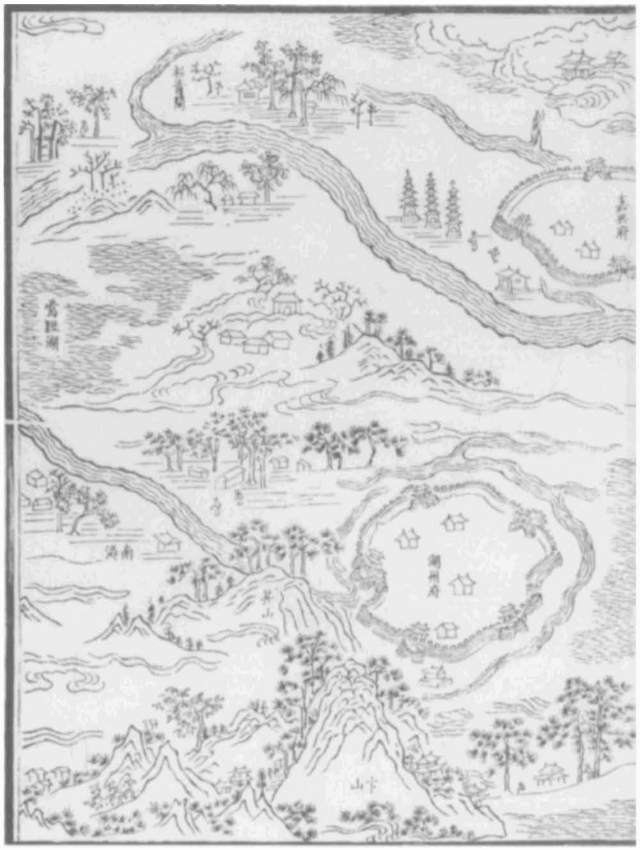
of Yu), the *Shui jing* (River classic), and the commentary on the *Shui jing*. The author of the *Xingshui jinjian* intrudes only to supplement, correct, or update information given in a prior text.

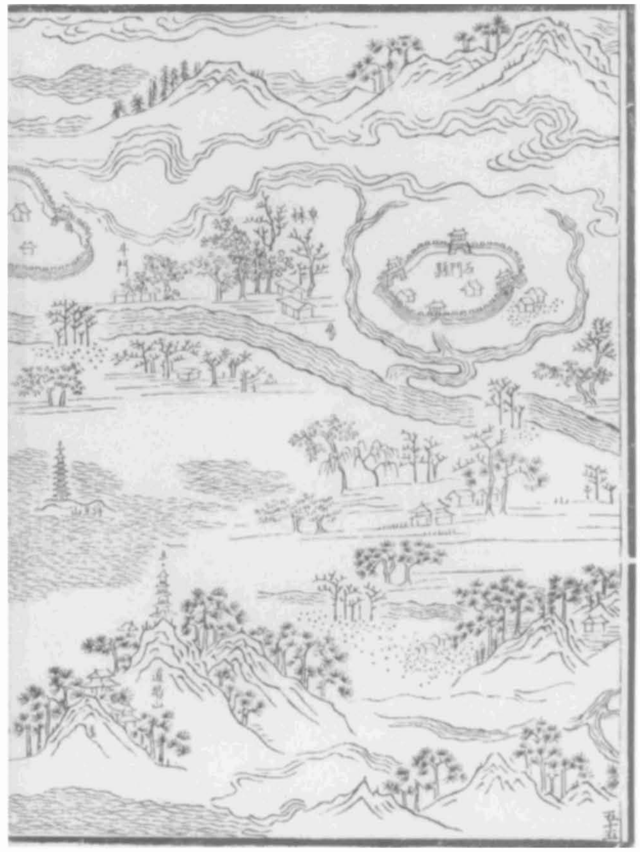
The *Xingshui jinjian* was compiled at roughly the same time as the Jesuit atlas of China, which was based primarily not on textual research, but on an actual survey of much of the empire. The maps in the atlas are uniformly planimetric in presentation, bear expressed scales, and indicate latitude and longitude. Looking at the atlas alone, one might be tempted to conclude that Chinese cartography had joined European cartography and left text behind. This view of Chinese cartography is untenable. As the preponderance of text in the *Xingshui jinjian* suggests, one also finds a strong interest in text among Chinese mapmakers even during the Qing.

Evidentiary Scholarship and Cartography

The late Ming (1368–1644) and early Qing dynasties were marked by what Sivin, Elman, and others have described as a revolution in Chinese intellectual discourse, the rise of *kaozheng* (evidential research).[23] At the heart of evidential scholarship was a faith in textual research as a ground for knowledge—primarily knowledge of what was meant in canonical texts. Textual scholarship was a means of recovering the past, a pursuit of prime importance, since the way of the ancients was considered the

23. See, for example, Nathan Sivin, "Wang Hsi-shan," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie, 16 vols. (New York: Charles Scribner's Sons, 1970–80), 14:159–68, esp. 160–61; Benjamin A. Elman, *From Philosophy to Philology: Intellectual and Social Aspects of Change in Late Imperial China* (Cambridge: Council on East Asian Studies, Harvard University, 1984); Liang Ch'i-ch'ao (Liang Qichao), *Intellectual Trends in the Ch'ing Period*, trans. with introduction and notes by Immanuel C. Y. Hsü (Cambridge: Harvard University Press, 1959) (translation of *Qingdai xueshu gailun* [Survey of Qing scholarship, 1921]); and R. Kent Guy, *The Emperor's Four Treasuries: Scholars and the State in the Late Ch'ien-lung Era* (Cambridge: Council on East Asian Studies, Harvard University, 1987), 39–49. For an analysis of the *kaozheng* movement as the logical outcome of preceding intellectual trends, not a departure from them, see Yu Yingshi (Ying-shih Yü), "Qingdai sixiang shi di yige xin jieshi" (New interpretation of Qing intellectual history), in his *Lishi yu sixiang* (History and thought) (Taipei: Lianjing Chuban Gongsi, 1976), 121–56.





pattern for the present. One of the main factors in the rise of this type of scholarship was dissatisfaction with Song and Ming Neo-Confucian discourse, which its detractors claimed imparted to the classics a metaphysical significance inconceivable to their original authors. Also contributing to the development of evidential research was contact with the West. Confronted with European mathematical and scientific achievements, Chinese scholars reexamined their past in an attempt to rediscover their own traditions of astronomy and mathematics. There were those who claimed that Western mathematics and astronomy were actually of Chinese origin—thus ancient Chinese mathematics and astronomy were part of the lost past that needed to be reconstructed.[24]

Given the variety of the kinds of texts to be used in reconstructing the past, it was almost inevitable that some academic specialization occurred—scholars often focused their energies on texts from specific fields, such as mathematical astronomy, mathematics, and history. Regardless of specialty, the evidential scholars used a common method, one based on the examination and comparison of textual sources.

In efforts by *kaozheng* scholars to recover the past, geography had its place—historical geography was a means of reconstructing the past. In this research, maps were used as documentary sources and could also serve as a means of presenting research results, for example, in studies of ancient places. One such study was undertaken by the scholar Xu Song (1781–1848), in the *Tang liang jing chengfang kao* (Study of the walled cities and wards of the two Tang capitals). In the preface to his study Xu explains his motivation: "I delight in reading the *Jiu Tang shu* [Old history of the Tang] and Tang fiction. Whenever they mention palaces and gardens with their crooks and bends and alleys and lanes that fork and branch out, I reach for the *Chang'an zhi* [Gazetteer of Chang'an, by Song Minqiu (1019–79)] to verify them. What I always get are errors, and with the eastern capital the mistakes are similar."[25] Part of the rationale behind

24. See John B. Henderson, "Ch'ing Scholars' Views of Western Astronomy," *Harvard Journal of Asiatic Studies* 46 (1986): 121–48, esp. 138–43.

25. Xu Song, *Tang liang jing chengfang kao* (1848); *Baibu congshu jicheng* edition, preface, 1a.

Xu's study was to correct errors in previous descriptions of the Tang capitals. As might be expected of a work of *kaozheng* scholarship, Xu's method of verification involves textual research, the collation and comparison of a variety of documentary sources: histories, gazetteers, encyclopedias, maps, and inscriptions.

In presenting his research results, Xu makes use of maps, though the great bulk of his work consists of verbal description. In using maps, Xu says he is following ancient precedent: "In antiquity, those engaged in scholarship had maps on the left and history on the right. Maps must be interrelated with history."[26] In accord with the tenets of *kaozheng* scholarship, Xu conceives of maps as tools for historical reconstruction. The intimate connection Xu sees between map (or chart) and history may be a residuum of the earlier Qing reaction against the abstract geography of those Neo-Confucian intellectuals who were more interested in geometric regularity and metaphysical correspondences than in empirical reality and who saw no problem with constructing charts of the nine regions (*jiu zhou*) with no reference to geographic reality. In opposition to this practice, Xu affirms that maps should have a basis in historical actualities. Xu is interested in historical reconstruction not for its own sake, but as a means of clarifying ancient precedent. The purpose of his work, he says, is to serve as "an aid in singing praises of the poetic compositions by Tang exemplars."[27] By Xu's time, Tang poetry had long been regarded as the high point in Chinese literary history, and Xu intends his study as a work of literary scholarship—it is supposed to further one's appreciation of Tang literature.

Much of Tang literature, poetry and fiction, is set in one of the two capitals, Chang'an or Luoyang, which attracted literati seeking careers in government. From the descriptions in Xu's study, one can infer that his study was meant to be used to reestablish the connection between Tang literary works and historical actuality. True to what he says in his preface, Xu provides, for example, a plan and narrative description of the palace city, once used as the residence of the emperor and his court. The plan (fig. 5.8) has no scale indications and seems to serve mainly to indicate the relative positions of various landmarks. More detailed information including measurements is provided in the text, a typical passage from which reads: "The palace wall is 4 *li* from east to west and 2 *li* and 270 *bu* from south to north. In perimeter it is 13 *li* and 180 *bu*. Its height is 3 *zhang* and 5 *chi*."[28] Such descriptions, drawing from dynastic histories, gazetteers, encyclopedias, anecdotes, inscriptions, maps, and other sources, account for almost all of Xu's study.

The maps and chorographic information are supposed to be in the service of literary criticism, but rarely does Xu cite the Tang poetic and fictional works his study is supposed to illumine. Occasionally he quotes a few lines from a poem written at a particular place, and sometimes he merely notes that a certain poet wrote a poem about a certain place. Beyond that, Xu does not discuss how the maps and chorographic information he provides increase one's appreciation for literature. For this reason, Xu's study might seem to fall short in comparison with modern works of literary scholarship, which tend to quote extensively from and to closely analyze the literary texts under study. Xu, however, may be excused for forgoing such quotations and close readings. Readers of Chinese poetry in imperial times expected that poems set in a city would incorporate accurate descriptions of that city. Thus a major aim of literary criticism was to determine whether a poem's description of place was accurate, for example, verifying what was actually visible from a given location. It is therefore not surprising that Xu does not quote a great deal of poetry. To depend on the poetry would have defeated the book's critical enterprise.

The usefulness of cartography as textual criticism, though important for historical reconstruction, was also recognized in projects that aimed at further understanding of the present. The compilation of the imperially sponsored *Da Qing yitong zhi* (Comprehensive gazetteer of the Great Qing realm, completed 1746) involved a number of textual scholars, who collected and compared documents containing geographic information. The gazetteer includes maps, but the bulk of the work consists of verbal descriptions. The maps in the gazetteer's last revised edition, completed in 1820 and printed in 1842, have no grids or meridians and parallels and no expressed scale. It seems that even after Matteo Ricci's world map and after the Jesuit survey of China, a considerable group of Chinese intellectuals still remained unconvinced of the advantages of Western European cartography. Maps, it appears, were useful in providing a quick grasp of the spatial relationships between the landmarks represented, but for detailed information about distance and direction, the preferred means of presentation remained verbal description.

This lack of attention to cartographic representation by Chinese scholars was pointed out in a work roughly contemporaneous with the last revised edition of the *Da Qing yitong zhi*. This work was the *Yinghuan zhilüe* (Short account of the maritime circuit), a world geography completed in 1848 by Xu Jiyu (1795–1873). Xu, who served as governor of Fujian Province, was writing in the aftermath of the Opium War, which demonstrated the empire's vulnerability to foreigners it had regarded as inferior. In order to deal with the new challenge from without and to accurately assess their place in the world,

26. Xu, *Tang liang jing chengfang kao*, preface, 1a (note 25).
27. Xu, *Tang liang jing chengfang kao*, preface, 1a (note 25).
28. Xu, *Tang liang jing chengfang kao*, 1.1a–b (note 25).

