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Origins and Development of the Ichnographic City Plan

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A CRUCIAL DEVELOPMENT to influence Renaissance art and architecture was the ability to represent three-dimensional space on a flat surface by means of scientific perspective. From the correct application of perspective, an illusion of space resulted which was a new conceptual formulation involving the mathematical abstraction of objective reality. The principles of perspective assumed a human observer whose physical limitations (eye level and distance from the picture plane) were essential components of the *costruzione legittima*. The perspective system was admirably suited to representations which could be viewed by a single observer situated at a particular point. However, in order to represent a complex object such as a city, which could not be seen in its totality by a single observer standing earthbound at a fixed point, a different representational method was necessary. The depiction of cities in oblique projection, as well as the familiar bird's-eye view, permitted an illusion of total vision. In Renaissance plans of this type, cities are shown as if seen from a single elevated viewpoint, from which the projected line of sight meets the earth's surface at an oblique angle. Civic monuments nearer to the fictive observer suspended in mid-air appear larger than ones more distant, and spatial relationships within the city are distorted. To overcome these limitations another method of portraying cities was necessary.

During the century from approximately 1450 to 1550, the efforts of artists and scientists on both sides of the Alps yielded a new means of representing cities graphically.[1] Unlike perspective views, in which topographical features are drawn in relief, this new type of plan delineates every building, street, and square in outline as a ground plan. All topographical features are drawn as if reflected on a single horizontal plane. The characteristic flatness of the resulting image may be termed ichnographic, a compound of the Greek words ἴχνος (meaning tracing or outline) and γραφή (writing).[2] Moreover, as in Leonardo da Vinci's drawing of Imola of 1502, a city is represented as if viewed from an infinite number of viewpoints, all perpendicular to each topographical feature (Fig. 1). Such a view is not to be seen in reality; it is an abstraction requiring a high degree of skill to measure and record. Ichnographic plans constituted a new conceptual attitude toward the representation of cities, in which quantitative topographical relationships were given visual priority over both symbolic values and the actual appearance of the city. In ichnographic plans the abstraction of physical reality resulted in an image conveying selective information about a city which other kinds of plans were able to represent much less accurately. Although depicting spatial relationships with precision, ichnographic plans carried with them certain limitations. Such plans were, for example, ill-suited to expressing symbolic values or conveying the impression a city might produce upon first sight. The potential as well as the limitations of ichnographic plans can

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1. The *Forma Urbis Romae*, a marble plan of the ancient city dating from the third century A.D., is an ichnographic plan. Cf. G. Carettoni et al., *La pianta marmorea di Roma antica* (Rome, 1960). Fragments of the *Forma Urbis* were not discovered until the pontificate of Pius IV (1559–1565), by which time the Renaissance topographers had already independently formulated the principles underlying ichnographic city plans.

2. *Ichnographia* was first used by Vitruvius (*De Architectura*, I, 2, 2) to signify a ground plan. In the Renaissance *ichnographia* came into common usage, as in "... Ichnografia, cioè descrittione delle piante ..." (D. Barbaro, *La prattica della perspettiva* [Venice, 1569], p. 25). G. B. De' Rossi was the first to use an adjectival form of *ichnographia* to define a specific category of city plans (*Piante icnografice e prospettiche di Roma anteriori al secolo XVI* [Rome, 1879]). While *ichnographia* passed into the English language toward the end of the sixteenth century, and continues to be accepted in modern usage (cf. *The Concise Oxford Dictionary of Current English* [1964], p. 100), it has not been applied critically to the analysis of city plans. The systematic use of this term to characterize the specific type of city plan described in this essay would, I think, facilitate further study in a field which suffers today from the lack of a precise technical vocabulary.

be explained by examining the purposes for which they were intended and the method by which they were prepared.

An examination of the origin and specific characteristics of the ichnographic city plan underscores a remarkable similarity of method and intention among a number of examples which previously have been considered only in isolation. This essay attempts to sketch a broad outline of a problem only generally understood at this time, to provide definitions, and to identify directions which further study in this field might take.[3] The study of ichnographic city plans and their relationship to the development of sixteenth-century surveying techniques enhances our understanding of an especially significant branch of Renaissance cartography and related aspects of military and urban planning. Moreover, such a study provides a specific example of the application of scientific empiricism and technology to the formulation of new conceptual and representational modes in the Renaissance.

In late mediaeval plans, cities are represented iconically as a collection of isolated monuments, marvels chosen to typify the city. No coherent system determines spatial relationships among the individual monuments, making it impossible for the observer to judge their scale or distance from one another.[4] Similarly, mediaeval world maps or *mappaemundi* are far from being precise visual records of scientific observation; they are complex iconographic compilations of mythical peoples and popular lore.[5] Both *mappaemundi* and iconic city views depict symbolic abstractions that do not correspond to physical reality. Both types are contained within a circular format, both share a hierarchical view of the cosmos. Just as Jerusalem appears at the precise geometrical center of the Ebstorf *Mappamundo*, so the Capitolium occupies the middle of most iconic views of Rome.[6] City and world, *urbs et orbis*: both reflect the same cosmic order.

A parallel relationship between mediaeval world and city images persisted well into the fifteenth century. Already in the thirteenth century, however, a new kind of map was developed which departed from the formal and symbolic conventions of the *mappaemundi*. This was the portolan chart, made by mariners specifically for use by other seamen, which was the natural outgrowth of practical navigational experience with the magnetic compass.[7] Unlike the *mappaemundi*, portolan charts resulted from direct observation of the earth's surface with the aid of scientific instruments. The accuracy of the portolans was constantly being improved by corrections and additions made after each voyage. While portolan charts represented an important advance in cartography both in terms of accuracy and method, they did not provide a uniform framework for perceiving the earth as a whole.[8] This only came about following the intense study of Ptolemy's world delineation, which became the basis for a coherent structural approach to geography in the Renaissance.

In particular, Ptolemy's coherent structural approach to geography constituted a working model which inspired many of Leon Battista Alberti's theoretical attitudes.[9] Alberti's brief description of his survey of Rome known as the *Descriptio Urbis Romae*, which he wrote during his second residence there between 1443 and 1455, is an example of such an exercise.[10] Together with what is known of Alberti's surveying method from his *Ludi Matematici*, the *Descriptio* documents what may be termed the first step toward realizing an accurate topographical representation by scientific means.[11] Since no Renaissance plans drawn to Alberti's

3. For useful introductions to the history of city plans in relation to cartography cf. E. Oberhummer, "Der Stadtplan, seine Entwicklung und geografische Bedeutung," *Verhandlungen des XVI Deutschen Geographentages zu Nürnberg* (1907), pp. 66–101; and W. W. Ristow, comp., *Guide to the History of Cartography, an Annotated List of References on the History of Maps and Mapmaking* (Washington, D.C., 1973).

4. Mediaeval city representations of this iconic type exert a marked influence on later Renaissance plans, which frequently retained a circular format and employed graphic conventions, like the arbitrary manipulation of scale, for visual emphasis. Presumably the circular format was common to both world maps and city views as early as the eighth century. Cf. Einhart's description of a circular plan of Rome inscribed on top of a table in the *Vita Caroli Magni* (Berlin, 1876), p. 55. Another circular Carolingian plan of Rome has been reconstructed from the Itinerary of the Anonymous Einsidlensis: C. Huelsen, "La pianta di Roma dell'Anonimo Einsidlense," *Atti della pontificia accademia romana di archeologia*, IX (1907), 379–423 (esp. tav. XVI); and R. Lanciani, *L'itinerario di Einsiedeln e l'ordine di Benedetto Canonico* (Rome, 1891).

5. R. Almagia and M. Destombes, *Monumenta cartographica vetustioris aevi, A.D. 1200–1500*, I, *Mappaemondi* (Amsterdam, 1964).

6. W. Rosien, *Die Ebstorfer Weltkarte* (Hannover, 1952). A Frutaz, *Le piante di Roma*, 3 vols. (Rome, 1962), II, tav. 140, reproduces an enlarged detail of the Ebstorf map of ca. 1235 showing the circular plan of Rome.

7. K. Kresctchmer, "Die italienischen Portolane des Mittelalters," *Veröffentlichungen des Instituts für Meereskunde und des geographischen Instituts an der Universität Berlin*, XIII (1909). For a discussion of portolan charts and their relation to Ptolemaic cartography, cf. S. Y. Edgerton, Jr., "Florentine Interest in Ptolemaic Cartography as Background for Renaissance Painting, Architecture, and the Discovery of America," *JSAH*, XXXIII (1974), 281–282.

8. Portolan charts were prepared simply as practical aids to navigation and were never intended to represent large-scale geographical relationships.