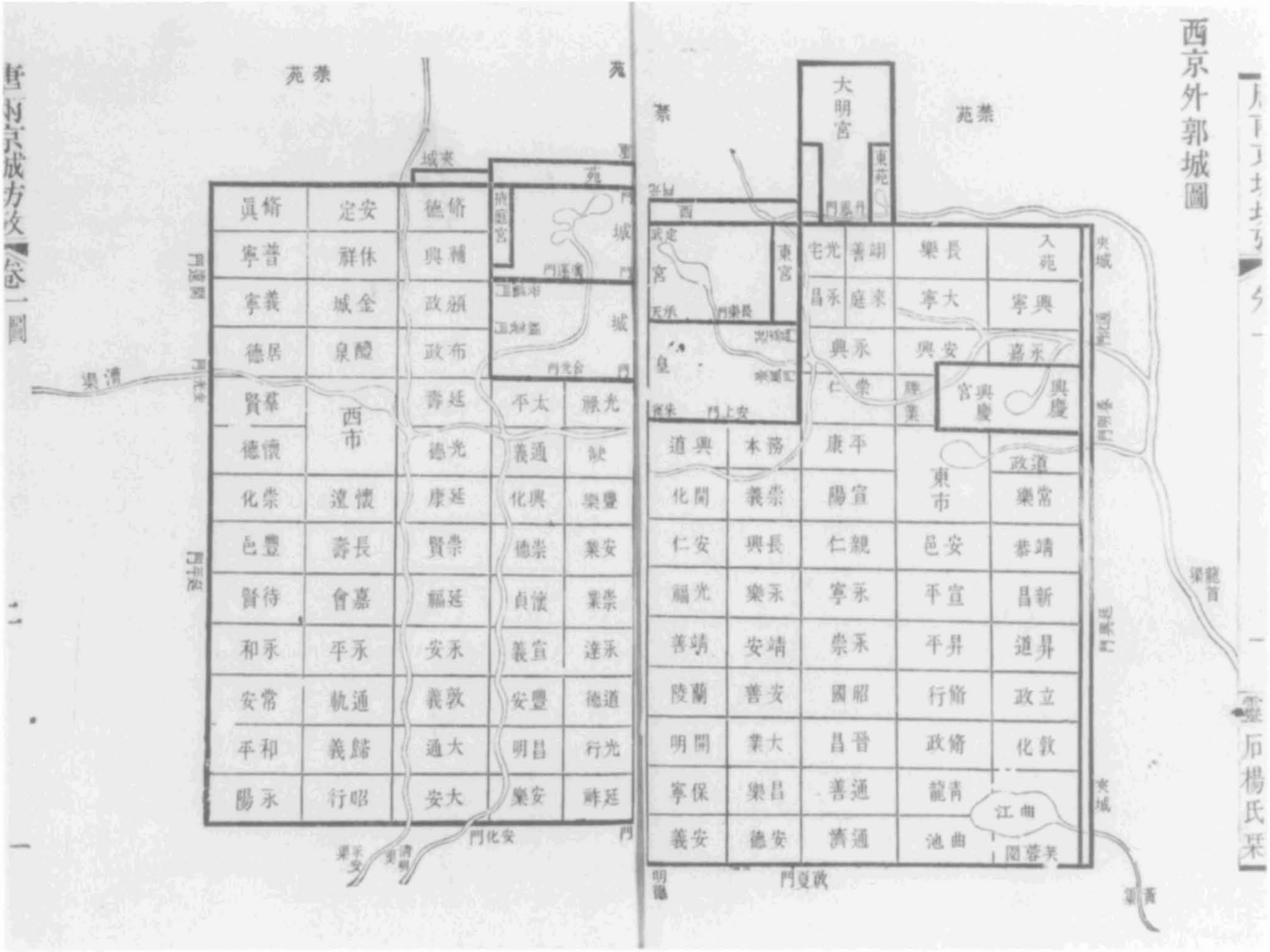


FIG. 5.8. MAP OF CHANG'AN DURING THE TANG DYNASTY.
Size of the original: 26.5 × 29 cm. From Xu Song, *Tang liang jing chengfang kao* (Study of the walled cities and wards of the two Tang capitals, 1848), *tu* 1b–2a. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

the Chinese needed reliable information about their competitors. This is precisely what Xu Jiyu set out to provide.

In the *Yinghuan zhilüe* Xu countered at least one scholarly tendency of his time—what has been called an inward turn in scholarship during the Qing. The emphasis of *kaozheng* scholarship, as I explained above, was Chinese texts and their role in the reconstruction of the Chinese past. Xu did not reject *kaozheng*, but he extended its application to foreign sources. For his study he did use Chinese sources, such as the dynastic histories, but he "repeatedly sought and collected various kinds" of Western sources. When the accounts in these sources diverged, he followed the most recent, and whenever he met a Westerner, he "would at once open a volume so that person would verify it regarding the topography and present conditions of the various countries beyond our territory."[29] Xu goes on to say: "Whenever I received a book or there was some new information, I at once revised the draft or added to it, so that it was all changed dozens of times."[30]

Although most of his study consists of verbal description, as was typical of Chinese geographic studies, Xu stresses the centrality of maps to his work: "This book takes maps as its leading principle."[31] Chinese maps, however, Xu implies, cannot compare with those of Westerners: "Westerners are good at traveling afar. Their sails and masts encircle the four seas. Wherever they land, they at once pull out pens and draw maps. Therefore their maps are the only ones that are reliable." Xu's dissatisfaction with native cartography stems not only from comparison with foreign models but from what he per-

29. Xu Jiyu, *Yinghuan zhilüe* (completed 1848) (1850; reprinted Taipei: Jinghua Shuju, 1968), preface, 8a. The type of volume opened is not specified.

30. Xu, *Yinghuan zhilüe*, preface, 8b (note 29).

31. Xu, *Yinghuan zhilüe*, "Fanli" (principles), 1a (note 29).

ceives as lack of correspondence to observed reality: "Geography without maps is unclear, but maps not based on observation are incomplete in detail. The world has a form; one cannot simply imagine its extensions and contractions."[32] The challenge to the schemes of abstract geography propounded by Song metaphysicians is clear from the empiricism implied by Xu's emphasis on observation as a basis for mapping. Given Xu's views regarding the merits of Western maps, it is not surprising that Western models served as the basis of all but one of the forty-two maps in the *Yinghuan zhilüe*: "The maps here have been copied in outline from original maps in original books of Westerners. The courses and arteries of rivers are as fine as hair; mountain ranges and cities, large and small, are exhaustively presented."[33]

Xu offered his work ostensibly as a geographic treatise, but his intent went beyond presenting information. The book's political implications were recognized by Xu's colleagues. Those who contributed prefaces to the work praised it for correcting the falsehoods in past Chinese accounts of foreign countries and said it would help the country deal more effectively with foreigners. The ideological import of Xu's work is apparent from the beginning—with its world map. The body of the *Yinghuan zhilüe* begins with a map of the Eastern Hemisphere, in which China appears in the upper right quadrant as a country smaller than Africa (fig. 5.9): thus Xu's early readers saw that China had to adjust its foreign policy.

More than two centuries after the Jesuits had helped to propagate the notion of a round earth among the Chinese, Xu still believed he must educate his readers, members of the literate elite, about the true shape of things: "The shape of the earth is like a ball; on the basis of the period of one revolution, it is divided into warp and woof, and lines are drawn vertically and horizontally across it. Each revolution equals 360 degrees; each degree is equal to 250 Chinese *li*. The sea covers more than six-tenths [of the earth], and land less than four-tenths."[34] Later Xu explains that the earth's landmasses, according to Western divisions, consist of four continents: "Of the four continents, Asia is the largest, and China is located in its southeast portion."[35] Xu seems to have recognized, as Drake has suggested, that the worldview he was offering would meet resistance from those committed to the idea of China's political centrality and geographic importance.[36] Thus he points out that the extent of the Qing empire has never been matched in the past and that China is master among the countries of Asia. Apparently as a concession to those who believed in Chinese preeminence, he also follows his general description of the world with a map of the Qing empire accompanied with a brief geographic description. He will not deal with the empire in detail, because "it is not fitting to speak of it in a history of foreign places."[37] By excluding China from his account of the world, Xu gained a rhetorical advantage: he could, as Drake has observed, avoid explicit comparisons of China with powerful Western nations.[38] The necessity for Xu's rhetoric of silence becomes clear further on in his work: the major power in the world, Xu makes clear, is England, not China.[39]

The praise for England contains implicit criticism of the Chinese government, which had just been humbled by the British. Xu Jiyu's work represents a contribution to a political debate about China's future: the description of England, for example, implies that China might do well to adopt Western technology if it is to match the military power of countries seeking to open China to more trade, and in his choice of maps itself, Xu makes an assertion regarding the state of cartography in China in comparison with that of the West. In copying Western-made maps, however, Xu Jiyu does not simply advocate a "scientific" cartography, one intended to present information dispassionately. Maps, as Xu uses them, constitute a form of political expression—they function as texts with rhetorical intent. This is not surprising in a setting in which—as in England during the nineteenth century—statecraft, not science, was regarded as the highest calling of the intellectual. The best preparation for that calling was not technical, but literary.

The textualism characterizing much Qing cartography is hardly an anomaly, but it has usually been overlooked in favor of the Manchu dynasty's adoption of European techniques. It is, however, a product of the same institutional setting as are the mathematical and mensurational techniques mentioned above. The main practitioners of those techniques were not primarily scientists in any modern sense of the word, but traditional scholars serving political aims. This is not to minimize the importance of quantitative techniques in cartographic theory and practice, but merely to point out an aspect of Chinese cartography often overlooked, one related to the emphasis placed in political life on the written word as a medium of communication.

32. Xu, *Yinghuan zhilüe*, preface, 8a (note 29).

33. Xu, *Yinghuan zhilüe*, "Fanli," 1a (note 29).

34. Xu, *Yinghuan zhilüe*, 1.4a (note 29). On Chinese conceptions of the shape of the world, see below, pp. 117–24.

35. Xu, *Yinghuan zhilüe*, 1.5b (note 29).

36. Fred W. Drake, *China Charts the World: Hsu Chi-yü and His Geography of 1848* (Cambridge: East Asian Research Center, Harvard University, 1975), 58–59.

37. Xu, *Yinghuan zhilüe*, 1.11a (note 29).

38. Drake, *China Charts the World*, 68 (note 36).

39. Among the attractions of England for Xu Jiyu are its naval power and the character of its people: "Their plans are clever and precise, their actions resolute, and their spirit brave and doughty. This places them at the top of the several European countries" (Xu, *Yinghuan zhilüe*, 7.49a [note 29]).

FIG. 5.9. NINETEENTH-CENTURY MAP OF THE EASTERN HEMISPHERE.
Size of the original: 28 × 36 cm. From Xu Jiyu, *Yinghuan zhilüe* (Short account of the maritime circuit, completed 1848, printed 1850), 1.1b–2a. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

MAPS, MEASUREMENT, AND TEXT

As a result of that emphasis, traditional Chinese cartography is marked by the coexistence of two major tendencies. These two tendencies can be termed mensurational (or more broadly, observational) and textualist. The latter strand can be seen as having two aspects: first, a reliance on texts as sources of information in the compiling of maps and, second, a reliance on text to complement the presentation of information in maps. The mensurational and textualist tendencies of Chinese cartography are apparent early in its history.

During the Han dynasty at least some intellectuals were conceiving mapmaking in terms of mathematical proportion. They recognized that ratios, or scales, could govern the representation of actual distances on a map. In a passage from the *Han shu* (History of the Former Han), Liu An discusses the idea of map scale in connection with military strategy: "When one uses a map to inspect hills, streams, and strategic passes [of the kingdom of Min-Yue, in present-day Fujian], distances are no more than several inches, but are really several hundred or thousand *li*. Obstructions, narrow passes, forests, and woods cannot all be recorded. When you look at a map, [the route] looks easy, but to traverse it is extremely difficult."[40] Liu An was noted for his patronage of scholarship, but the extent of his involvement with mapmaking is hard to ascertain. Scale was often considered a means of achieving correspondence with observed reality, but here Liu An recognizes that it can lead to distortion of that reality: the choice of scale may limit the number of features a map can represent. The compendium attributed to Liu

40. Ban Gu, *Han shu* (compiled first century A.D.), chap. 64A; see the edition in 12 vols. (Beijing: Zhonghua Shuju, 1962), 9:2778.

An, the *Huainanzi*, illustrates the limitations of maps in a different way. The book's sections on cosmology and geography give an account of world geography but include no maps, relying solely on verbal description. That description poses cartographic difficulties. The *Huainanzi*, Major has shown, gives such divergent information, particularly about the center of the world, that it is impossible to draw a map fully consistent with the text.[41]

Number and Text in Pei Xiu's Cartography

The problem of correspondence between map and reality was also taken up by Pei Xiu (223–71). While serving as minister of works (*sikong*) under the Western Jin (265–317), Pei Xiu compiled the *Yu gong diyu tu* (Regional maps for the "Yu gong" [Tribute of Yu]), now lost. A portion of the preface to that work, however, is preserved in the *Jin shu* (History of the Jin), compiled during the Tang. In the preface, Pei Xiu echoes Liu An's dissatisfaction with Han maps: "None gives a complete record of the famous mountains and great rivers. Although they roughly depict forms, this is not done carefully, and one cannot rely on them."[42] Pei Xiu's major criticism of Han maps is their lack of correspondence to observed reality: they record things that do not exist, incompletely record things that do, and are not drawn with precision. In discussions of Pei's proposed correctives to this state of affairs, historians of Chinese cartography have focused on Pei's six principles of mapmaking: proportional measure (*fenlü*), standard or regulated view (*zhunwang*), road measurement (*daoli*), leveling (or lowering) of heights (*gaoxia*), determination of diagonal distance (*fangxie*), and straightening of curves (*yuzhi*).[43] These are commonly interpreted as involving various types of direct and indirect measurements.

The first principle, proportional measure, seems to involve map scale. It is "a means by which the units of measurement [in the map] are determined" and preserves "the actualities of distance." If a map is made without a proportional measure, "it will not distinguish between what is far and near." The second principle, standard or regulated view, has to do with directional orientation: it deals with the positions of points on the map and their relation to one another. In other words, it preserves "the actualities of relative positions."[44] If the principle is correctly applied, "the curved and straight and the far and near can conceal nothing of their form."[45] The third principle, road measurement, is "a means of determining distance from a point of origin" along a given route: road measurement preserves "the actualities of paths and roads."

The other three principles—leveling of heights, deter-

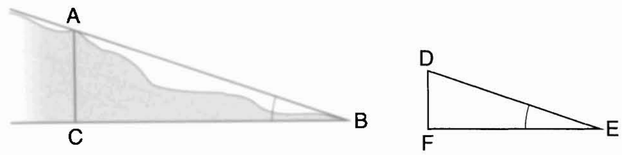


FIG. 5.10. INTERPRETATION OF PEI XIU'S METHOD OF LEVELING HEIGHTS. Three of Pei Xiu's six principles seem to involve the application of geometric principles as a means of indirect measurement. The use of right-triangle geometry seems to be called for by the fourth and fifth principles, *gaoxia* (lowering or leveling of heights) and *fangxie* (determination of diagonal distance). A situation involving the leveling of heights may be pictured as in this figure. Distance AB along an elevation can be measured directly, but the actual horizontal distance between points A and B is distance BC. Distance BC may be calculated by creating a right triangle similar to triangle ABC, for example, DEF, with angle FED equal to angle CBA. Since distance AB and all the dimensions of triangle DEF are known, the distance BC can be derived by applying the principle that corresponding sides of similar right triangles are proportional. This interpretation of *gaoxia* has some contextual support. At least one Han dynasty text, the *Jiuzhang suanshu* (Nine chapters on mathematical art), contains problems that require the use of similar right triangles.

41. See John S. Major, "The Five Phases, Magic Squares, and Schematic Cosmography," in *Explorations in Early Chinese Cosmology*, ed. Henry Rosemont, Jr. (Chico, Calif.: Scholars Press, 1984), 133–66, esp. 133–37. A more detailed account of Chinese cosmography appears in chapter 8 below.

42. Fang Xuanling et al., *Jin shu* (compiled 646–48), chap. 35; see the edition in 10 vols. (Beijing: Zhonghua Shuju, 1974), 4:1039. Some modern scholars would dispute Pei Xiu's characterization of Han maps, especially based on the silk maps discovered at Mawangdui. In Pei's favor, however, the scale of the Mawangdui maps varies and detail decreases as one moves from the center toward the edges. For further discussion of the Mawangdui maps and other Han specimens, see pp. 40–46 and 147–51.

43. See *Jin shu*, chap. 35 (4:1040) (note 42). In this exposition of Pei Xiu's six principles, all quotations from Pei's preface are from this source unless otherwise noted. The translations of Pei's terms are tentative, since it is sometimes unclear exactly what he intended. None of Pei's own cartographic work, which could be expected to illustrate his principles, survives. For another translation, see Joseph Needham, *Science and Civilisation in China* (Cambridge: Cambridge University Press, 1954–), vol. 3, with Wang Ling, *Mathematics and the Sciences of the Heavens and the Earth* (1959), 539–40.

44. Here the translation follows the excerpt from Pei Xiu's preface quoted in the *Yiwen leiju* (Classified compendium of arts and letters), comp. Ouyang Xun (557–641), chap. 6; see the edition in 2 vols. (Beijing: Zhonghua Shuju, 1965), 1:101. Ouyang Xun is a contemporary of the compiler of the *Jin shu*, Fang Xuanling (576–648), but his version of Pei Xiu's preface has some phrases not included in the *Jin shu*.

45. Interpretations of the principle of *zhunwang* vary. It has been interpreted as involving the use of the magnetic compass to determine direction, but this is unlikely since the use of the compass for wayfinding is unattested for Pei Xiu's time. The principle has also been interpreted as involving the use of a cartographic square grid. This interpretation is also unlikely, for reasons given later in this chapter when the grid is discussed. At that time I propose a third interpretation of the principle.

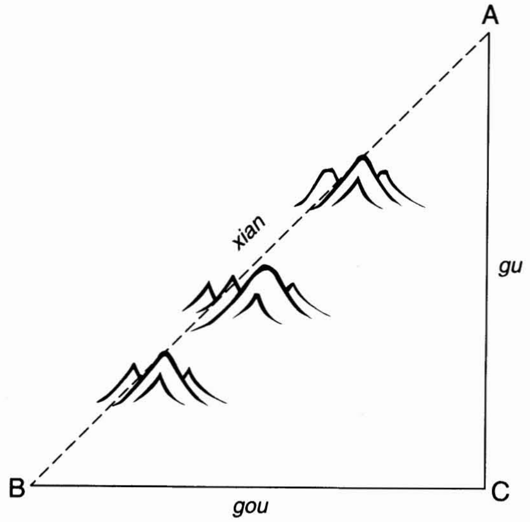


FIG. 5.11. INTERPRETATION OF PEI XIU'S METHOD OF DETERMINING DIAGONAL DISTANCE. Pei's fifth principle seems to require knowledge of the *gougu* (*gou* = base, *gu* = altitude) theorem, the equivalent of the Pythagorean theorem. A problem whose solution requires the *gougu* theorem appears in the *Zhoubi suan jing* (Arithmetical classic of the Zhou gnomon), which attained its present form no earlier than 200 B.C. As expressed by Zhao Junqing, the Han commentator on the *Zhoubi suan jing*, the *gougu* theorem may be used to derive the length of the hypotenuse: "Multiply base [*gou*] and height [*gu*] by their own values, and add these results to get the square of the hypotenuse [*xian*]. Divide this by its square root. This is the hypotenuse." This appears to be the calculation required to determine diagonal distance. Application of the principle seems to involve envisioning two points separated by inaccessible terrain as opposite vertices of a square (*fang*) and then using the *gougu* theorem to determine the length of the diagonal (*xie*) between them. In other words, distance AB across a mountain range can derived by taking the square root of the sum of the squares of distances AC and CB.

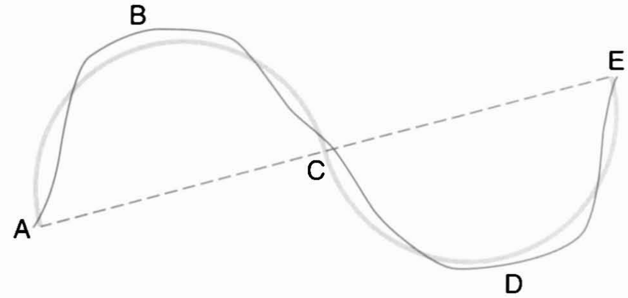


FIG. 5.12. INTERPRETATION OF PEI XIU'S METHOD OF STRAIGHTENING CURVES. In some cases, the application of Pei Xiu's sixth principle, straightening of curves (*yuzhi*), seems to have required knowledge of the properties of circles. Points A and E are joined by a winding road, ABCDE, which has been measured. A cartographer wishing to know the straight-line distance between A and E would be able to derive an approximation by regarding the curve described by ABC and the curve described by CDE as semicircles and segments AC and CE as the diameters of those semicircles. By doubling the lengths of curves ABC and CDE and dividing each of the resulting values by the ratio of circumference to diameter (*yuanzhou lü*), the equivalent of pi, one could derive rough values for AC and CE. By the early Han dynasty, the ratio of circumference to diameter had been approximated as 3, and about Pei Xiu's time, Liu Hui (fl. late third century) calculated the ratio of circumference to diameter as 157 to 50, or about 3.14. For more on the history of Chinese mathematics, see Jean-Claude Martzloff, *Histoire des mathématiques chinoises* (Paris: Masson, 1988).

mination of diagonal distance, and straightening of curves—are explained even more concisely. Instead of dealing with them individually, Pei Xiu explains them collectively: "The last three principles are applied according to the nature of the terrain, so that differences between hills and plains are taken into account." These three rules seem to deal with the problem of converting actual ground distances, which may be curved in both horizontal and vertical dimensions, to straight-line distances and depicting them on a flat map. Pei Xiu does not provide any information on the way these conversions are to be performed, but he does list the benefits of following them: "The actualities of distance measure are preserved by the leveling of heights, the determination of diagonal distances, and the straightening of curves. Although there are obstacles of steep mountains and vast seas, distant places in inaccessible and strange lands, routes that climb and descend and twist and turn, and difficult curves and slopes, all these can be taken into account and determined." From this passage one can infer that the method of leveling heights seems to be a way of adjusting distances on a map for variations in elevation, "routes that climb and descend." The determination of diagonal distance seems to be a way of calculating the straight-line distance between points separated by natural obstacles such as mountains and seas. Finally, the method of straightening curves seems to be a means of adjusting distances for routes that "twist and turn." What survives of Pei's preface does not specify how one is to realize these principles. If Pei Xiu deliberately refrained from providing those details, he may have believed that the means of applying his rules were common knowledge. In any case, literary sources, predating Pei Xiu, do provide enough information about mensurational and mathematical methods to enable one to reconstruct how he might have applied his principles of indirect measurement (see figs. 5.10 to 5.12).

Pei Xiu stresses that the six principles form a coherent whole. Failure to observe one vitiates the quality of the map, no matter how scrupulously a cartographer has adhered to the others:

> If a map has a standard or regulated view but no road measurement, then in extending [the map] to lands cut

> off by mountains and seas, one will be unable to make connections. If a map shows road distance without leveling heights, determining diagonal distance, and straightening curves, then the figures for distance shown on paths and roads will contradict the facts about what is far and near, and the accuracy of the standard view will be lost. Thus, one must verify a map using these six principles in association.

The six principles constitute the earliest surviving statement in China about the application of mensurational techniques to cartography, and as such they are worthy of attention. But accounts of Pei Xiu's practice point toward another means of verification in cartography. The *Jin shu*, for example, provides this account of the circumstances that led Pei to produce the *Yu gong diyu tu*: "He found that the names of mountains, streams and places in the 'Yu gong' had changed many times since antiquity. Later expositors of those names sometimes forced interpretations, which gradually became obscure and beclouded. Thus Pei examined ancient writings, rejecting what was doubtful, and annotating and listing as far as possible now nameless places that formerly had names. Then he produced the *Yu gong diyu tu* in eighteen sections."[46] In this account of Pei's practice, the six principles are conspicuous by their absence. His work on the *Yu gong diyu tu* does not seem to have involved direct or indirect measurements at all. While at first sight this might seem inconsistent with Pei's six "scientific" principles, it is in fact quite consistent with the interplay of map and text that characterizes premodern Chinese cartography.

Indeed, as Pei's preface also implies, one of his major sources of information was text. In his preface he identifies the types of information he sought from textual sources, one of which is the "Yu gong": "I have studied the mountains and seas, rivers and streams, and the high and low marshlands in the 'Yu gong'; the nine regions of antiquity; the sixteen provinces, the prefectures and principalities, and the counties and cities of the present; border areas and outlying districts; the names of places where ancient kingdoms concluded treaties; navigable waters and roads and paths. Then I produced this map in eighteen sections."[47] Exactly how all this information was reflected in this map is unclear, since it does not survive.

Information concerning another lost map attributed Pei Xiu, the *fangzhang tu* (one-*zhang*-square map) (*zhang* = roughly 3 m), is similarly sketchy. The art historian Zhang Yanyuan (ca. 815 to after 875) lists this as the *dixing fangzhang tu* (topographical one-*zhang*-square map) and classifies it under the category "rare paintings and precious drawings from antiquity."[48] No details other than its authorship are provided, so its mode of representing topography is unknown. The notes of another writer, Yu Shinan (558–638), supply more information. The map was a reduction of an "old great map of the world." Consisting of eighty bolts of silk (each 40 *chi* long, or about 12.2 m), the old map was considered too unwieldy. In accordance with Pei Xiu's first principle, the new map, the *fangzhang tu*, was drawn to scale: "one *fen* equal to ten *li* [1:1,800,000], one *cun* [equal to ten *fen*] equal to one hundred *li*."[49] In showing the locations of "famous mountains and cities," it seems to have measured up to Pei's insistence on correspondence to observed reality. It could substitute for firsthand observation: "Rulers, without descending from their halls, could comprehend the four quarters of the world."[50] Yu Shinan's notes on the *fangzhang tu* do not explain how Pei Xiu made it, whether he merely redrew the old map, accepting its details, or reconfirmed them, relying on textual sources. The latter course, however, would seem to conform more closely to his practice with the *Yu gong diyu tu*.

The textualist aspect of Pei's cartographic practice might be expected when one remembers the value placed on text in the institutional structure in which he worked. That value extended beyond administrative utility or the need to exercise control. Chinese political thinkers early on recognized the temptations to corruption and abuses of power within the bureaucratic ranks, especially among those officials charged with revenue collection. As a counterweight to those temptations, some political thinkers advocated the cultivation of values in literary texts: "A great man's virtue is vast; his writings will be brilliant. A lesser man's virtue may shine; but his writings will be flawed. If an official is esteemed, his writings will be abundant; if virtue is high, literary compositions will multiply."[51]

The connection between literary talent and integrity seems to have been instrumental in advancing Pei Xiu's career. Pei entered government service on the strength of a general's recommendation. According to the *Jin shu*, Pei was singled out not for his mathematical ability, but for his moral virtue and broad learning: "There is not a piece of literature with which he is not familiar."[52] Within

46. *Jin shu*, chap. 35 (4:1039) (note 42).

47. *Jin shu*, chap. 35 (4:1040) (note 42).

48. Zhang Yanyuan, *Lidai minghua ji* (Record of famous painters through the dynasties, completed 847), chap. 3; see the modern edition (Beijing: Renmin Meishu Chubanshe, 1963), 76.

49. Yu Shinan, *Beitang shuchao* (Transcriptions from the Northern Hall, compiled ca. 630) (Taipei: Yiwen Yinshuguan, [1968?]), 96.6a.

50. Yu, *Beitang shuchao*, 96.6a (note 49).

51. Wang Chong, *Lun heng* (Balanced discussions, ca. 82–83), chap. 28; see the modern edition (Shanghai: Renmin Chubanshe, 1974), 431.

52. *Jin shu*, chap. 35 (4:1038) (note 42).

the government, Pei was recognized not only for his cartography but also for his literary ability. Before serving as minister of works, he rose to the post of prefect of the masters of writing (*shangshu ling*). In this capacity he acted as an imperial secretary, handling documents addressed to the emperor and composing his replies and orders.

In light of his considerable literary background, Pei's reliance on textual scholarship in his cartographic practice might be predicted. But focus on the six principles has tended to overshadow the textualism implicit in his practice. This is understandable, since Pei's explanation of the six principles, taken in isolation, does not so much as allude to textual research. But that explanation occurs immediately after his description of the role of textual scholarship as a means of verification in his own work. Furthermore, in the preface Pei implies that his critique of Han maps that introduces his explanation arose from archival research. One should also remember that the preface, as it survives in the *Jin shu*, was selected by compilers who frame it in the context of Pei's textual scholarship. Narrative and quotation need to be considered together, not separately.

As a consequence, to characterize Pei Xiu as originating or even inheriting a "scientific" or quantitative tradition of cartography, as many have done, tells only half the story.[53] There is no denying that quantitative methods constitute an important part of his theory—they are crucial to his aim of achieving correspondence between map and reality. But in practice Pei seems to have relied heavily on textual sources to achieve that correspondence, so that one also cannot deny the significance of textual research, an aspect of "humanistic" learning. Textual sources might provide quantitative information, but their value went beyond that, preserving information about changes in place-names and administrative units. They were, as Qing textual scholars were to recognize, a means of recovering the past. Pei Xiu's legacy to Chinese cartography thus might be described as a blending of the "two cultures" or, in other words, a combination of empiricism and textualism. Both the evidence of the senses and the authority of textual sources served as grounds for knowledge.