9. Edgerton, "Florentine Interest in Ptolemaic Cartography," pp. 288–290.

10. Frutaz, *Le piante*, I, 127–128; L. Vagnetti, "La 'Descriptio Urbis Romae' di L. B. Alberti," *Quaderni della facoltà di architettura, Università di Genova*, I (1968), 25–78; and J. Gadol, *Leon Battista Alberti, Universal Man of the Early Renaissance* (Chicago, 1969), pp. 157–195.

11. A. Bonucci, ed., *L. B. Alberti, Opere volgari* (Florence, 1847), IV, 401–440, provides the complete text of the *Ludi Matematici*.

Fig. 1. Leonardo da Vinci, Plan of Imola, ca. 1503, Royal Library, Windsor Castle, no. 12284 (reproduced by gracious permission of Her Majesty the Queen).

measurements survive, any discussion of the visual appearance of Alberti's plan rests solely on the bare bones of its underlying theory.[12] In the *Descriptio* Alberti outlined a method which permitted any point in the city to be fixed on his plan by establishing its polar coordinates. All distances were measured from a point at the center of the city, the Capitolium. A circle (which Alberti called the horizon) was divided into forty-eight degrees; from the center, the horizon was met by a movable radius divided into fifty degrees. By means of this mechanism any building in the city could be located by two figures, one indicating the point on the horizon which the movable radius pointed to when it ran through the building, the other indicating the distance measured from the center along the radius when it intersected the building.

To determine precisely distances and topographical locations of the civic monuments he listed, Alberti employed an odometer and a primitive equivalent of the modern surveyor's transit. An instrument able to measure distances in the field was important to the improved accuracy of Alberti's plan. To produce the ungainly odometer described in the *Ludi Matematici*, a small hole was bored through the axle of an ordinary cart wheel so that once every rotation one small pellet would fall from a container above the axle through the hole and into a pouch.[13] The distance to be measured having been covered, the pellets were counted and the distance ascertained. Alberti's transit was an improved version of the Roman *groma* employed in land centuriation and in laying out military camps, towns, and roads throughout the empire, apparently in continuous use since antiq-

12. Attempts to see reflections of Alberti's lost plan in subsequent fifteenth-century views of Rome seem unconvincing. Cf. Frutaz, *Le piante*, I, 19–20, for a discussion of circular plans in general and the Rosselli group in particular.

13. *Ludi Matematici*, chap. XVIII. Alberti's odometer is clearly derived from a similar instrument described by Vitruvius in *De Architectura*, X, 9, 1–4.

uity.[14] According to the *Ludi Matematici* this transit had a circular dial divided into forty-eight degrees; it permitted Alberti to fix a topographical feature relative to two or more points by elementary triangulation.[15] Alberti's transit, as well as his odometer, were the forerunners of the more sophisticated instruments which Leonardo used at Imola some fifty years later.[16]

What is known of Alberti's surveying method and the fact that he used the intersection of a single set of numerical coordinates to locate three-dimensional buildings make it unlikely that the plan accompanying the *Descriptio* would have been a perspective or bird's-eye view.[17] All that can be said securely in seeking to reconstruct the lost plan accompanying Alberti's survey is that Rome was represented within a circular format with each of its major monuments located by a single dimensionless point.[18] Alberti's list of coordinates provides no indication whatsoever of the orientation and plan of each monument, and it is difficult to imagine how these could have been accurately and coherently established without the aid of a magnetic compass. Alberti's failure to recognize the value of the compass as a precise and constant reference of orientation must be considered a major obstacle to his ever having produced a true ichnographic plan, in which each salient topographical feature is not only pinpointed, but outlined in every facet of its plan as well.

Vagnetti's opinion that the drawing accompanying the *Descriptio* can not have been a perspective view is convincing, but the mere absence of relief does not necessarily mean that Alberti's plan was ichnographic, as he maintains.[19] It seems more reasonable to take the *Descriptio* at face value and accept it for what it is: an impressive theoretical mechanism for locating (but in no way describing) monuments in an urban setting. Such a plan would have provided the first coherent, all-embracing framework for the topographical study of Rome, and, by implication, of other cities as well. If Alberti's survey did not actually result in an ichnographic plan, it nonetheless showed an awareness of the essential theoretical concerns which ultimately made such a plan possible. Foremost among these were the principles of Ptolemaic geography, the idea and mechanism of proportional depiction, and the application of scientific instruments to the mathematical description and subsequent representation of people's environment.

Leonardo da Vinci's reputation as a cartographer is based primarily on the magnificent series of colored relief maps in the Windsor collection.[20] These sheets represent sections of the central portion of Italy roughly from Florence to Terracina, bounded by the Apennine watershed and the Tyrrhenian coastline. The impression of altitude conveyed by these bird's-eye views as well as the clarity with which river systems and mountain ranges are represented demonstrate the degree to which art and science are united in Leonardo's cartography.[21] Another group of Leonardo's drawings, comprising the plan of Imola (Windsor 12284), its related studies (Windsor 12686r), and other sheets of topographical observations, permits a detailed analysis of his application of the ichnographic plan to the representation of cities.

In 1502 Leonardo entered the service of Cesare Borgia in the capacity of architect and engineer.[22] From July to September of that year he travelled throughout Romagna, stopping successively at Urbino, Pesaro, Rimini, Cesena, and Cesenatico. By early October he had arrived at Imola, where he and Cesare Borgia were apparently confined for a few weeks due to a revolt of the Prince's mercenaries. During those weeks Leonardo probably prepared the detailed circular plan of Imola now at Windsor (Fig. 1).[23]

14. M. della Corte, "Groma," *Monumenti Antichi*, XXVIII (1922), 6–99; O. A. W. Dilke, "Map in the Treatises of Roman Land Surveyors," *Geographical Journal*, CXXVII (1961), 417–426; and C. Thulin, *Corpus Agrimensorum Romanorum Recensvit* (Leipzig, 1913).

15. Alberti, *Ludi Matematici*, chap. XVI. Triangulation requires at least three steps: (1) making a sighting to the topographical feature from a fixed point to obtain the angle formed by this bearing and a base line connecting the first sighting point with a second one; (2) taking a bearing from the second observation point to obtain the angle between the base line and the feature; (3) measuring the base line. While Alberti does not specifically mention measuring the base line, this is implied by the steps which follow and by his results: cf. Vagnetti, "La 'Descriptio Urbis Romae,'" p. 40.

16. Leonardo's familiarity with the transit and odometer described by Alberti in the *Ludi Matematici* may be assumed on the basis of notes in MS. *F* (fol. 82r) and MS. *G* (fol. 54r). The transit described by Francesco di Giorgio in his architectural treatise is similar to Alberti's in lacking a magnetic compass: cf. C. Maltese and L. M. Degrassi, eds., *Francesco di Giorgio Martini, Trattati di architettura, ingegneria e arte militare* (Milan, 1967), I, 133–134; tav. 58.

17. Recent scholars (Frutaz, Vagnetti, and Gadol) concur with this view.

18. This is precisely how it appears in Vagnetti's reconstruction drawing, which accurately superimposes Alberti's coordinates onto a modern plan of Rome.

19. Vagnetti, "La 'Descriptio Urbis Romae,'" p. 29.

20. Windsor 12277, 12278, 12683, and 12684. Cf. M. Baratta, *I disegni geografici . . . di Windsor* (Rome, 1941), tavs. 14, 12, 15, and 16 respectively for color facsimiles.

21. E. Oberhummer, "Leonardo da Vinci and the Art of the Renaissance in its Relation to Geography," *Geographical Journal*, XXXIII (1909), 540–569.

22. C. Pedretti, "Leonardo architetto a Imola," *Architectura*, II (1972), 92–105. Leonardo's activity in the service of Cesare Borgia is extensively examined by I. Calvi, *L'architettura militare di Leonardo da Vinci* (Milan, 1943), pp. 128-161. The letter (dated 12 August 1502) from Cesare Borgia which refers to Leonardo as his architect and engineer is transcribed on pp. 129-130.

23. K. Clark, *The Drawings of Leonardo da Vinci in the Collection of Her Majesty the Queen at Windsor Castle* (London, 1968), I, 10; and Baratta, *I disegni*, tav. 18, for a color facsimile of the Imola plan.