Text and Measurement in Later Cartography

The textualist tendencies focused on here are not isolated phenomena but constitute an important element of traditional Chinese cartography. Cartographic writings after Pei Xiu are consistent in their insistence on the importance of textual research and the complementarity of map and text as well as the need for measurement. One indication of this attitude appears in the writing of Jia Dan (730–805), regarded as the foremost mapmaker of the Tang dynasty. Jia recognizes the value of Pei's principles, describing them as a "new conception" of mapmaking, which they can seem to be when they are considered in isolation from developments in collateral fields and evidence from other sources. He also makes explicit what is at best only implicit in Pei's practice, stating that maps require verbal supplementation. It is impossible for representation in a map to approach completeness: "With the various prefectures and armies, one must discuss distances in *li* and numbers of heads; with the various mountains and rivers, one must talk of heads and tails and sources and reaches. On a map, one cannot completely draw these things; for reliability, one must depend on notes."[54] A map, even if drawn in accordance with Pei Xiu's six principles, Jia Dan implies, has its limits. By themselves they cannot, to borrow a phrase from Pei, "preserve actualities." Although one could understand much by looking at a map, one could understand even more through verbal texts. Pei Xiu's practice had implied the importance of texts as sources of information. Jia Dan goes a step further by advocating that texts supplement or accompany maps for a fuller geographic understanding.[55] Apparently others shared Jia's belief, as suggested by the sheer quantity of atlases and gazetteers in which verbal geographic descriptions greatly outbulk maps and illustrations.

An exception to this rule is the stone *Yu ji tu* (Map of the tracks of Yu), dating from 1136. It is drawn with a square grid, bears clear indications of scale, and contains a minimum of verbal annotation. The absence of

53. See, for example, Edouard Chavannes, "Les deux plus anciens spécimens de la cartographie chinoise," *Bulletin de l'Ecole Française d'Extrême Orient* 3 (1903): 214–47, esp. 241; W. E. Soothill, "The Two Oldest Maps of China Extant," *Geographical Journal* 69 (1927): 532–55, esp. 534; Needham, *Science and Civilisation*, 3:538–41 (note 43); and Chen Cheng-siang (Chen Zhengxiang), "The Historical Development of Cartography in China," *Progress in Human Geography* 2 (1978): 101–20. Chen makes the extreme assertion that Pei Xiu's six principles constitute "a perfect discourse on the cartographic art as we know it today." He also downgrades the importance of Claudius Ptolemy because his writings on mapmaking are "mainly about the problem of map projection and can hardly be termed cartography" (104). There is ample evidence to undermine Chen's statements about the modernity of Pei's cartography, as we will see later in this chapter.

54. Liu Xu et al., *Jiu Tang shu* (Old history of the Tang, compiled 940–45), chap. 138; see the edition in 16 vols. (Beijing: Zhonghua Shuju, 1975), 12:3784. None of Jia's maps survive, so the extensiveness of his annotation is unknown. A map perhaps based on one of his works, the *Hua yi tu* (Map of Chinese and foreign lands, engraved 1136), is bordered with lengthy notes (see fig. 3.13 above).

55. The practice of supplementing map with text does not violate Pei's principles, but since none of Pei Xiu's maps survive, we do not know whether they were accompanied by narrative descriptions. Written accounts of his maps are silent on this matter.

verbal description, however, is the exception in traditional Chinese cartography—a fact belied by much scholarship on Chinese cartography.

For example, contrary to accounts that place Shen Kuo (1031–95) firmly in a mathematical tradition, a belief in the complementarity of map and text seems to underlie Shen's cartography. None of the maps he made are extant, but written accounts of them give no hint that they were heavily annotated or accompanied by extensive verbal descriptions. In one instance, Shen says that if his maps were to be lost in the future, they could be reconstructed from information in his writings.[56] This statement can be interpreted in two ways. In support of those who see Shen Kuo primarily as a practitioner of mathematical cartography, this remark indicates that he saw his maps and verbal descriptions as two separate entities. In support of a more textualist view, however, Shen also sees map and text as interchangeable.

Shen's own writings on mapmaking also suggest a combination of empiricism and textualism. In one document Shen says that to make the *Shouling tu* (Map of prefectures and counties), he applied "six principles" (*liu ti*)—the same term Pei Xiu used to name his cartographic rules.[57] This might seem to support a quantitative interpretation of Shen's cartography, but in his *Mengxi bitan* (Brush talks from Dream Brook), he refers to "seven methods" (*qi fa*): "I once made the *Shouling tu*, although I used a scale [*fenlü*] of two *cun* to one hundred *li* [1:900,000], I also adopted a regulated view [*zhunwang*] and mutual inclusions [*hurong*], and indirect verification [*pangyan*], lowering of heights [*gaoxia*], diagonal distance [*fangxie*], and straightening of curves [*yuzhi*]—[in all] seven methods, in order to obtain distances as the bird flies."[58] Shen Kuo does not mention Pei Xiu here, but five of the six technical terms used here—*fenlü*, *zhunwang*, *gaoxia*, *fangxie*, and *yuzhi*—are identical to those used in Pei's statement of six principles. Shen does not explain the meaning of these terms or their application, so perhaps one can assume their equivalence with Pei Xiu's usage. Shen does not explain the remaining two terms, *hurong* and *pangyan*, either. As far as I have been able to determine, the two terms do not recur in later discussions of cartographic method. The parallelism in the morphology of the two terms—both can be read as adjective-noun or adverb-verb compounds—suggests that they are meant to be paired.[59] In the document where Shen speaks of "six principles," he emphasizes the textual research, not the measurements, he performed to prepare the *Shouling tu*: "As an official I consulted documents daily to verify information."[60] Thus the two terms in question may refer to textual criticism. In this context the term *hurong*, or "mutual inclusions," might refer to a process of comparing material common to contemporaneous documents, including maps, as a means of verifying locations and distances, and the term *pangyan*, "collateral" or indirect verification, might refer to the use of later documents to verify information.[61] As we saw earlier, this was the type of research Pei Xiu undertook to correct old maps. Shen's use of the terms *hurong* and *pangyan*, according to the interpretation proposed here, thus represents an attempt to formalize what could only be inferred from accounts of Pei's practice. In addition, under this interpretation, *hurong* and *pangyan* seem to be precursors of the distinction late Ming and Qing dynasty textual critics made between *benzheng* (internal evidence) and *pangzheng* (collateral or external evidence).[62]

The textual emphasis of his account of the *Shouling tu* might give the impression that observation and measurement had only small parts in his practice. Elsewhere, however, such as in an account of his topographic models, Shen does say that he used notes taken while actually traversing the terrain (p. 87). Like Pei Xiu and

56. See Shen Kuo, *Mengxi bitan* (Brush talks from Dream Brook, ca. 1088), chap. 3 suppl., par. 575, in *Xin jiaozheng Mengxi bitan* (Newly edited *Mengxi bitan*), ed. Hu Daojing (1957; reprinted Hong Kong: Zhonghua Shuju, 1975), 322 (the same paragraph number, 575, can be used to locate this passage in *Mengxi bitan jiaozheng* [*Mengxi bitan* edited], 2 vols., ed. Hu Daojing, rev. ed. [1960; reprinted Taipei: Shijie Shuju, 1961]). A European analogy to what Shen describes here is Claudius Ptolemy's *Geography*. Although it contains no maps, it is possible to "reconstruct" them from Ptolemy's coordinates. See O. A. W. Dilke, "The Culmination of Greek Cartography in Ptolemy," in *The History of Cartography*, ed. J. B. Harley and David Woodward (Chicago: University of Chicago Press, 1987–), 1:177–200, esp. 189–90.

57. Shen Kuo, *Changxing ji* (Collected works of [the viscount of] Changxing), chap. 16, in *Shen shi san xiansheng wen ji* (Collected works of the three masters of the Shen clan, compiled 1718), *Sibu congkan* edition, 4.27a.

58. Shen, *Xin jiaozheng Mengxi bitan*, chap. 3 suppl., par. 575 (322) (note 56).

59. For the linguistic analyses here, I am indebted to Tsai Fa Cheng, a specialist in Chinese historical linguistics at the University of Wisconsin–Madison.

60. Shen, *Changxing ji*, chap. 16 (4.27b) (note 57).

61. Another interpretation has been suggested by Cao Wanru in "Lun Shen Kuo zai dituxue fangmian di gongxian" (On Shen Kuo's contributions to cartography), *Keji Shi Wenji* 3 (1980): 81–84, esp. 83. She argues that the passage should be read as listing only six methods, and that the graph for "seven" (*qi*) is a typographical error—a misprint, Cao suggests, for *zhi*, a particle indicating a partitive genitive. There is, however, no bibliographic evidence for such an emendation, and it is possible to read the passage as listing seven methods. Elsewhere Shen does mention applying six embodiments (*liu ti*), but this does not necessarily contradict what he says here. Shen does seem to distinguish "methods" (*fa*) from "embodiments" (*ti*). See Shen's *Changxing ji*, chap. 16 (4.27a) (note 57).

62. The terms *benzheng* and *pangzheng* are usually credited to the philologist Chen Di (1541–1617). To reconstruct the phonological system reflected in the *Shi jing* (Book of odes, ca. twelfth to seventh century B.C.), Chen drew on evidence from the classic itself (*benzheng*) and then on evidence from texts of the same age or slightly later (*pangzheng*).

Jia Dan before him, Shen Kuo seems to regard cartography as an endeavor combining empirical and textual methods.

The extent to which he applied mensurational techniques in his cartography is unclear, but Shen was obviously well versed in such methods. As I have noted elsewhere, Pei Xiu had available to him the mathematics and instruments needed to apply the six principles with some rigor, but it is unknown whether he actually used them. In contrast, our knowledge concerning Shen's application of mensurational techniques is more certain. Shen often describes instruments and techniques applicable to cartographic problems, and in certain instances he may have been able to apply quantitative methods more rigorously than Pei.

This seems particularly true in two areas: direction readings and linear measurements. Before the Song dynasty, there is no clear evidence of the existence of compasses of magnetized iron as distinct from lodestone compasses, nor is there evidence that a dial or card with indications of direction was ever attached to a lodestone.[63] Even without such a dial, rough determinations of direction could be made by suspending a lodestone to indicate south and then using one's arms to approximate the angular deviation from the southerly direction. During the Song, a steel industry developed, allowing the manufacture of alloys able to retain magnetization for long periods, and it is possible that compasses made with a needle-shaped piece of metal—important for its ability to provide precise readings from an attached direction card—were in use. Shen Kuo describes the magnetization of a needle in the *Mengxi bitan*: "Technicians rub the point of a needle with a lodestone; then it can point south. But it always inclines slightly to the east, not pointing directly south."[64] In the same passage Shen also speaks of needles that point north—a situation that results from needles being magnetized at different poles of the lodestone. According to Shen, magnetized needles could be suspended in several ways. They could, for example, be floated on water or balanced on a thin object like one's fingernail or the rim of a bowl. In the first instance, the needle would tend to shake; in the second, it would be likely to fall. The best way to suspend the needle, Shen says, is by a thread: "one takes a single cocoon fiber from new silk and attaches it to the middle of the needle with a piece of wax the size of a mustard seed; then when one hangs it in a windless place, the needle will always point south."[65]

The evidence for the use of a dial or card during the Song is less certain than that for the use of a magnetized needle. Again, Shen Kuo supplies key information. He describes his *Shouling tu* as distinguishing twenty-four directions, each with its own name: "Even if the map is lost in later generations, one may obtain my writings so as to arrange the prefectures and counties according to the twenty-four directions and reconstruct the map quickly without the slightest discrepancy."[66] The *Shouling tu* has been lost, and the writings the map was based on also seem to have disappeared, so it is not clear how Shen Kuo determined direction. His distinguishing twenty-four directions, however, suggests the existence of some means of taking such directional bearings—for example, a magnetized needle with a dial or card marked with those compass points. Shen Kuo, however, does not say that he ever used such a device in his cartography—his description of the magnetized needle occurs in the context of divination. In addition, no such dial or card for navigational or direction-finding purposes survives from the Song, and their use during that period can only be inferred from texts like Shen Kuo's. Examples of maritime compasses with dials indicating twenty-four directions date from the Ming and Qing dynasties.[67]

For linear measurements, Shen Kuo could have used a variety of instruments. Like Pei Xiu, he would have

63. The earliest reference to the "south pointer" probably occurs in the *Han Feizi*, a work dating from the third century B.C. This text states merely that these devices were used to avoid getting lost and to determine direction. No information as to their manufacture or appearance is given. See *Han Feizi*, 6.5, in *Han Feizi suoyin* (Concordance to *Han Feizi*), ed. Zhou Zhongling et al. (Beijing: Zhonghua Shuju, 1982), 737. Another indicator of direction, the south-pointing carriage, was available during Pei Xiu's time, but its cartographic application has not been established. The *Jin shu* contains this description of the device: "The *sinan che*, also called the *zhinan che*, is drawn by four horses. Its lower part was made like a tower with three levels; on its four corners four golden dragons held a plumed canopy with their mouths; and wood was carved into the shape of a transcendent being. It wore feathered garments and stood on top of the carriage. Even if the carriage turned as it moved, the figure's hand always pointed south" (chap. 25 [3:755] [note 42]). This seventh-century text provides no details on how the carriage worked. For a reconstruction of Song versions of the carriage, see André Wegener Sleeswyk, "Reconstruction of the South-Pointing Chariots of the Northern Sung Dynasty: Escapement and Differential Gearing in 11th Century China," *Chinese Science* 2 (1977): 4–36.

64. Shen, *Xin jiaozheng Mengxi bitan*, chap. 24, par. 437 (240) (note 56).

65. Shen, *Xin jiaozheng Mengxi bitan*, chap. 24, par. 437 (240) (note 56).

66. Shen, *Xin jiaozheng Mengxi bitan*, chap. 3 suppl., par. 575 (322) (note 56). The twenty-four directions were named after the twelve earthly branches, eight of the ten heavenly stems, and four of the eight trigrams.

67. Divination boards dating from as early as the Han have been described as "geomantic" compasses. These have bands marked with the names of the twenty-eight *xiu* (lunar lodges) and the twenty-four directions. Describing these boards as compasses, however, is misleading, since they were made for fortune-telling. Their use in navigation or direction finding has not been established. See Michael A. N. Loewe, *Ways to Paradise: The Chinese Quest for Immortality* (London: George Allen and Unwin, 1979), 75–80; and Marc Kalinowski, "Les instruments astro-calendériques des Han et la méthode *liu ren*," *Bulletin de l'Ecole Française d'Extrême-Orient* 72 (1983): 311–419.

been able to use the water level, graduated rod, plumb lines, and a sighting instrument. References to these instruments occur in texts dating from at least the Han dynasty. The forms these instruments took during Pei Xiu's time, however, are a matter of conjecture, for no descriptions of them before the Tang and no illustrations from before the Ming have survived. For Shen Kuo's time, our knowledge of these instruments is more detailed. They are described in a Tang text, and these descriptions are repeated in a Song text, suggesting that in form they had changed little if at all. According to these texts, the water level consisted of a block of wood mounted on a stand with a pivot. Carved into the block of wood were three compartments of the same size, one in the middle and one at each end. The compartments were filled with water, which was able to flow freely between them by a connecting groove. Inside each compartment was a wooden float that rose and sank depending on the level of the water. On top of each float were toothlike sights: "When the three compartments are filled with water, the wooden floats rise. When the three sets of teeth are level, when viewed with one eye, this can be taken as a universal standard."[68]

The water level could be used with a graduated rod and sighting board to determine distance and height. The graduated pole was two *zhang* long and was marked with two thousand divisions. The sighting board is described as being shaped like a square fan and as having a square opening in the center.[69] For distance determination, the sighting board could be used with the water level and graduated rod (figs. 5.13 to 5.15).

The rod and a plumb line could also be used to calculate distance—for example, the width of a stream can be calculated when one is standing on one of its banks (as illustrated in figs. 5.16 and 5.17). For determination of height, the graduated rod could be planted vertically on ground lower than the water level (fig. 5.18). One could then sight along the floats in the level and read the corresponding height on the rod. Elevation could be obtained by subtracting the height of the level from the reading taken from the rod.[70]

From this discussion, one can conclude that by the Song dynasty, if not before, the Chinese possessed the means to produce maps based on direct and indirect measurements. Such mensurational techniques are often used to justify claims of a distinct quantitative tradition of Chinese cartography, one relying heavily on measurement. Such a tradition is identifiable if one ignores the textualism of Chinese cartography, a tendency that coexisted with and in some cases outweighed the observational and mathematical. For example, a conflict between observation and text seems to have arisen regarding the shape of the earth. As described above, the mensurational techniques employed in cartography emphasized straight-

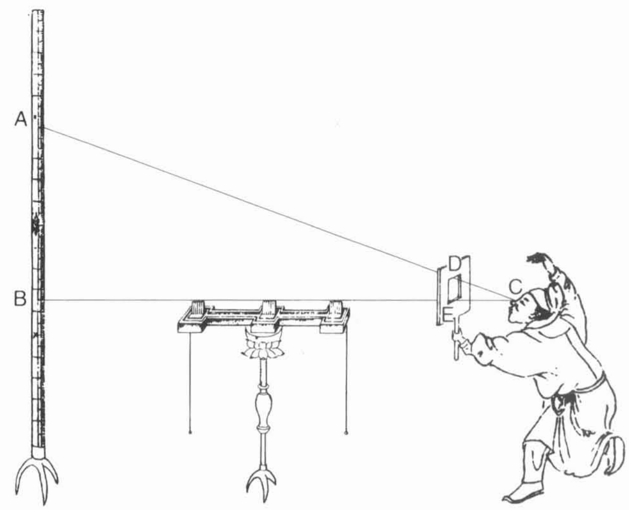


FIG. 5.13. CALCULATION OF DISTANCE USING A SIGHTING BOARD, WATER LEVEL, AND GRADUATED ROD. This method involves the use of similar right triangles, here triangles ABC and DEC. Length AB would be the section of the rod seen through the opening (length DE) of the sighting board. The water level would be used to determine the line BC, which corresponds to the distance being measured. Since AB, DE, and CE are known, it is a simple matter to calculate BC by applying the principle that the corresponding sides of similar triangles are proportional. (This representation is assembled from elements in figs. 5.14 and 5.15.)

68. Li Quan, *Taibai yin jing* (Secret classic of the Grand White [star; i.e., Venus, planet of war], 759) (also known as *Shenji zhidi Taibai yin jing* [Secret classic of the Grand White on wondrous contrivances for subduing an enemy]), *Baibu congshu jicheng* edition, 4.6a. See also Zeng Gongliang, *Wujing zongyao* (Conspectus of essential military techniques, 1044), *Siku quanshu* edition, *qianji* (part 1) 11.3a. The use of three floats when two would have been sufficient might seem curious. The third float may have been added as a means of determining when the board became warped: if the water level was made so that the line connecting the floats was perpendicular to the grain, the third float would reveal when the board was out of line. For an illustration of the water level, see figure 5.14.

69. Li, *Taibai yin jing*, 4.6a (note 68).

70. Shen Kuo's work in waterworks resulted in the invention of another means of determining height. In 1072 he was sent to inspect a land reclamation project in the drainage basin of the Bian River and to make a topographic survey as a preliminary step to dredging and deepening the Bian Canal, a waterway important for the transport of grain tribute to the capital of Kaifeng. In carrying out the survey, Shen measured the difference in elevation between the canal's upper and lower reaches, more than 840 *li* apart. The problem of measuring differences in altitude across a long distance was compounded by the flatness of the terrain. In these circumstances measurements obtained with water level, sighting tube, and graduated rod would not be reliable, since angular variation would be hard to discern. As Shen Kuo recognized, "small errors would be unavoidable." Those small errors, especially in angular measurements, would have led to large ones. To avoid such errors, Shen constructed weirs layer by layer in a temporary channel parallel to the canal. "When the water was level [with one weir], [the section] above it would gradually become shallow and dry. Then another weir would be built to mesh like teeth [with the one below, the result being] like a series of steps. I measured the level of the water

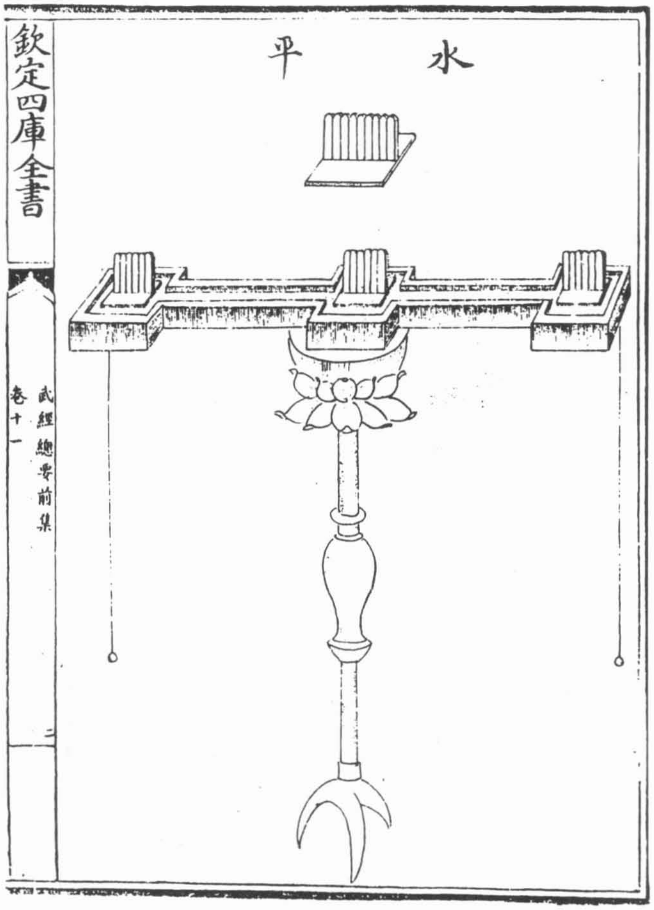


FIG. 5.14. RENDITION OF A WATER LEVEL.
Size of the original: 10.5 × 7 cm. From a Qing edition of Zeng Gongliang, *Wujing zongyao* (Conspectus of essential military techniques, written 1044), *Siku quanshu* edition (photoreprinted Taipei, 1983). Photograph courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

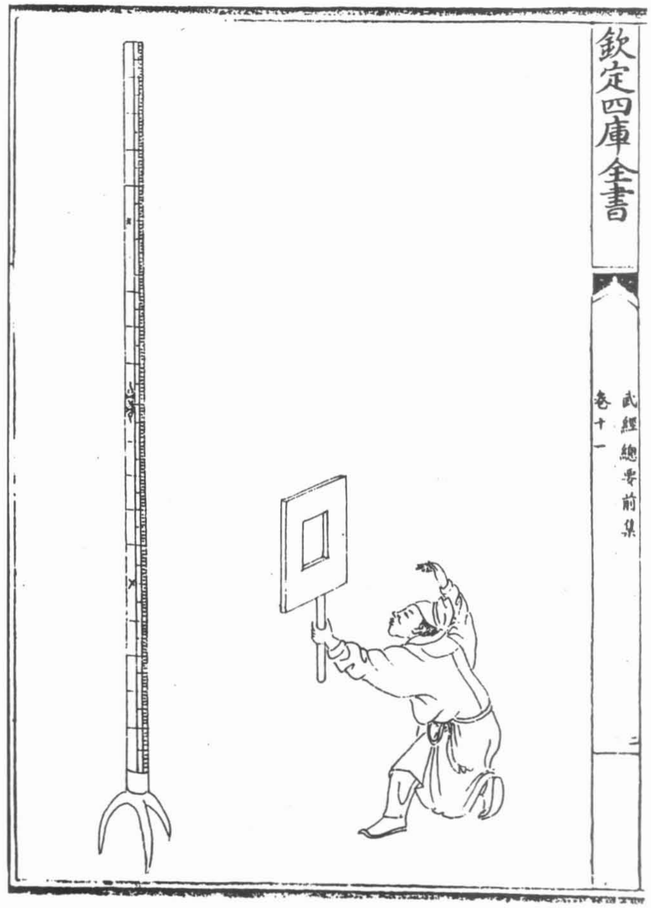


FIG. 5.15. RENDITION OF SIGHTING BOARD.
Size of the original: 10.5 × 7 cm. From a Qing edition of Zeng Gongliang, *Wujing zongyao* (Conspectus of essential military techniques, written 1044), *Siku quanshu* edition (photoreprinted Taipei, 1983). Photograph courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

line measurements. From a twentieth-century point of view this emphasis is a source of error, since it does not correct for the curvature of the earth. From a pre-Qing point of view, however, there was no need to correct for curvature, since cartographers generally seem to have treated the the earth as flat.

The Shape of the World: Observation versus Text

This last statement seems to be contradicted by some recent scholarship in the history of Chinese science, according to which the Chinese knew the world was spherical as early as the Han dynasty.[71] The argument for this view rests on a round-earth interpretation of the *huntian* (enveloping heaven) theory, a cosmology developed during the Han. The evidence for this interpretation is equivocal, however, and this ambiguity would have

above and below each weir, and totaled the heights between them. Thus I obtained the actual height of the terrain" (*Xin jiaozheng Mengxi bitan*, chap. 25, par. 457 [250] [note 56]).

Another means of determining height may have been a graduated crossbow sight and trigger assembly. The only reference to this instrument comes from Shen Kuo, who says he saw it unearthed at Haizhou (in present-day Jiangsu Province): "The original idea behind it was that by sighting one's eye along the shaft of an arrow, one could sight a mountain and measure its height in degrees. One could then obtain its height by using the *gougu* method ["base-height" method, equivalent to the Pythagorean theorem; see fig. 5.11] of the mathematicians" (*Xin jiaozheng Mengxi bitan*, chap. 19, par. 331 [194] [note 56]). It is unknown whether the two methods of determining elevation described here were actually used for cartography.

71. See, for example, Cheng Yen-tsu, "Cosmological Theories in Ancient China," *Scientia Sinica* 19 (1976): 291–309, esp. 294–97. In Wallis and Robinson's book the Chinese are credited, apparently based on descriptions of armillary spheres, with making terrestrial globes as early as 260 (*Cartographical Innovations*, 25 [note 1]). Needham, however, is more circumspect, stating that if the Chinese believed in a spherical earth, that belief was not expressed cartographically, at least

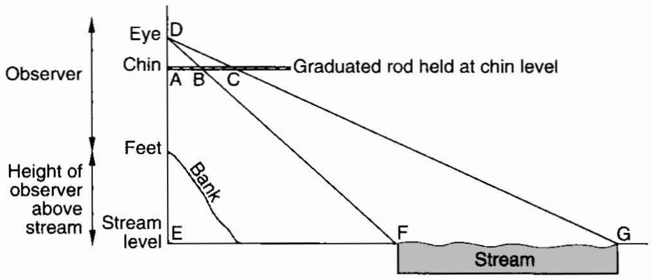


FIG. 5.16. CALCULATING THE WIDTH OF A STREAM WHILE STANDING ON ONE OF ITS BANKS. The length DE, the sum of the eye height of the observer and the height of the bank above the stream, can be determined with a plumb line (perhaps suspended from a rod to obtain the height of the bank). To find the width of the stream (FG), one holds a graduated rod parallel to the ground at chin level and sights and marks two points: the point on the rod (C) that coincides with the far edge of the stream, and the point on the rod (B) that coincides with the near edge of the stream. The length FG can be determined by using two sets of similar triangles: DAC and DEG, and DBC and DFG. The ratio of FG to BC is equal to the ratio of DC to DG, and the ratio of DC to DG in turn is equal to the ratio of DA to DE. The ratio of DA (the distance from observer's eye to chin) to DE is known, as is the distance BC on the rod. Thus the distance FG is easily derived.
After Ulrich Libbrecht, *Chinese Mathematics in the Thirteenth Century: The Shu-shu Chiu-chang of Ch'in Chiu-shao* (Cambridge: MIT Press, 1973), 131.

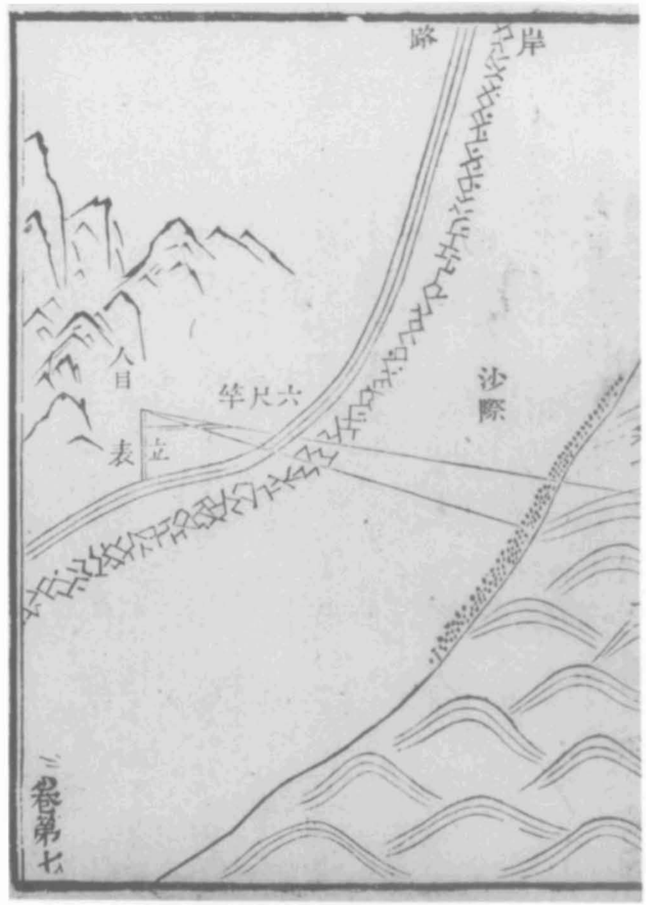


FIG. 5.17. WOODBLOCK ILLUSTRATION SHOWING THE CALCULATION OF THE WIDTH OF A STREAM.
Size of the original: 17.5 × 25 cm. From Qin Jiushao, *Shushu*

allowed mapmakers to hold a view of the earth as flat—a conception perhaps sanctioned by textual sources.