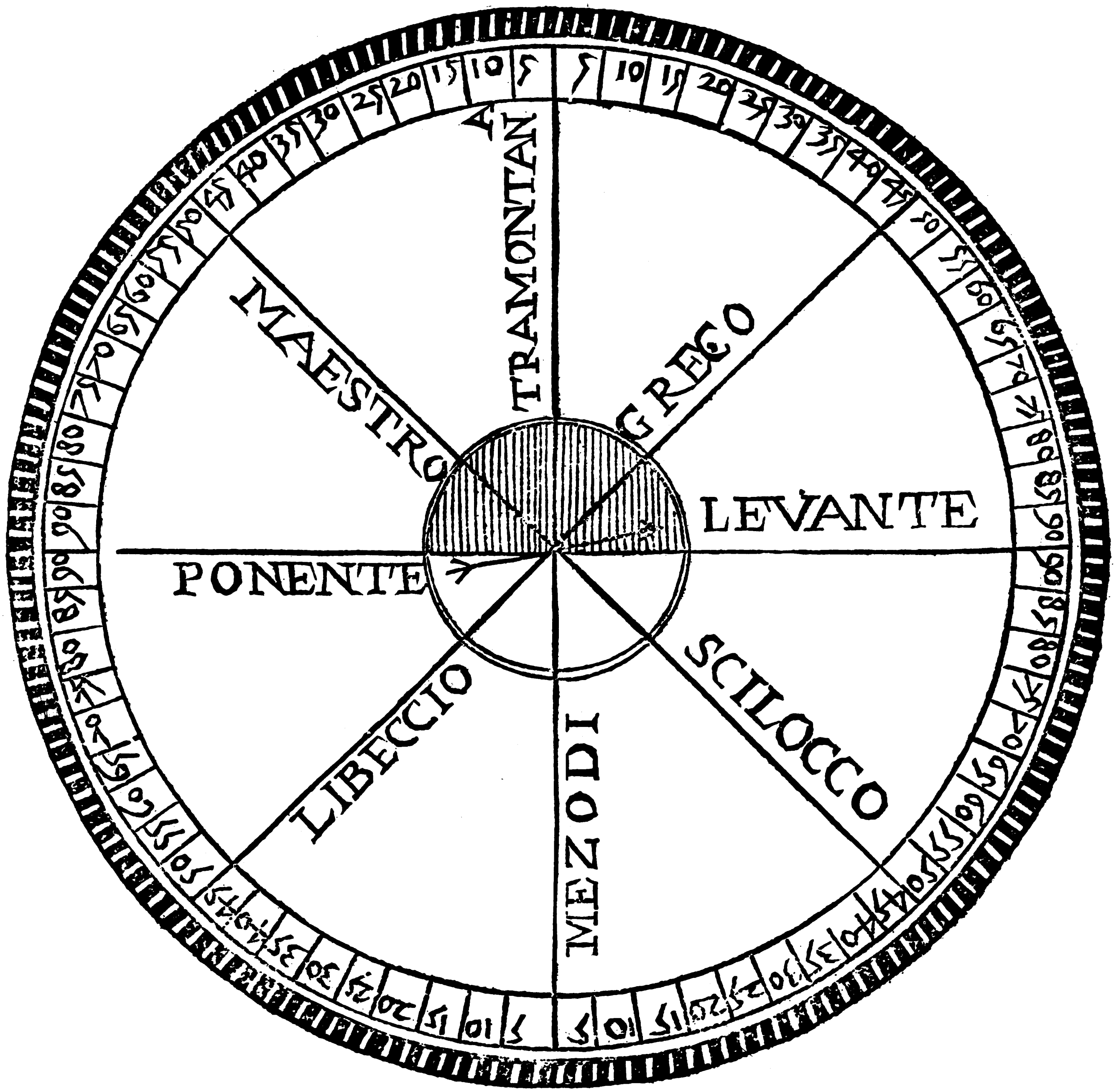

Fig. 2. Transit Dial with Magnetic Compass, from Bartoli, 1564 (courtesy: Houghton Library, Harvard University).

Situated on the Via Aemilia halfway between Cesena and Bologna, the small Emilian town of Imola was founded as a military colony (Forum Corneli) under Augustus. Leonardo's plan clearly shows the intersection of the *decumanus* and *cardo*, the basic grid plan of streets, and the four major gates of the Roman town, features which remain essentially unchanged to this day.[24] In his plan, the walls and moat surrounding Imola form an irregular rectangle beyond which stretch the open fields of the Val Padana. Within the circuit of walls, each block and the individual buildings which compose it are represented with meticulous care and accuracy.[25] Particularly remarkable is the reduction of every element of the town to a ground plan. In representing Imola, Leonardo adopted a plurality of hypothetical viewpoints, each perpendicular to the earth's surface. Buildings and

24. The modern Via Emilia corresponds to the ancient *decumanus*.

25. M. Baratta, "La pianta d'Imola di Leonardo da Vinci," *Bollettino della Società Geografica Italiana*, XII (1911), 945–967, treats the accuracy of Leonardo's plan and identifies the major buildings. J. P. Richter, *The Notebooks of Leonardo da Vinci* (New York, 1970), II, 242–243, transcribes the inscription accompanying the plan.

topographical features do not block others from sight, as in bird's-eye views, every point on the map is rendered equidistant from the observer, and the distortions of parallax are eliminated. The result is a comprehensive and accurate city image, the earliest true ichnographic plan which survives.

The circular format of the Imola plan constitutes one of its most notable features. Equally remarkable is the system of lines radiating from the center to divide the plan into pie-shaped segments. The eight major divisions are labelled with the names of the winds, associated during the Renaissance with the directions of the compass. The implications of this circular frame and accompanying grid system were not properly understood until Pedretti recognized in them the essential characteristics of an approach to topographical representation described by Raphael in his well-known letter to Pope Leo X.[26] The unusual format of the Imola plan and its preparatory drawings may thus be understood in terms of an important innovation in surveying, practiced by both Leonardo and Raphael in the opening years of the sixteenth century.[27]

The realization of a rational image of the city depended on the development of scientific instruments to record the abstract mathematical description of physical reality. Traditional methods of surveying along with the advances of late mediaeval navigators provided the essential tools to implement this new means of representing cities. The instruments employed by Leonardo in preparing his plan of Imola are particularly instructive.

Leonardo's transit consisted of a circular, dial-like surface with its circumference divided into eight parts corresponding to the eight winds, each further subdivided into eight degrees. At the center of this disk was a magnetic compass, precisely as may be seen in a woodcut from an Italian surveying treatise of 1564 (Fig. 2).[28] With the addition of a movable sight vane, also pivoted at the center, the transit was identical in all its essentials to a modern surveying instrument.[29] In setting up this instrument before surveying, magnetic north on the compass was lined up with the north wind (*tramontana*) engraved on the dial. In this way, the magnetic meridian provided a constant reference for observations taken from a variety of different points.

This transit must have been complemented by an equally exact device for measuring distances, judging by the accuracy of the Imola plan. Shortly before 1502, Leonardo designed two versions of such a measuring device based on the ungainly odometers described by Vitruvius and Alberti (Fig. 3).[30] Leonardo's instruments made use of a large wheel ten *braccia* (ca. $^{1}/_{300}$ of a mile) in circumference. Each complete revolution of the large wheel was transferred through a system of gears to a smaller cogged wheel, which advanced one cog with the passage of each mile.[31]

The essential fieldwork for a plan like that of Imola consisted of two operations: establishing the orientation (relative to magnetic north) of each facet of the irregular shape being surveyed and then measuring each facet. This process is most easily illustrated by one of Leonardo's drawings relating to the fortifications of Cesena which he prepared using the same method, for the clarity and simplicity of this sheet makes it more instructive than the complex sketches for the Imola plan (Fig. 4).[32] Figure 4 represents almost the entire circuit of the city's defenses, which, due to the contours of the site, enclose an irregular, many-faceted polygon. At each turn of the walls Leonardo moved his transit, aligned it with regard to north, and sighted along the new stretch to be plotted. The direction of the sight vane relative to north was noted, thus establishing the wall's orientation, and the new stretch was then measured. The numbers on the inside of the line of defenses in Figure 4 denote the orientation of each segment of wall in degrees of the compass, while those on the outside indicate the length of every facet in *braccia*. Once distances and orientations were recorded, the fieldwork was at an end. The surveyor could then retire to his drafting table and transfer his notations onto paper in the form of a finished and accurate plan.

While the structural format of Leonardo's Imola plan has been explained by new technical advances in surveying, other aspects may be related to traditional practices of city planning and to contemporary theories of urban design. Ori-

26. C. Pedretti, *A Chronology of Leonardo da Vinci's Architectural Studies after 1500* (Geneva, 1962), pp. 157–171. V. Golzio, *Raffaello nei documenti e nelle testimonianze dei contemporanei e nella letteratura del suo secolo* (Vatican City, 1936), pp. 78–92, reprints the complete Italian text of Raphael's letter.

27. C. Pedretti, *Studi Vinciani: documenti, analisi e inediti Leonardeschi* (Geneva, 1957), pp. 217–221, analyzes the preparatory drawings in detail.

28. G. Boffito, *Gli strumenti della scienza e la scienza degli strumenti* (Florence, 1929), pp. 71–76, discusses the history of the magnatic compass and Leonardo's use of it. Three drawings of magnetic compasses by Leonardo are in the Windsor collection: 12282r, 12496, and 12701.

29. C. Singer et al., *A History of Technology* (Oxford, 1957), III, 627, discusses Renaissance surveying instruments.

30. *Codex Atlanticus*, fol. 312v-a and fol. 1r-a. Pedretti, *Studi Vinciani*, appendix, dates fol. 312v-a (the less complex instrument) between 1497 and 1500; fol. 1r-a is dated ca. 1500.