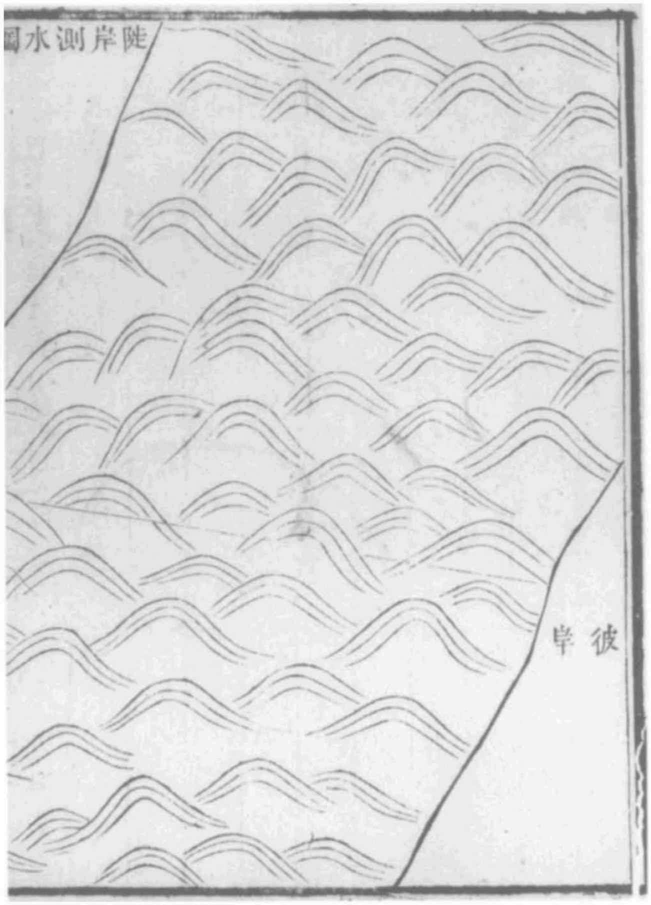
One of the earliest expositions of the *huntian* theory is attributed to the polymath Zhang Heng (78–139): "The enveloping heavens are like a chicken egg, and the celestial form is round like a crossbow pellet; the earth is like the egg yolk, alone occupying the center."[72] The egg metaphor might be interpreted as describing a spherical earth—a reading encouraged by the misconception that the *huntian* theory displaced the *gaitian* (covering heaven) theory, which seems to imply that the earth is flat. This conception of the earth is often traced to the *Zhoubi suan jing* (Arithmetical classic of the Zhou gnomon), which dates perhaps from the early Han: "Turning a carpenter's square creates a circle; combining carpenter's squares forms a square. Squareness belongs to the earth; circularity belongs to heaven. Heaven is round; the earth is square."[73] This is the cosmology that is believed to be symbolized on divination boards and cosmic mirrors dating from the Han (figs. 5.19 and 5.20).

The *huntian* theory is certainly not inconsistent with a conception of the earth as spherical, and it is difficult to imagine that Chinese astronomers who applied the theory in their calendrical calculations would have failed to appreciate the empirical evidence for curvature of the earth's surface. Zhang Heng, for example, states that the

not until the arrival of the Jesuits; see Needham, *Science and Civilisation*, 3:437–38, 498–99 (note 43). Tang Ruchuan makes a strong case that in the *huntian* cosmology the earth was conceived as hemispherical or, more likely, discoidal. See Tang's "Zhang Heng deng huntianjia di tian yuan di ping shuo" (On the theory of Zhang Heng and other uranosphere school cosmologists that the sky is spherical and the earth flat), *Kexue Shi Jikan*, 1962, no. 4:47–58. I am indebted to Nathan Sivin for the information on this citation.

72. Zhang Heng, "Hunyi tu zhu" (Commentary on a diagram of the armillary sphere, ca. 117), in Sun Wenqing, *Zhang Heng nianpu* (Chronological biography of Zhang Heng), rev. ed. (Shanghai: Shangwu Yinshuguan, 1956), 72–75, esp. 72. A clear account of Chinese cosmological theories can be found in Shigeru Nakayama, *A History of Japanese Astronomy: Chinese Background and Western Impact* (Cambridge: Harvard University Press, 1969), 24–43.

73. *Zhoubi suan jing* (ca. 200 B.C.), *Siku quanshu* edition, 1A.15b. See also *Huainanzi zhu*, chap. 3 (44) (note 6), which says, "Heaven is round; earth is square."



jiuzhang (Mathematical treatise in nine chapters, 1247), ed. Song Jingchang, 1841 edition, 7.17a–b. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

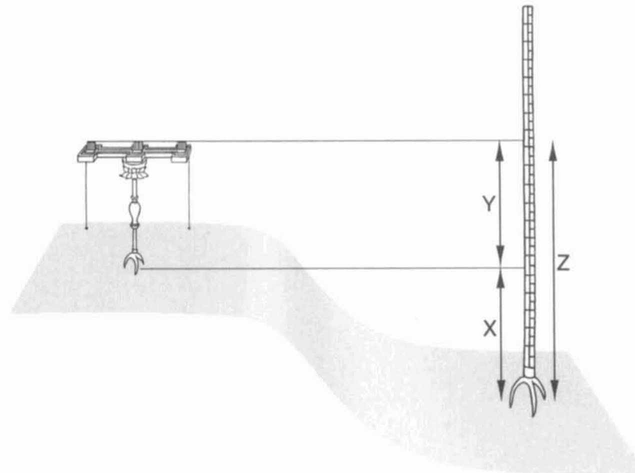


FIG. 5.18. DETERMINATION OF HEIGHT USING A WATER LEVEL AND GRADUATED ROD. To determine height X, read height Z sighting with a water level, then subtract the height of the water level (Y).

moon reflects the sun's light, and that lunar eclipses are caused by the earth's shadow.[74] The Ming encyclopedia *Sancai tuhui* (Illustrated compendium of the three powers [heaven, earth, man], completed 1607) explains lunar eclipses with an illustration showing the earth between sun and moon (fig. 5.21).[75] The resulting shadow, as anyone who has witnessed a lunar eclipse can attest, is at least curved, if not round. From this one might conclude that the earth is flat and round like a disk, but Chinese cosmologists do not seem to have entertained this possibility. If the idea of roundness was considered, the earth's entire surface was regarded as curved. The Song philosopher Zhu Xi (1130–1200), for example, describes the shape of the heavens and earth in terms suggesting curved surfaces: "The form of heaven and earth is like someone putting two bowls together, holding water within. If they are constantly turned with the hands, the water remains inside without spilling. But if the hands are stopped, the water leaks out."[76]

It is thus plausible to suppose that Chinese astronomers had reason to believe the earth was round by the time Matteo Ricci (1552–1610) made his maps depicting a spherical earth.[77] Legends on the cartographic works

74. Zhang Heng, "Lingxian" (Spiritual constitution of the universe, ca. 118), quoted in Sun, *Zhang Heng nianpu*, 79 (note 72).

75. But it also illustrates solar eclipses with the earth between the sun and moon.

76. Zhu Xi, *Zhuzi yulei* (Classified conversations of Master Zhu, 1270), comp. Li Jingde (1473; reprinted Taipei: Zhengzhong Shuju, 1962), 1.6a–b.

77. At least one representation of a round earth was introduced into China before Ricci's. During the Yuan dynasty, Chinese astronomers may have seen a representation of a terrestrial globe, one of seven "representations [simulacra or images] of instruments [*yixiang*]" made in 1267 by a Persian astronomer who later served as director of the Islamic observatory in Dadu (Beijing). It is unclear whether these representations took the form of drawings or models. A description of the representations appears in Song Lian et al., *Yuan shi* (History of the Yuan, compiled 1369–70), chap. 48; see the edition in 15 vols. (Beijing: Zhonghua Shuju, 1976), 4:998–99. The terrestrial globe, which the *Yuan shi* explains as a kind of "geographic record" (*dilizhi*), does not seem to have influenced Chinese cartography or, some have maintained, Chinese astronomy. Yabuuchi comments: "The terrestrial globe that was kept in the Islamic observatory did not interest the Chinese astronomers, who had other ideas about the form of the earth." See Kiyoshi Yabuuchi (Kiyosi Yabuuti), "The Influence of Islamic Astronomy in China," in *From Deferent to Equant: A Volume of Studies in the History of Science in the Ancient and Medieval Near East in Honor of E. S. Kennedy*, ed. David A. King and George Saliba (New York: New York Academy of Sciences, 1987), 547–59, esp. 549. See also Christopher Cullen, "A Chinese Eratosthenes of the Flat Earth: A Study of a Fragment of Cosmology in *Huai Nan Tzu*," *Bulletin of the School of Oriental and African Studies* 39 (1976): 106–27. Cullen asserts that for the Chinese the earth was "at all times flat, although perhaps bulging up slightly," and that Chinese ideas on the shape of the earth remained unchanged from "early times until the first contacts with modern science through the medium of Jesuit missionaries in the seventeenth century" (107). Evidence from sources apparently not considered by Cullen, however, suggests a more complex history of Chinese ideas on the shape of the earth—a history I have tried to summarize here.

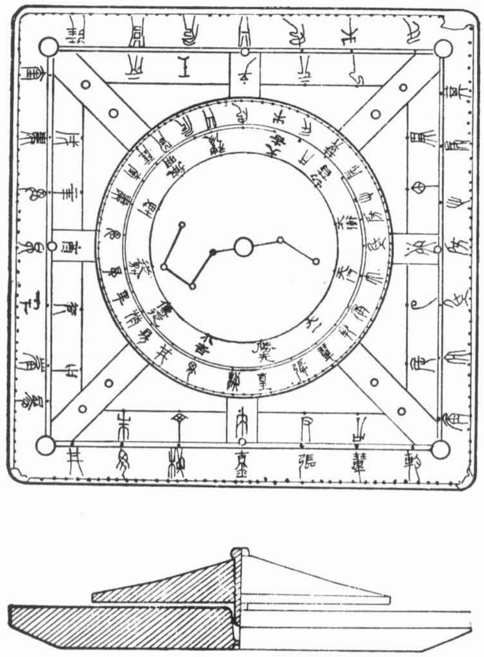


FIG. 5.19. HAN DIVINATION BOARD. The board perhaps symbolizes a round heaven and square earth. The original was found in tomb 62, Mozuizi, Gansu.
Size of the original: 9 × 9 cm (diameter of inner circle, ca. 6 cm). From Gansusheng Bowuguan (Gansu Provincial Museum), "Wuwei Mozuizi sanzuo Hanmu fajue jianbao" (Brief report on the excavations of the three Han tombs at Mozuizi in Wuwei County), *Wenwu*, 1972, no. 12:9–21, esp. 15.

made in China by Ricci and other Jesuits suggest that they were made to contradict a flat-earth conception. But precisely because they held that conception, Chinese intellectuals had trouble accepting Ricci's maps.[78] This seems curious, since Ricci arrived in China centuries after the *huntian* theory had supposedly prevailed over the *gaitian* theory.

The contradiction here is only apparent. As I pointed out above, the *huntian* theory is consistent with a round-earth conception, but that does not mean it is inconsistent with a flat-earth conception. Beyond Zhang Heng's egg yolk image, which is primarily a metaphor for position, the *huntian* theory suggests nothing about the earth's shape, and it is possible to realize the cosmic egg metaphor with an image of a flat earth. Two Ming dynasty encyclopedias, for example, illustrate the *huntian* theory by depicting heaven as round and the earth as flat (figs. 5.22 and 5.23). In one of his writings Zhang Heng, regarded as an adherent of the *huntian* theory, describes three imperial "ritual buildings." One of them uses imagery consistent with the *gaitian* theory: "One has two stories and a double roof, / Eight windows and nine rooms. / It is round like Heaven, square like Earth."[79] This passage appears in a rhapsody (*fu*) contained in the *Wen xuan* (Literary selections), a sixth-century anthology revered by the educated elite from the Tang onward.[80] The majority of that elite did not consist of astronomers, and as I mentioned above, they valued literary training above technical knowledge. Among that group, Zhang Heng would have been proof that despite what the *huntian* theory said, the *gaitian* theory that heaven is round and earth square—a conception expressed in works like the *Huainanzi* and *Zhoubi suan jing*—was still tenable.

Unno has argued that this description is meant to be read metaphorically, that roundness and squareness do not literally refer to shape but suggest metaphysical properties. For support Unno cites Zhao Junqing, who says that roundness and squareness do not refer to the actual shapes of heaven and earth.[81] Zhao, however, was writing

78. See Helen Wallis, "The Influence of Father Ricci on Far Eastern Cartography," *Imago Mundi* 19 (1965): 38–45; and *China in the Sixteenth Century: The Journals of Matthew Ricci, 1583–1610*, trans. Louis J. Gallagher from the Latin version of Nicolas Trigault (New York: Random House, 1953), 325. Trigault's book, originally published in 1615, is based in large part on Ricci's account of China and his mission. Matteo Ricci's own account can be found in *Storia dell'introduzione del Cristianesimo in Cina*, 3 vols., ed. Pasquale M. d'Elia, Fonti Ricciane: Documenti Originali concernenti Matteo Ricci e la Storia delle Prime Relazioni tra l'Europa e la Cina (1579–1615) (Rome: Libreria dello Stato, 1942–49). For a general discussion of Chinese resistance to Western science during the Ming and Qing, see George H. C. Wong, "China's Opposition to Western Science during Late Ming and Early Ch'ing," *Isis* 54 (1963): 29–49. One Chinese intellectual who denounced the round-earth conception promulgated by the Europeans was Wang Fuzhi (1619–92); see p. 225. Ricci's maps also incurred criticism because of their depiction of five major continents—Europe, Africa, America, Asia, and Magellanica—a world situation that reduced the geographic importance of China. The compilers of the *Ming shi* state that the explanation of world geography in terms of five continents is "nonsensical and hard to verify." They do admit, however, that the presence of visitors to China from places named on the map is proof that such places exist. See Zhang Tingyu et al., *Ming shi* (History of the Ming, 1739), chap. 326; see the modern edition in 28 vols. (Beijing: Zhonghua Shuju, 1974), 28:8459. There were, of course, some Chinese intellectuals sympathetic to Western learning. For more discussion of the Chinese response to Ricci's maps, see pp. 174–76.

79. Zhang Heng, "Er jing fu" (Two metropolises rhapsody, ca. 107), in Xiao Tong, comp., *Wen xuan* (Literary selections, completed ca. 526–31), ed. Hu Kejia (1809; reprinted Kyōto: Chūbun Shuppansha, 1971), 3.11b. The translation is that of David R. Knechtges, trans. and annotator, *Wen xuan; or, Selections of Refined Literature* (Princeton: Princeton University Press, 1982–), 1:263. In his "Lingxian," Zhang also describes the earth as being "flat and at rest" (*Zhang Heng nianpu*, 77 [note 72]).

80. Through at least the Song dynasty, the *Wen xuan* was studied by candidates for civil service degrees. See Knechtges, *Refined Literature*, 1:54–55 (introduction) (note 79); and David McMullen, *State and Scholars in T'ang China* (Cambridge: Cambridge University Press, 1988), 223–25.

81. Kazutaka Unno makes these points in two articles: "Japan before the Introduction of the Global Theory of the Earth: In Search of a Japanese Image of the Earth," *Memoirs of the Research Department of the Toyo Bunko* 38 (1980): 39–69; and "Kodai Chūgokujin no chiriteki sekaikan" (The ancient Chinese people's geographical conception of the world), *Tōhō Shūkyō* 42 (1973): 35–51.

FIG. 5.20. HAN COSMIC MIRROR. The mirror is believed to represent a square earth and round heaven. Diameter of the original: 14.3 cm. Courtesy of the Freer Gallery of Art, Smithsonian Institution, Washington, D.C.

perhaps during the third century, a time when the *huntian* theory seems to have been well established, and thus may have been attempting to reconcile astronomical knowledge with textual authority. Although he does not do so, Unno might also have cited Zhang Huang, compiler of the Ming encyclopedia *Tushu bian* (Compilation of illustrations and writings), who says that roundness refers to the motion of the heavens, and squareness to the stillness of the earth.[82] Zhang Huang's reading may be atypical, however, since he was acquainted with Matteo Ricci and may be reacting to Western conceptions of the world. In the *Tushu bian* he includes a copy of Ricci's map of the world, and he defends the spherical conception of the earth. Zhang's interpretation of the "heaven is round, earth is square" formula may have been motivated by a desire to harmonize traditional conceptions with Western ideas.

82. Zhang Huang, comp., *Tushu bian* (compiled 1562–77) (1613; reprinted Taipei: Chengwen Chubanshe, 1970), 29.34b.

FIG. 5.21. ILLUSTRATION EXPLAINING LUNAR ECLIPSES. Size of the original: 21 × 14 cm. From Wang Qi, comp., *Sancai tuhui* (completed 1607, printed 1609), *tianwen* [astronomy], 4.9a. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

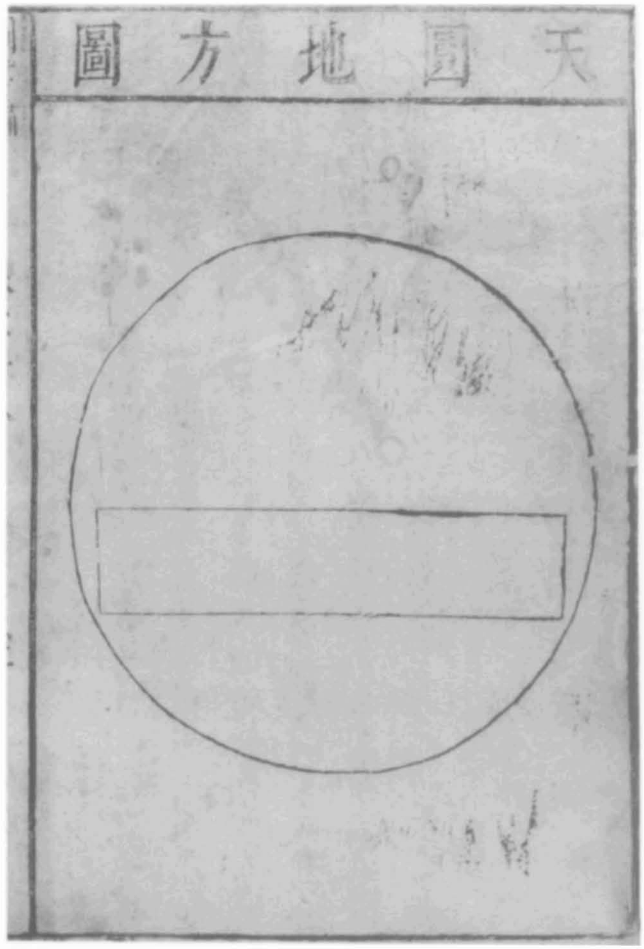


FIG. 5.22. ZHANG HUANG'S DEPICTION OF THE HEAVENS AS ROUND AND THE EARTH AS SQUARE. Size of the original: 22.5 × 15 cm. From Zhang Huang, comp., *Tushu bian* (1613), 28.2a. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

The persistence of the flat-earth conception despite astronomical evidence to the contrary serves as a reminder that not all astronomical innovations with potential applications in cartography were realized in cartographic practice. This fact supports Sivin's suggestion that there was no "systematic connection between all the sciences in the minds of the people who did them."[83] Elsewhere Sivin points to an explanation for this: traditions of learning were regarded as consisting of lineages of texts. This conception of learning did not preclude innovation, but it did place some restrictions of how much innovation was permissible: "Those who worked in the sciences accepted and carried on their forebears' sense of the enterprise, often modifying it in the process. In certain periods innovation was recognized and prized in astronomy and medicine as in many other aspects of Chinese life, but the new became more acceptable to the extent that precedents showed it was not wholly new."[84] To apply this conception of multilineality to the case at hand, the *huntian* and *gaitian* theories had different textual lineages and tended to be used in different contexts. In addition, they were associated with instruments having different purposes. The *huntian* theory represented the spatial orientation of the armillary sphere, used for the demonstration and observation of celestial motions, and the *gaitian* theory represented that of the gnomon, used to measure the length of the sun's shadow. In these circumstances, the two representations were not necessarily juxtaposed for comparison.

83. Nathan Sivin, "Why the Scientific Revolution Did Not Take Place in China—Or Didn't It?" *Chinese Science* 5 (1982): 45–66, esp. 48.

84. Sivin, "Science and Medicine," 43 (note 2). The idea of textual lineages also applies to Western scientific traditions, but perhaps, as Sivin suggests, to a lesser extent than in China.

FIG. 5.23. WANG QI'S DEPICTION OF THE HEAVENS AS ROUND AND THE EARTH AS SQUARE.
Size of the original: 21 × 14 cm. From Wang Qi, comp., *Sancai tuhui* (completed 1607, printed 1609), *tianwen* [astronomy], 4.6a. Reproduced courtesy of the Harvard-Yenching Library, Harvard University, Cambridge.

The multilineal conception of learning can perhaps explain why other astronomical innovations did not realize their cartographic potential. For instance, the astronomical survey performed by Yixing (682–727) and Nangong Yue during the Tang dynasty calculated that a change of one degree in celestial latitude (determined by observing a difference of one degree in the altitude of the Pole Star) corresponded to a change of about 351 *li* in terrestrial distance. This ratio makes sense only if one assumes a terrestrial meridian that traces a circle. The ratio would then allow one to determine ground distances indirectly using astronomical measurements and thus seems to have cartographic significance. The ratio determined by Yixing and Nangong Yue was helpful to court astronomers, who could use it to calibrate gnomon shadow lengths, which were used to determine reference dates, such as the summer solstice, important in the construction of calendars.

Outside astronomical circles, however, as Beer and others have suggested, the implications of the ratio would have made it unacceptable to adherents of the *gaitian* theory.[85] After describing the astronomical survey, the compilers of the *Jiu Tang shu* (Old history of the Tang, compiled 940–45) note this discrepancy between the two schools: "Adherents of the *hun* and *gai* schools have not yet been able to reconcile their theories."[86]

Similarly, the results of the "survey of the four seas" (that is, the world), directed by the Yuan astronomer Guo Shoujing (1231–1316), would not have been applied by cartographers adhering to a flat-earth conception. The survey established twenty-seven observation stations at which the height of the North Star in degrees was determined. The results of the survey are recorded in the *Yuan shi* (History of the Yuan), compiled shortly after the fall of the Yuan dynasty. For seven observation sites, including the capital, the *Yuan shi* records, in addition to the height of the North Star in degrees, the gnomon shadow length at the summer solstice and the length of day and night at the summer solstice.[87] This information would have been of use in constructing calendars, one of the main duties of court astronomers. In addition, the correlation of celestial positions with terrestrial locations had potential cartographic significance, since it would have permitted indirect measurement of ground distances based on celestial observations. As in the case of the Tang astronomical survey, however, the cartographic potential does not seem to have been realized.

The correlation of celestial degree measurements with ground distance is possible only on the assumption that the earth's surface parallels the celestial sphere or, in other words, that the earth is round. Those responsible for mapmaking within the political establishment, however, generally seem to have adhered to the flat-earth conception. This idea was sanctioned by a number of ancient texts and, furthermore, was implied by the indirect methods of measuring ground distances described in mathematical texts.

This conclusion, at any rate, is supported by the history of Chinese cartographic theory and practice after the

85. Arthur Beer et al., "An 8th-Century Meridian Line: I-Hsing's Chain of Gnomons and the Pre-history of the Metric System," *Vistas in Astronomy* 4 (1961): 3–28, esp. 25. With regard to the results of the astronomical survey, the point of contention between the adherents of the two theories would not have been whether the observed height of heavenly bodies varied with distance from a given reference point, but the rate at which the height varied. Under the *gaitian* conception, equal increments of arc measurement would not correspond to equal increments of ground distance.

86. *Jiu Tang shu*, chap. 35 (4:1307) (note 54).

87. *Yuan shi*, chap. 48 (4:1000) (note 77).

Tang. Shen Kuo's statement of methods says nothing about correcting for curvature of the earth's surface. A rough gauge of the strength of the flat-earth conception is the Suzhou astronomical chart (fig. 13.21 below). Carved in stone in 1247, it purports to be a copy of a star map prepared for the education of a royal prince. According to the text accompanying the chart, the "essentials" of astrology include a conception of the earth as flat and static: "The body of Heaven is round and the body of Earth is square. The round is in motion and the square is at rest."[88]

Patterns in the use of the cartographic grid also do not support the notion that Chinese cartographers accepted a round-earth conception to any appreciable degree. Grids seem to have been used primarily on small-scale maps representing large areas, such as whole provinces or all of China. Yet these maps are, of course, the ones on which distortion from the earth's curvature would be most apparent. On large-scale maps representing smaller areas such as counties or prefectures, grids are rare. The use of the grid to support a textualist interpretation of Chinese cartographic history might appear to run counter to the grid's standard interpretation as a high point in Chinese mensurational cartography. As we will see, however, the grid, though highly suggestive of quantification, is not incompatible with textualism.

The Cartographic Grid

The first known use of the square grid occurs on the *Yu ji tu* (Map of the tracks of Yu), carved in stone in 1136.[89] A note on the map says, "[A side of] each square converts to one hundred *li*." The grid bears a superficial resemblance to the system of latitude and longitude that developed in Europe, but unlike the graticule, the Chinese grid is not a fixed coordinate system. In contrast to the graticule, which represents a mathematical structure underlying the two-dimensional projection of the terrestrial sphere, the square grid seems to have been superimposed arbitrarily on a given area of interest.

The graticule, as used in Europe, is based on ideas summarized by Claudius Ptolemy (ca. 90–168), the Alexandrian geographer and mathematical astronomer. Under Ptolemy's conception of mapping, space is composed of points, each occupying a specific location that can be determined mathematically on an x-y axis. The graticule provides a framework for organizing and locating specific points, thus permitting projection from a spherical to a plane surface. Geographers of the Renaissance constructed maps on this principle. A rectangular graticule was laid out on a blank plane surface as a way to delimit and organize space and determine its relative scale. Plotted on this base were a series of points in the form of geographical coordinates of latitude and longitude corresponding to features of the earth's surface. The rest of the map—linear and areal features—was filled in relative to these points.[90]

In contrast to European practice, map space was not treated analytically in China; points were located not by coordinates, but solely by distance and direction. In consequence, the grid served a function different from that of the graticule. From the indications of scale on grid maps, often expressed as a certain number of *li* per (side of a) square, one purpose of the grid was to help a map reader calculate distance and area. This contrasts with the function of the graticule, which has been used primarily as a means of locating position and relating the area mapped to the globe of which it is a part.[91] Underlying this difference are divergent views of the earth's shape: the square grid presupposes a generally flat surface. The graticule developed as a means of transferring points on a spherical surface to a plane surface, thus entailing some manipulation of the increments by the cartographer and an inevitable distortion of the image itself.

The origins of the grid are unknown. Several analogous schemes for spatial division or organization, however, predate its first appearance. One is the graph for "field," *tian* 田, which, according to a Han etymological dictionary, represents the configuration of paths in grain fields.[92] Land division by such crisscrossing paths, carried out over a large area, would result in a pattern similar to a grid. So too would the "well-field" system of land allocation, so called because it would create units resembling the graph for "well," *jing* 井 (fig. 8.1 below).[93] Literary

88. As translated in W. Carl Rufus and Hsing-chih Tien, *The Soochow Astronomical Chart* (Ann Arbor: University of Michigan Press, 1945), 2.