31. Boffito, *Strumenti*, pp. 72–73, transcribes Leonardo's explanatory inscription accompanying *Codex Atlanticus*, fol. 1r-a. The use of a pedometer of this kind over irregular terrain can result in considerable discrepancies, since variations in ground level between two points will cause the pedometer's wheel to cover a greater distance than that actually separating them. Due to Imola's level situation, the degree of error attributable to this factor in Leonardo's plan is minimal.

32. Ms. *L*, fol. 9v. A second more detailed sketch relating to the same survey appears on the recto of this sheet: cf. N. De Toni, "Leonardo da Vinci e i relievi topografici di Cesana," *Studi Romagnoli*, VIII (1957), 413–424.

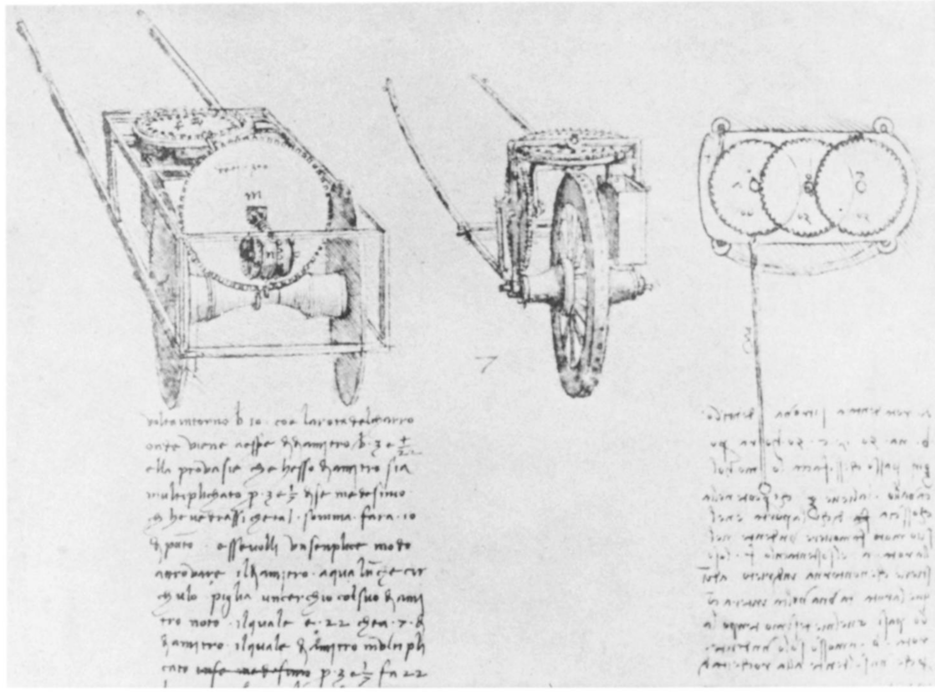

Fig. 3. Leonardo da Vinci, *Odometers*, ca. 1502, *Codex Atlanticus*, fol. 1r (after U. Hoepli, ed., *Il Codice Atlantico di Leonardo da Vinci nella Biblioteca Ambrosiana di Milano* [Milan, 1894], I, tav. I).

enting cities to the directions of the winds was recommended by Vitruvius in the first book of his *De Architectura*.[33] Vitruvius determined the directions of the winds and thus of the main city streets by a simple geometrical construction which, when interpreted literally, resulted in radial plans like Cesare Cesariano's reconstruction of the Vitruvian city in his 1521 edition of the classical treatise.[34] Since Leonardo seems to have been preparing an illustrated commentary on Vitruvius, his familiarity with this passage may be assumed.[35] A modification of the Vitruvian formula was used in planning certain Florentine military colonies (the so-called *terre murate*) late in the thirteenth century, but it would be difficult to prove that Leonardo was aware of the Vitruvian theory underlying their orthogonal grid plans.[36]

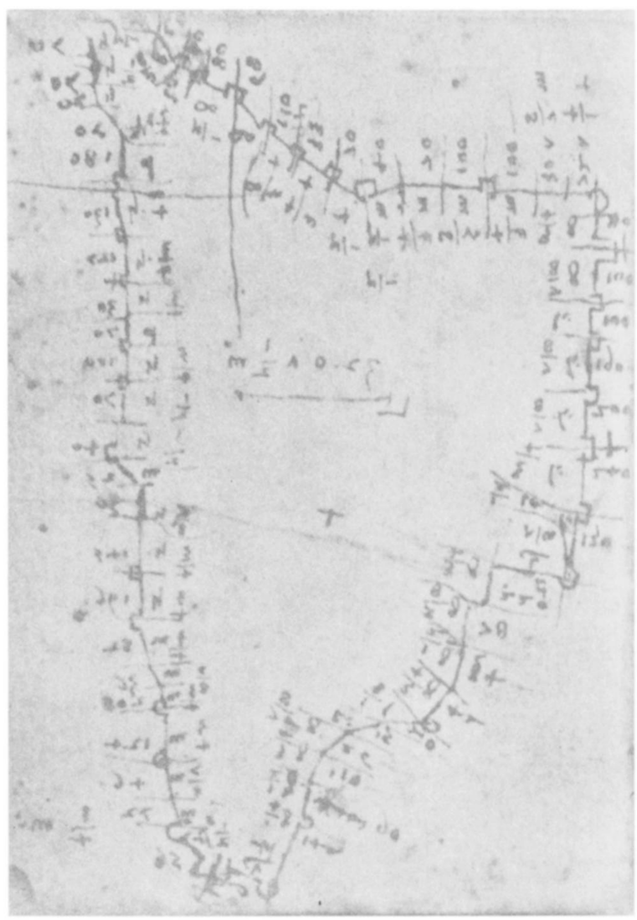

Fig. 4. Leonardo da Vinci, Survey of the City Walls, Cesena, ca. 1503, MS. *L*, fol. 9v (after C. Ravaisson-Mollien, ed., *Les manuscrits de Leónard De Vinci, Manuscrits G, L & M de la Bibliotèque de l'Institut* [Paris, 1890]).

33. Vitruvius, *De Architectura*, I, 6. Cf. Aristotle (*Politics*, VII, 10, and *De Mundo*, 394b) and Oribasius (*Medical Treatise*, IX, 20) for other classical references to the layout of cities according to the winds.

34. In classical antiquity, a Vitruvian method of determining the four cardinal points was used in laying out the orthogonal street system of many cities. Radially planned cities, however, do not appear to have existed in antiquity, and Vitruvius's model based on eight winds must be interpreted as an ideal city form. Renaissance theorists doubtless believed the formula reflected actual practice and considered their own radial city plans to be revivals of long-forgotten principles of ancient urban design.

35. Cf. Leonardo's drawing in the Accademia, Venice (no. 228), illustrating Vitruvian proportions.

36. E. Guidoni, *Arte e urbanistica in Toscana, 1000–1315* (Rome, 1970), pp. 229–234. The proportional relationships of city blocks to orthogonal (not radial) street systems in towns like Terranova, Bracciolini, and Scarperia were determined in Vitruvian fashion by the intersection of radials with a circle. For a Renaissance example of this practice, cf. P. G. Hamberg, "Vitruvius, Fra Giocondo and the City Plan of Naples," *Acta Archaeologica*, XXXVI (1965), 105–125.

On the other hand, Leonardo's documented preoccupation with the design of radial ideal city plans may well have influenced his choice of an ideal graphic format for the representation of existing cities. Indeed, a sheet in the *Codex Atlanticus* representing a regularized circular plan of Milan, drawn from a bird's-eye view of the same city below it, is particularly suggestive of the relationship between Leonardo's theories of urban design and topographical representation.[37]

Two sixteenth-century sources suggest that Leonardo was preparing a plan of Rome, but in the absence of any drawings of Roman monuments by Leonardo one can only speculate about this plan and the means by which it would have been produced.[38] In any case, Leonardo did not record his method of surveying systematically, and what he did note remained inaccessible in his notebooks. Raphael's interest and participation in preparing an ichnographic plan of Rome are well known, although due to his premature death in 1520 the plan was never completed.[39] Unpublished even in fragmented form, Raphael's results were also unavailable for study by architects, military engineers, and surveyors.[40]

Wolfgang Lotz's study of the ways in which Renaissance architectural drawings represent interior space points out Raphael's pivotal rôle in systematizing graphic methods of design.[41] Raphael's separation of ground plan, elevation, and section in his letter to Leo X was formulated in response to the problems of drawing the complex relationships of space and enclosing structure in Saint Peter's. Similarly, Raphael's definition of the orthogonal projection found practical application in the *Fabbrica* of Saint Peter's, particularly in drawings by Baldassare Peruzzi and Antonio da Sangallo the Younger.[42] The conceptual basis of this new form of architectural drawing parallels that of ichnographic city plans like Leonardo's survey of Imola.

> The new orthogonal projection compelled both artist and observer to a manifold abstraction. The building is not only represented intersected, but the illusion of seeing in is renounced and a quite new relationship between the drawn and the actual building, between ground plan and projecting wall, between interior and exterior, is established. The new method was simultaneously more expert and less clear; it could not, like the older one, represent the organic relationship of ground plan, exterior and space.[43]

Leonardo's plan of Imola is the only surviving ichnographic city plan drawn before the middle of the sixteenth century. Nonetheless, there is considerable evidence that the practical application of the surveying method involved in producing such plans, particularly to the drawing of site plans, enjoyed frequent use during the three decades following Raphael's death. In their work at Saint Peter's, Baldassare Peruzzi and Antonio da Sangallo the Younger probably became familiar with both Raphael's techniques of architectural rendering and his methods of surveying. Notations on certain of their sketches in the Uffizi reveal that both architects frequently employed a surveyor's transit in preparing accurate, measured drawings of Roman monuments.[44] Peruzzi and Sangallo also used the same surveying technique in drawing working site plans for their own designs.[45]

37. Richter, *Notebooks*, II, 233.

38. A rare printed edition of a poem describing Roman monuments, dedicated to a "prospettivo Milanese dipintore," may possibly refer to Leonardo's activities as a topographer around 1500: cf. G. Govi, "Intorno a un opuscolo rarissimo della fine del secolo XV, intitolato: 'Antiquarie prospetiche romane, composte per prospettivo milanese dipintore,'" *Atti della reale Accademia dei Lincei*, CCLXIII (1875/1876), 39–53. Pietro Aretino, in his *Ragionamento delle Corti* of 1538, describes a map of Rome prepared by a certain "gentile Intelleto" residing at the court of Leo X: cf. Golzio, *Raffaello nei documenti*, pp. 287–288, for a transcription of this passage.

39. A. Bartoli, "Raffaello archeologo e topografo di Roma antica," *Dissertazioni della pontificia accademia romana d'archeologia*, XV (1921), 11–15; and R. Lanciani, "La pianta di Roma antica e i disegni archeologici di Raffaello," *Rendiconti della reale Accademia dei Lincei*, III (1894), 791–804.

40. The plans that were published posthumously by Raphael's collaborator Marcus Fabius Calvus were not designed by Raphael nor were they prepared following the method described in his letter to Leo X: cf. M. F. Calvus, *Antiquae Urbis Romae cum Regionibus Simulachrum* (Rome, 1527), and Frutaz, *Le piante*, II, tavs. 16–19. Concerning Raphael's method, it is worth noting that Paolo Giovio made a direct comparison between Raphael's proposed plan of Rome and nautical (portolan) charts: cf. Golzio, *Raffaello nei documenti*, p. 192, for a transcription of Giovio's eulogy of Raphael in the *Elogia virorum doctorum* (Florence, 1546).

41. W. Lotz, "Das Raumbild in der Italianischen Architekturzeichnung der Renaissance," *Mitteilungen des Kunsthistorischen Instituts in Florenz*, VII (1956), 193–226.

42. H. Geymüller, *Les projects primitifs pour la basilique de Saint-Pierre de Rome* (Paris-Vienna, 1875).

43. Lotz, "Das Raumbild," pp. 223–224: "Die neue Orthogonalprojektion zwang ja Zeichner und Betrachter zu einer mehrfachen Abstraktion. Der Bau ist nicht nur durchschnitten vorzustellen, sondern es muss auch auf die Illusion des Hineinsehens in den aufgeschnittenen Bau verzichtet und eine ganz neue Relation zwischen gezeichnetem Bild und wirklichem Bau, zwischen Grundriss und aufgehender Wand, zwischen Aussen und Innen hergestellt werden. Die neue Methode war gleichzeitig fachmännischer und unanschaulicher; sie konnte nicht wie die ältere den organischen Zusammenhang von Grundriss, Aussenbau und Raumbild wiedergeben." The relationship between conventions of architectural drawings and the ichnographic plan in the Renaissance suggests a possible parallel between Gothic architectural plans and mediaeval city illustrations.

44. A. Bartoli, *I monumenti antichi di Roma nei disegni degli Uffizi di Firenze* (Rome, 1914–1922), II, tav. CXI, fig. 197, tav. CLXII, fig. 294, tav. CLXXVI, fig. 311, and tav. CLXXVII, fig. 312 (Peruzzi drawings); III, tav. CCII, fig. 342, tav. CCLXX, fig. 455, and tav. CCLXXII, fig. 457 (Sangallo drawings). Concerning Renaissance architects' use of the magnetic compass to make accurate measured drawings, cf. H. Burns, "I disegni," *Palladio, catalogo della mostra* (Venice, 1973), p. 139, fn. 17.

45. G. Zander, "Due disegni di Baldassare Peruzzi per il castello di Rocca Sinibalda," *Palladio*, V (1955), 124–134, esp. fig. 4. A. Guglielmotti, *Le fortificazioni della spiaggia romana* (Rome, 1887), X, pls. LX and LXI, reproduces two drawings of the Civitavecchia fortifications prepared by Antonio da Sangallo the Younger with the aid of a surveyor's transit. J. R. Hale, "The

The drawings by Sangallo and his assistants which relate to the new fortifications of Rome, initiated by Pope Paul III Farnese, are especially interesting because of their urban scale and associations.[46] Although the orientation of each small facet of the walls is not indicated by initials (designating the wind or compass direction) and numerals (designating degrees) as in Leonardo's sketches, there is little doubt that a transit was employed in the design process.[47] The few surviving large-scale drawings relating to the walls are essentially ichnographic in representing nearby buildings and streets by ground plans.[48] The military engineers called to Rome by Paul III applied a technique of surveying to the design of fortifications which they may well have acquired from Sangallo. One of their number, Leonardo Bufalini, recognized the implications of this method and used it in the delineation of an accurate ichnographic city plan.[49]

It seems clear that Bufalini's professional experience as a military engineer provided him with the technical means to realize his famous ichnographic plan of Rome, published in 1551.[50] However, it is difficult to agree with Guglielmotti's assessment of the plan as motivated primarily by military considerations, namely a desire to represent the city walls, both ancient and modern, in their relationship to the enclosed city.[51] To be sure, Bufalini's close study of the Roman fortifications is reflected in his plan, for the distance between each tower of the Aurelian walls is noted. Considerable attention is also lavished on the new bastions erected under Paul III. While one would expect this emphasis from a graphic artist of Bufalini's background, the plan appears primarily motivated by antiquarian interests: the major architectural complexes of ancient Rome are represented not in their ruined state, but in reconstructed ground plan (Fig. 5). Bufalini's ichnographic plan functions first as a visual aid in studying Rome's ancient topography, the subject of numerous archaeological treatises published around mid-century.[52]

End of Florentine Liberty: The Fortezza da Basso," *Florentine Studies*, N. Rubinstein, ed. (Evanston, 1968), fig. 9, reproduces a drawing by Antonio da Sangallo the Younger (Uffizi 773a) recording angles and distances to peripheral points made from a central observation point. David Friedman informs me that other drawings in this series were prepared by the same surveying method.

46. G. Giovannoni, *Antonio da Sangallo il giovane* (Rome, 1959), pp. 357–367; Guglielmotti, *Fortificazioni*, V, 307–385; and especially E. Rocchi, *Le piante ichnografiche e prospettiche di Roma nel secolo XVI con la riproduzione degli studi originali autografi di Antonio da Sangallo il giovane per le fortificazioni di Roma* (Roux-Viarengo, Turin-Rome, 1902).

47. Most of Sangallo's drawings relating to the fortifications of Rome, collected in the Uffizi, appear to be rough sketches made on the site without the aid of any instruments. At least one sheet (Rocchi, *Piante*, tav. XLV) suggests the use of a transit: a detailed drawing of the walls on both sides of the Porta Pertusa on which the directions of the winds, inscribed within a circle, are prominently displayed.

48. Rocchi, *Piante*, tavs. LV and LVI, which are attributed to Bartolomeo de Rocchi da Brianza and represent a large area as far north of the Vatican and the Porta del Popolo as the Ponte Milvio.

49. A document of 1548 records Bufalini's participation in the construction of bastions protecting the Vatican: cf. R. Lanciani, *Storia degli scavi di Roma* (Rome, 1903), II, 104-105. Bufalini's association with the military engineers gathered by Paul III is also recorded by Francesco de Marchi, *Dell'architettura militare libri tre* (Brescia, 1599), p. 78.