89. Contrary to the impression given by Needham (*Science and Civilisation*, 3:543 [note 43]), there is no evidence that square grids appeared on maps before the Song. The claim that Jia Dan used a grid seems to be based on a misreading of the *Jiu Tang shu*. It says that Jia drew a map with "a scale of one *cun* to one hundred *li*," not "one [side of a] square (*fang*) to one hundred *li*." See *Jiu Tang shu*, chap. 138 (12:3786) (note 54).

90. For more on Ptolemy, see Dilke, "Culmination of Greek Cartography" (note 56).

91. Thus Helen Wallis's description of the grid as a "cartographic reference system" is misleading, since it gives the impression that the grid was a coordinate system. See Helen Wallis, "Chinese Maps and Globes in the British Library and the Phillips Collection," in *Chinese Studies: Papers Presented at a Colloquium at the School of Oriental and African Studies, University of London, 24–26 August 1987*, ed. Frances Wood (London: British Library, 1988), 88–96, esp. 88.

92. Xu Shen, comp., *Shuowen jiezi* (Explanation of writing and explication of graphs, compiled ca. 100), s.v. *tian*, in *Shuowen jiezi gulin* (Collected glosses to the *Shuowen jiezi*), 12 vols., ed. Ding Fubao (Taipei: Shangwu Yinshuguan, 1959), 9:6183b.

93. The well-field system is just one manifestation of the nonary square pattern that was influential in Chinese cosmology. See pp. 205–16. As John Henderson points out below, the square pattern also manifested itself in city planning. For an example of this, see figure 8.6.

accounts of land division systems like the well-field system have often been dismissed as idealizations, but there is evidence that some system must have been practiced. Leeming has studied maps and aerial photographs of Chinese terrain and found that an ancient gridlike pattern of land division is often discernible.[94] The cartographic grid may in part represent an attempt to mimic this feature of the landscape.

Another possible source of the grid is Zhang Heng, who is credited with the *Suan wang lun* (Discourse on net calculations), now lost. The title is said to derive from the method of calculations described in the work: according to one commentary, Zhang Heng "cast a net around heaven and earth and calculated on the basis of it."[95] Joseph Needham has speculated that the net was a "rectangular grid system," the celestial coordinates corresponding to the *xiu* (lunar lodges) of traditional Chinese astrology. This speculation seems unlikely, since one cannot speak of a rectangular coordinate system when right ascension was measured in degrees and declination was recorded in various linear units. As for the terrestrial coordinates, Needham runs into the problem commonly encountered in the study of early Chinese cartography—insufficient detail in existing texts.[96] Needham speculates that Zhang Heng's terrestrial system consisted of rectangular grids.[97] Clues about Zhang's methods could normally be expected to come from his practice, but none of his maps are extant. He made a topographical map (*dixing tu*) that apparently survived until the Tang dynasty, since it is recorded in a catalog of Han paintings compiled in the ninth century.[98] Unfortunately, the catalog's compiler provides no information about the map's content or appearance.

Scholars since the seventeenth century have credited Pei Xiu with developing the square grid.[99] But unless one follows Needham, who interprets the second principle, *zhunwang*, as describing a rectangular grid system,[100] there is no evidence that Pei Xiu used a grid in the way it is used on, for example, the *Yu ji tu*. What the principle of *zhunwang* may entail is the use of a single reference point (A in fig. 5.24*a*) for measurements of distance and direction. The advantages become most apparent in small-scale mapping. If multiple reference points are used (A, B, and C in fig. 5.24*b*), cumulative errors in distance and direction measurements occur. A single reference point, however, allows backsighting as a means of checking one's bearings. Thus one can "regulate" one's directional sightings in the manner Pei Xiu implies: "Regulated sighting is a means of rectifying the configuration of this place and that [or in other words, relative position]. . . . If a map has proportional measure [or scale] but lacks regulated sighting, then, though it may be correct in one corner, it will fail in other places."[101] As interpreted here, applying *zhunwang* minimizes cumulative errors in directional measurement.[102]

The grid, though probably not employed by Pei Xiu, was used by later cartographers to facilitate the production of maps, particularly in plotting direction and distance in accordance with Pei's first two principles. In his preface to the *Guang yutu* (Enlarged terrestrial atlas, printed about 1555), Luo Hongxian (1504–64) says that his predecessor Zhu Siben (1273–1337) used the grid in this manner. The faithfulness of Zhu's maps to reality, Luo says, can be attributed to his use of the grid: "His maps employ the method of drawing squares for measuring distance, and as a result, their depiction of reality is reliable. Thus, whether one divides or combines them, east and west match each other without incurring any discrepancy."[103]

The use of the grid, together with scale indications, perhaps warrants the conclusion that maps like the *Yu ji tu* relied at least in part on direct and indirect measure-

94. Frank Leeming, "Official Landscapes in Traditional China," *Journal of the Economic and Social History of the Orient* 23 (1980): 153–204.

95. Quoted in Fan Ye, *Hou Han shu* (History of the Later Han, compiled fifth century A.D.), chap. 59; see the edition in 12 vols. (Beijing: Zhonghua Shuju, 1965), 7:1898 n.

96. Needham, *Science and Civilisation*, 3:537–38 (note 43). Needham's speculation about the net corresponding to the *xiu* seems to have little to support it, unless it is derived from a rectangular projection of the sky. For more on the *xiu*, see the chapters below on celestial mapping.

97. Needham, *Science and Civilisation*, 3:541 (note 43).

98. Zhang, *Lidai minghua ji*, chap. 3 (76) (note 48).

99. See Wang Yong, *Zhongguo dilixue shi* (History of geography in China) (1938; reprinted Taipei: Tiawan Shangwu Yinshuguan, 1974), 57–59. In this work Wang expresses some doubts about Pei Xiu's knowledge of the square grid system, but in his later work he changes his mind. See Wang Yong, *Zhongguo ditu shi gang* (Brief history of Chinese cartography) (Beijing: Sanlian Shudian, 1958), 20. In addition, Needham, *Science and Civilisation*, 3:539–41 (note 43), and Chen, "Historical Development of Cartography," 103–4 (note 53), attribute the cartographic grid to Pei Xiu.

100. Needham, *Science and Civilisation*, 3:539–41 (note 43). Needham's evidence for interpreting *wang* as implying verticality is not convincing. The Han dictionary *Shuowen jiezi* defines *wang* as "going into exile and gazing at [one's homeland] in the distance" (*Shuowen jiezi gulin*, ed. Ding Fubao, 9:5717b [note 92]). The graph *zhun* can mean "regulated" or "standard," thus the translation of *zhunwang* adopted here—regulated viewing or sighting.

101. *Jin shu*, chap. 35 (4:1040) (note 42).

102. This interpretation of *zhunwang* was proposed to me by Tsai Fa Cheng. Gari Ledyard proposes a different interpretation of *zhunwang* as "balanced sighting" from two or more reference points (personal correspondence).

103. Luo Hongxian, *Guang yutu* (ca. 1555), 6th ed. (1579; reprinted Taipei: Xuehai Chubanshe, 1969), preface, 2a. The quotation points to another function of the grid: to provide register marks that ensure accuracy when two sections are joined along their edges to form a single large map.

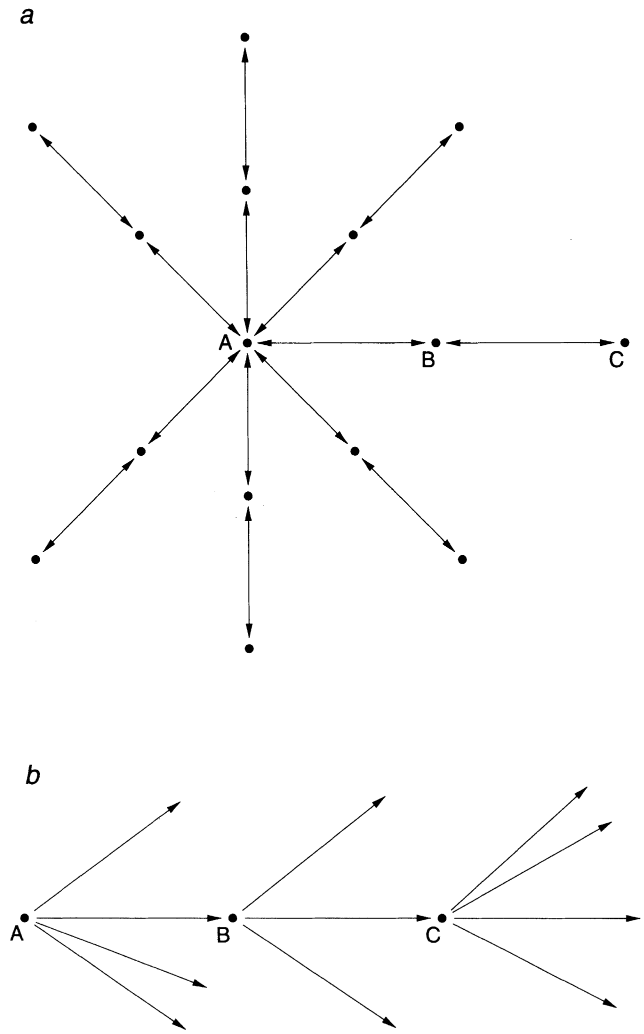


FIG. 5.24. INTERPRETATION OF *ZHUNWANG*. (*a*) The use of a single control point (or "regulated sighting") from which to observe all features (A) permits one to backsight and minimize errors in directional readings. (*b*) The use of multiple reference points for directional measurements results in an accumulation of errors as one moves from point to point (A to B to C) and takes one's bearings on local features.

ments of ground distances.[104] As I stated above, however, grid use does not necessarily imply an attenuation of the textualism discussed earlier. This is particularly true of large-area maps, in which case a mapmaker would often be unwilling or unable to survey all the distances involved and would have to rely on secondary sources. In preparing his map of China, the *Yutu* (Terrestrial map), Zhu Siben relied on earlier maps (including the *Yu ji tu*), literary sources, and personal observations, not necessarily on survey measurements. Zhu, though eclectic in his sources, cautions against using them uncritically. Some foreign countries were omitted from the *Yutu* because Zhu lacked reliable information: "As for the various foreign lands southeast of the South Sea and northwest of the great desert [Mongolia], although they at times send tribute to the court, their distance precludes investigation. Those who speak of them are unable to be specific. Those who are specific cannot be trusted."[105] Similarly, Luo Hongxian consulted literary sources when expanding Zhu's work. This willingness to rely on literary sources, though treating them critically, is perfectly consistent with Chinese cartographic theory and practice from Pei Xiu through Shen Kuo.

The state of Luo's atlas suggests a reason for this. It seems to have been conceived as a treatise: most of the work consists not of maps, but of verbal description. In fact, bibliographic treatises have traditionally classified maps in a manner that emphasizes their character as text. Maps and geographic works are classed together under the rubric "history" (*shi*)—in short, they were considered a form of narrative literature. Thus, during the Qing, maps, as we saw above, were important tools of historical research, both as source material and as a means of presenting results. The evidentiary approach Luo adopts in his cartography, based on careful attention to documentary sources and verification, might be considered as foreshadowing later *kaozheng* practices.

The textualist orientation persisted until at least the end of the nineteenth century when the central government attempted to Westernize Chinese mapmaking practices. The installation of Western techniques stressing measurement and mathematical projections did not displace text-based verification. According to the *huidianguan* (bureau of institutional studies), the work of compiling an atlas from maps submitted by provincial governments was complicated by divergent methods of mapmaking—this despite the promulgation of cartographic standards: "When [new maps] were compared with old accounts, there were still discrepancies and similarities. These were all checked by measuring distances and by widely searching through records in an effort to resolve ambiguities and reach a single conclusion."[106] In a departure from the European ideal, text together with measurement serves as the final authority.

Conclusion

In light of the material presented here, to subject Chinese

104. As, for example, P. D. A. Harvey has concluded in *The History of Topographical Maps: Symbols, Pictures and Surveys* (London: Thames and Hudson, 1980), 133–36.

105. Zhu Siben, preface to the *Yutu*, in Luo, *Guang yutu*, 1b (note 103).

106. *Qinding Da Qing huidian* (Imperially commissioned collected statutes of the Great Qing), 24 vols. (1899; reprinted Taipei: Zhongwen Shuju, 1963), 2:1022.

cartographic history to the kind of treatment once accorded early Western maps—as precursors of "modern scientific" cartography based on mathematical techniques—is to give undue weight to fragments of texts isolated from their total contexts. Such a treatment introduces a modern bias toward mathematics as the foundation of scientific knowledge into a context where the bias tended in the opposite direction. The persistence of a textualist attitude among cartographers in premodern China does not lessen the achievement of premodern Chinese cartography, but it shows it in a different light, suggesting the need for a reorientation in the way historians of Chinese cartography have regarded their subject.

The interplay between observation and textualism traced here is proposed as an explanatory model for some of the features observed in Chinese maps—features not always taken into account in previous accounts of Chinese cartography: the lack of consistency in applying the cartographic grid, the complementarity of text and map in Chinese atlases, and the heavy reliance on textual methods of verification even after mensurational techniques had developed to a high degree. The textualist tendency in Chinese cartography suggests that a fruitful approach to the study of Chinese maps might involve interpretive principles commonly invoked in literary study. More specifically, such research might involve what Schleiermacher called "subjective reconstruction": "One seeks to understand the writer intimately . . . to the point that one transforms oneself into the other." The point is "not to understand an ancient text in view of modern thinking, but to rediscover the original relationship between the writer and his audience."[107] Traditional Chinese cartography thus demands to be conceived in broader terms than it has been in previous modern studies. In other words, what is needed is a better match between interpreter and original audience. The Chinese intellectuals who made and read maps held *boxue* (broad learning), not specialization, as an educational ideal and seem to have regarded cartography in those terms.[108] This view of the subject is not unique. Late in the twentieth century, a textualist tendency can be seen in more than a few geographers who work in the academy, a setting in which what one has seen can seem less important than what one cites. Such is the reverence for the published word.

107. Friedrich D. E. Schleiermacher, "*The Hermeneutics*: Outline of the 1819 Lectures," trans. Jan Wojcik and Roland Haas, *New Literary History* 10 (1978): 1–16, esp. quotations on 14 and 6.

108. Thus it was with considerable trepidation that I, a specialist in literary studies, undertook this essay at all, since the research involved would make my incompetencies painfully apparent. I owe considerable debts to those who helped me compensate for those weaknesses by allowing me to stand on their shoulders: David Woodward, Kevin Kaufman, Brian Harley, Jude Leimer, Tsai Fa Cheng, and Nathan Sivin.