50. F. Ehrle, *Roma al tempo di Giulio III, la pianta di Roma di Leonardo Bufalini del 1551* (Rome, 1911).

51. Guglielmotti, *Fortificazioni*, V, 310.

52. Bartolomeo Marliano (1544), Lucio Fauno (1548), Pirro Ligorio (1553), Andrea Palladio (1554), Onofrio Panvinio (1558), and others. Bufalini's plan also represents the densely built-up quarters of the Renaissance city in accurate detail. However, the fact that the "modern city" occupies less

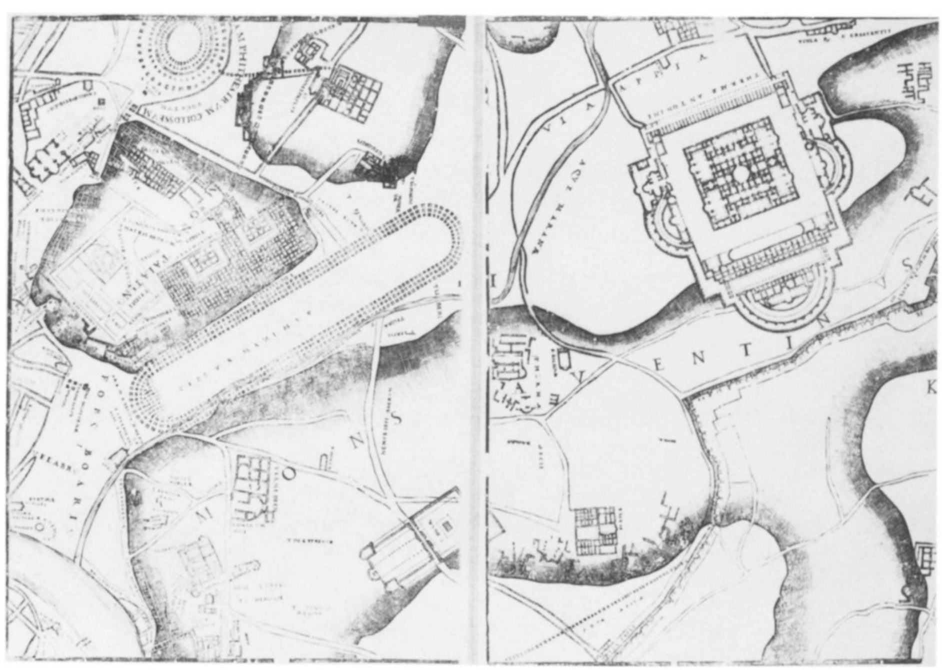

Fig. 5. Leonardo Bufalini, Plan of Rome (detail), 1551 (after Ehrle).

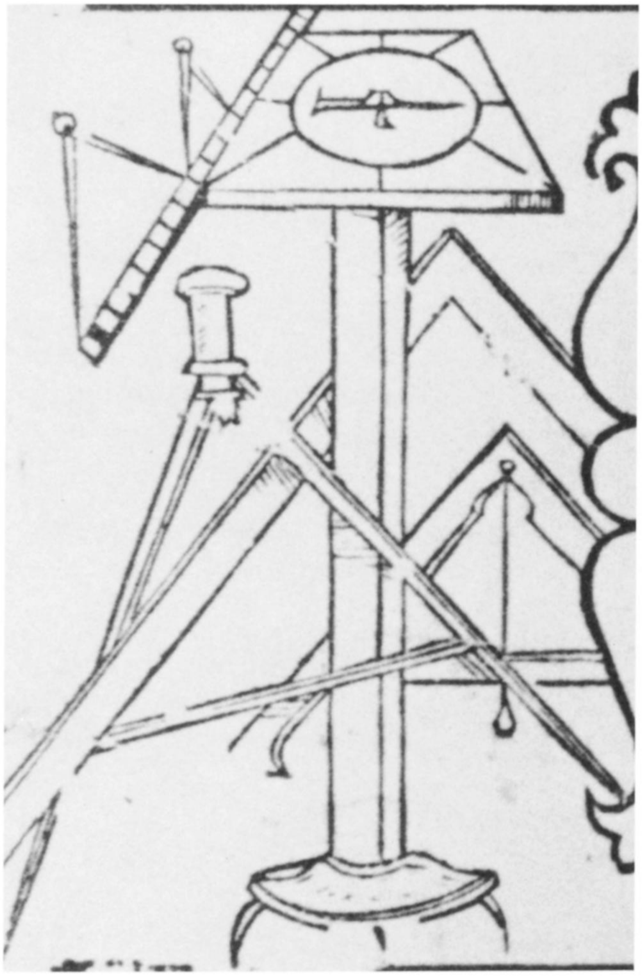

Fig. 6. Leonardo Bufalini's Surveying Instruments, 1551 (after Ehrle).

The accuracy of Bufalini's ichnographic plan was far in advance of the perspective plans which were repeatedly issued in the course of the sixteenth century. Indeed, Giambattista Nolli, whose magnificent 1748 plan of Rome established a new standard of excellence in the graphic representation of urban topography, thought so highly of Bufalini's effort that he reissued it in a revised and reduced format.[53] Lest there be any doubt that Bufalini's accuracy derived from the same methods of surveying employed by Leonardo, the topographer's own transit and other instruments appear as decorative elements along the lower margin of his plan (Fig. 6).[54] The lack of any of Bufalini's field sketches precludes a detailed analysis of his method, but it is certain that he followed much the same steps that Raphael outlined and Leonardo employed at the beginning of the century. Bufalini's plan does differ from Leonardo's plan of Imola in one important respect, however: a degree of topographical relief is introduced by means of cross-hatching to delineate the major hills of Rome, which anticipates the use of contour lines.

Bufalini's hatching is not systematically applied, nor does it correspond to a fixed scale of vertical measurement. On the other hand, Bufalini is not merely attempting to indicate shadows cast by the sun. He is concerned directly with the formulation of new graphic conventions to indicate changes in ground level, an important step in the development of city plans. By means of contour lines the greatest disadvantage of ichnographic city plans—that as *plans*, pure and simple, they provide no sense of relative elevation—could be remedied. Indeed, with the refined and systematic use of contour lines it is possible to cut a section through any portion of a city and thereby reveal the actual slopes of hills and valleys. Contour lines thus permit a degree of accuracy much greater than the illusion of topographical relief conveyed by perspective plans and bird's-eye views. While the potential accuracy pointed to in Bufalini's plan was never reached in the Renaissance, the effective combination of spatial measurability with topographical relief was a continual preoccupation of sixteenth-century topographers.

While there appear to be no surviving ichnographic plans of Florence which date from before the middle of the sixteenth century, a number of references leave little doubt that at least two plans of that city were prepared using a magnetic compass.[55] Giorgio Vasari's biography of Nicolò Tribolo relates that Tribolo, with the assistance of an instrument maker named Benvenuto di Lorenzo della Volpaia, made a plan of Florence during the siege of 1530.[56] It is clear from Vasari's description that this plan was made with the aid of a compass and was circular in format, for it represented all the Florentine territory within a radius of one mile from the dome of the cathedral, the plan's center.[57] Concerning his own bird's-eye view of Florence under siege in the Palazzo della Signoria, Vasari wrote that he made many observations from the surrounding hills, using a compass to control the relative orientation of the drawings which he made at each point.[58]

than a tenth of the area represented on the plan, which includes the entire circuit of the ancient walls and all the Roman monuments they enclose, further demonstrates its antiquarian emphasis.

53. Frutaz, *Piante*, III, tav. 420.

54. In addition to Bufalini's transit (which has a compass mounted at its center) there appears to be a set of geometer's squares, presumably used in determining distances.

55. G. Boffito and A. Mori, *Piante e vedute di Firenze* (Florence, 1926).

56. G. Vasari, *Le vite de' più eccellenti pittori, scultori ed architettori* (Florence, 1881), VI, 61–63. Cf. also Boffito and Mori, *Piante*, pp. xxi–xxii, 30–31.

57. Like Tribolo's plan of Florence, Giovanni Battista Peloro's lost survey of Siena was motivated by military concerns: cf. Vasari, *Le vite* (Florence, 1879), IV, 608.

58. Vasari, *Opere*, ed. G. Milanesi (Florence, 1882), VIII, 174–175, for Vasari's description of this painting in the *Ragionamenti*.

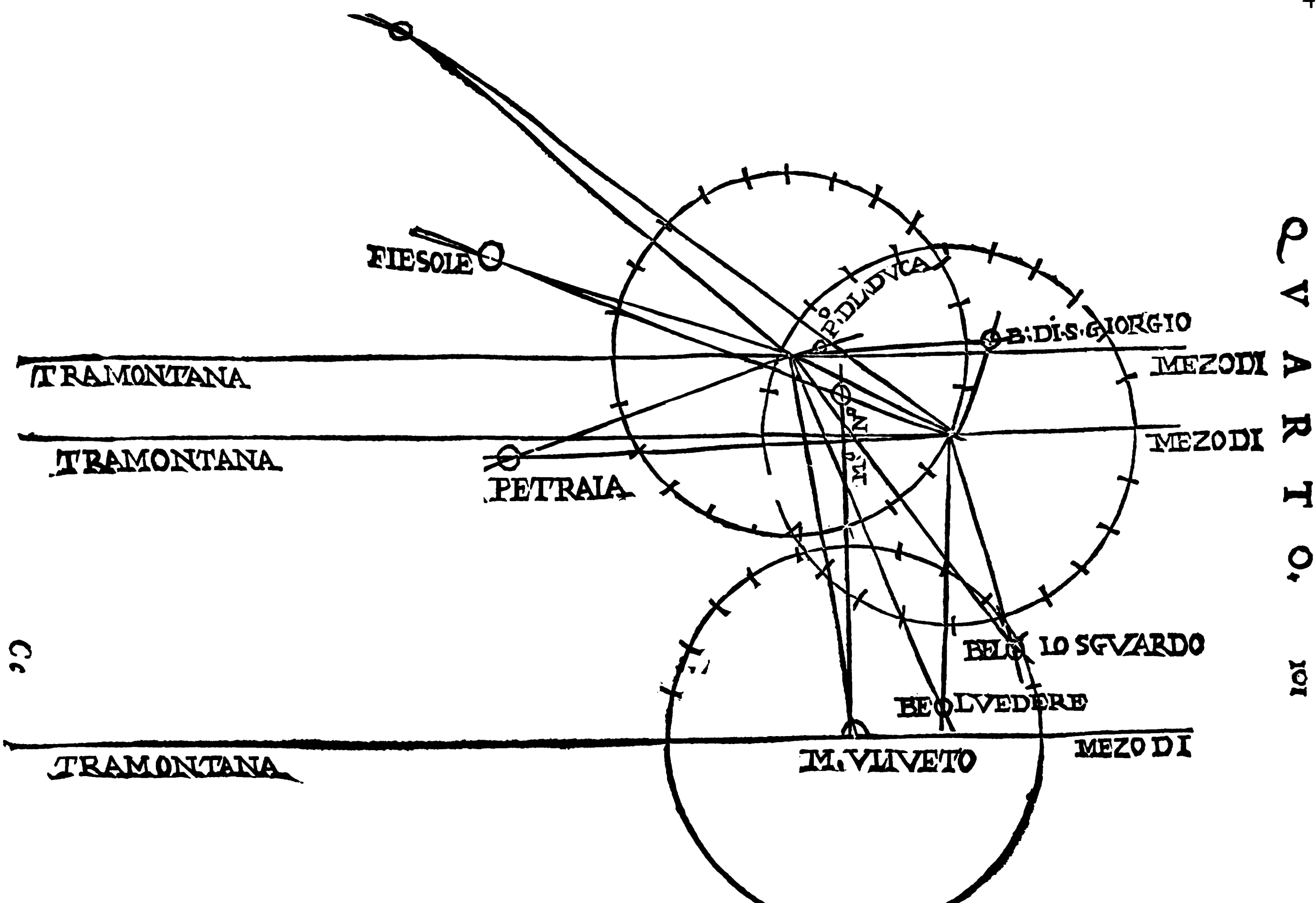

Fig. 7. An Abbreviated Survey of Florence, from Bartoli, 1564 (courtesy: Houghton Library, Harvard University).

Preliminary research in the literature of surveying reveals little to suggest that the theory underlying ichnographic city plans was well known before the middle of the sixteenth century. Nonetheless, the possible influence of technical treatises on city plans must not be disregarded, particularly in the light of one early theoretical breakthrough and its close relationship to books on surveying published shortly after mid-century. In 1533 the young Belgian cartographer Gemma Frisius published a short treatise on triangulation entitled *Libellus de locorum describendorum ratione*.[59] In this treatise, Frisius explained how a grid or network of intersecting pointings could be drawn on paper which form the basis of a map of the country surveyed. His method of triangulation, using angles of position, is virtually identical to that described by Alberti in the *Ludi Matematici*.[60] However, the highly technical nature of these early treatises, combined with the fact that Gemma Frisius was concerned primarily with surveying large regions, seems to have kept artists from applying these principles to the depiction of cities.

Two publications of a more practical nature, Nicolò Tartaglia's *La nuova scientia* (1554)[61] and Cosimo Bartoli's *Del modo di misurare* (1564)[62] contain illustrated step-by-step procedures for constructing a surveying transit and using it in the field. Both authors rely on the principles of triangulation, though Bartoli presents the more advanced application of these principles to the survey of cities.[63] Using Florence as

59. A. Pogo, "Gemma Frisius, his method of determining differences of longitude by transporting timepieces (1530), and his treatise on triangulation (1533)," *Isis*, XXII (1935), 469–507, for a facsimile edition of the *Libellus*. The most complete treatment of Gemma Frisius remains F. van Ortroy's *Bio-bibliographie de Gemma Frisius fondateur de l'ecole belge de geógraphie, de son fils Corneille et de ses neveaux les Ansenius* (Brussels, 1920).

60. Gadol, *L. B. Alberti*, p. 178.

61. N. Tartaglia, *La nuova scientia, quesiti et inventioni diverse* (Brescia, 1554), esp. Bk. V: "... sopra el mettere, over tuore rettamente in disegno con il bossolo, li site, paesi, e finalmente le piante della citta, con el modo da sapere fabricare el detto bossolo. . . ."

62. C. Bartoli, *Del modo di misurare* (Venice, 1564), esp. Bk. IV (pp. 92–98). It should be noted that Bartoli edited L. B. Alberti's *Ludi Matematici* and was therefore well acquainted with Alberti's surveying techniques. In the introduction to his treatise, Bartoli specifically acknowledges his debt to Alberti and Gemma Frisius.

63. L. Vagnetti, "Cosimo Bartoli e la teoria mensoria nel secolo XVI," *Quaderni della Facoltà di Architettura, Università di Genova*, IV (1970), 109–164.

Fig. 8. Bonifaz Wohlmuet, Plan of Vienna, 1547 (after Eisler).

an example, he explains how to take sightings from three important points (Giotto's campanile, the Palazzo Pitti, and Monte Oliveto), and thereby locate all the major monuments of the city (Fig. 7). Bartoli's woodcut shows the intersection of a few of these bearings, and clearly illustrates the importance of the meridian pointing north (*tramontana*) as a constant reference of orientation. Thus, after fifty years, the method of producing ichnographic plans applied by Leonardo da Vinci and Raphael at the beginning of the century was finally given widespread publication in these and other treatises.[64] At the same time, a number of developments on the other side of the Alps closely paralleled Bufalini's ichnographic plan of Rome and the publications of Tartaglia and Bartoli, and it is to them that we now turn our attention.

Long before the middle of the sixteenth century, German astronomers and cartographers had reacted to the stimulus of the work of their Italian colleagues. A century earlier, the astronomical research of Regiomontanus (Johannes Müller, 1436–1437) led him to a consideration first of Ptolemy's *Almagest* and then of the *Geography*. Regiomontanus was also well acquainted with the activities of his Italian contemporaries, such as the astronomical observations of Toscanelli and Alberti.[65] Throughout the fifteenth century, Germany continued to be a center of mathematical and astronomical research. The practical application of this research to surveying appears in a number of publications dating from the first half of the sixteenth century.[66] As the century progressed the German cartographers, especially at Nürnberg, challenged the primacy of the Italians.[67] Italian cartography declined from preeminence under the strain of various adverse economic factors, notably a falling off of overseas trade due to the discovery of Atlantic trade routes less favorable to her Mediterranean situation. Along with the other branches of science in Italy, cartography also suffered from the atmosphere of intolerance which prevailed during the Counter Reformation. In northern Europe, on the other hand, a spirit of rational inquiry based on mathematics coincided with the shift of trade to North Atlantic ports. It was natural that the growing German interest in cartography

64. A. Foullon, *Descrittione et uso dell'holometro* (Venice, 1564); S. Belli, *Libro di misurar con la vista . . . con il quadrato geometrico, e con altri stromenti* (Venice, 1566); and M. G. Cataneo, *Dell'arte di misurare, libri due* (Brescia, 1583).

65. G. Uzielli, *La vita e i tempi di Paolo dal Pozzo Toscanelli: ricerche e studi* (Rome, 1894), pp. 284–285.

66. A. Dürer, *Unterweisung der Messung mit dem Zirkel und dem Richtscheit* (Nürnberg, 1538); and H. J. Kobel, *Von Feldmessen, geometrischen Messen und Absehen* (Frankfurt, 1531), are especially worthy of note.

67. L. Gallois, *Les géographes allemands de la Renaissance* (Paris, 1890). Jacopo de Barbari, who visited Nürnberg in 1505 after completing his monumental perspective view of Venice, may have stimulated German artists and topographers to attempt new means of representing cities. A study of landscape painting in Italy and the North during this period might help document changing attitudes toward the depiction of cities.

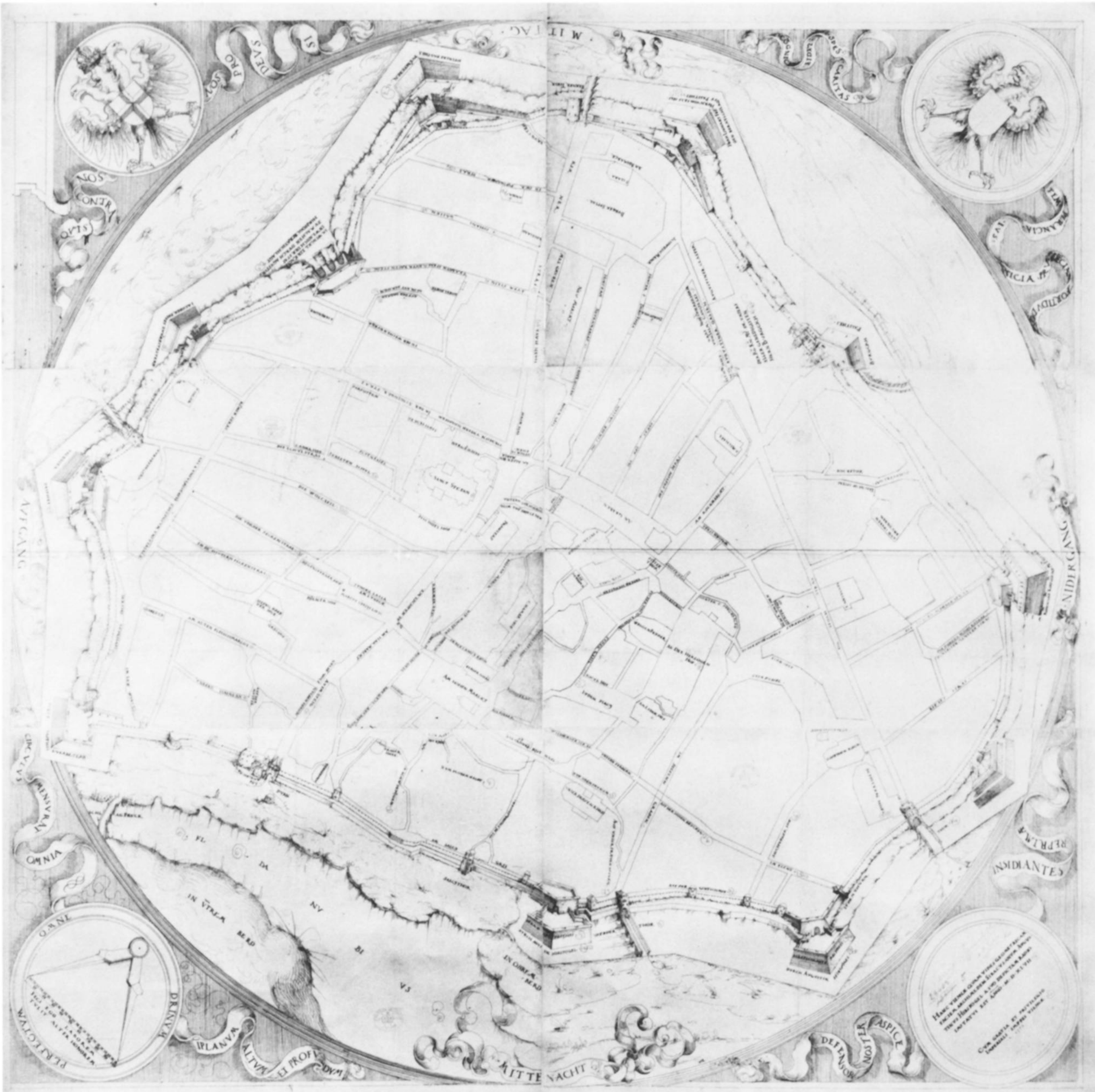

Fig. 9. Augustin Hirschvogel, Circular Plan of Vienna, 1552 (courtesy: Map Room, British Museum Library).

was reflected in a new approach to the representation of city plans as well.

At the same time that Leonardo Bufalini was preparing his plan of Rome, Augustin Hirschvogel, a mathematician and cartographer from Nürnberg (1503–1553), and Bonifaz Wohlmuet, master mason of Saint Stephen's cathedral in Vienna, were both commissioned to make accurate plans of Vienna.[68] In 1547 Wohlmuet was paid for a large rectangular ichnographic plan of the city (painted in oil on paper mounted on wood), which is now in the Historical Museum of Vienna (Fig. 8).[69] Hirschvogel's circular plan of Vienna, etched on six rectangular plates in 1547, was not issued until 1552 when he was granted permission to print it (Fig. 9).[70] In

68. Concerning Hirschvogel's life and artistic activity, cf. K. Schwarz, *Augustin Hirschvogel. Ein deutscher Meister der Renaissance* (Berlin, 1917); and *sub voce* "Hirschvogel, Augustin," *Thieme Beckers Allgemeines Lexikon der Bildenden Künstler*, XVII (Leipzig, 1924), 138–140.

69. M. Eisler, ed., *Historischer Atlas des Wiener Statbildes* (Vienna, 1919), tav. IV.

70. S. Wellish, "Die Wiener Stadtpläne zur seit der ersten Türkenbelagerung," *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereines*, L (1898), 537–541, 552–555, and 562–565; and Eisler, *Historischer Atlas*, tav. III. Because of Hirschvogel's reputation as a cartographer and his manuscript treatise on surveying, Wohlmuet is generally considered to have plagiarized Hirschvogel's technical expertise in making his own plan. Such a

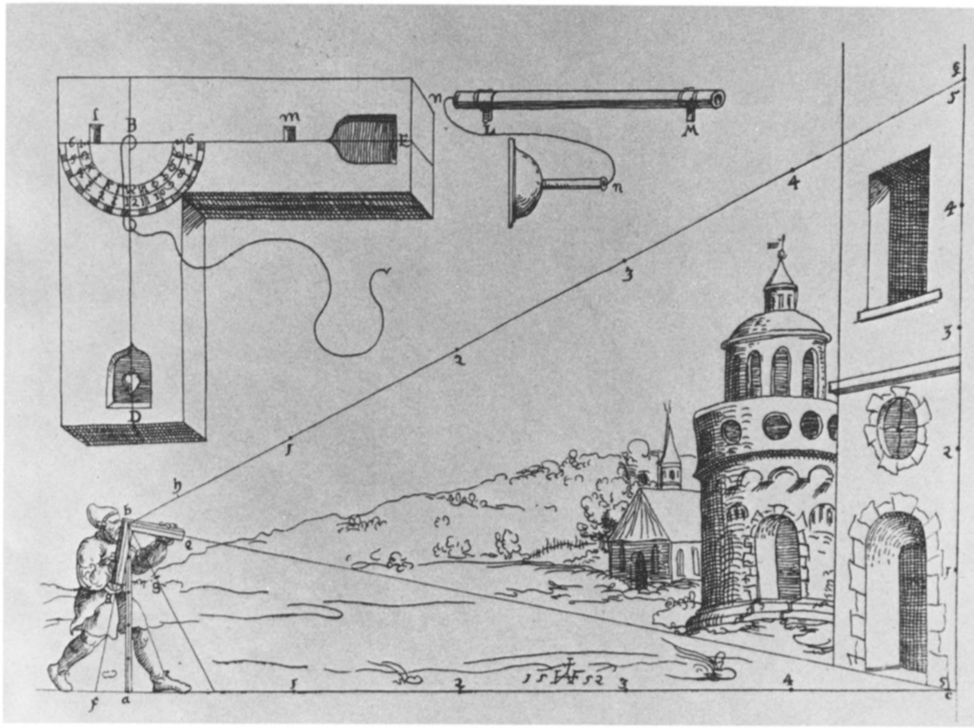

Fig. 10. Hirschvogel's Surveying Transit, 1552 (after Camesina).

1549 Hirschvogel drew an enlarged version of his Vienna plan on the surface of a large round table more than ten feet in diameter. Three years later, he wrote an extensive description of his surveying instruments and their proper use, placing particular emphasis on the means utilized in preparing his plan of Vienna.[71] The plans of Wohlmuet and Hirschvogel, considered together with the latter's surveying manual of 1552, permit a detailed analysis of an especially significant step in the historical development of the ichnographic plan.

As recorded in his surveying manual, Hirschvogel's first step in preparing his plan of Vienna was to measure every facet of the city walls, precisely as Leonardo had done in surveying Cesena.[72] Next he placed six circular disks, which he called *Mulstaine*, at important points within the city. Each disk was divided into ninety degrees and oriented with respect to north. From each point he made sightings toward the other five *Mulstaine* as well as toward certain key points along the walls. In this operation Hirschvogel employed a sophisticated transit of his own design, on which were mounted a compass and a narrow tube through which the sightings were made (Fig. 10). He used a variation of this transit to determine the height of monuments and their distance from the observation point by triangulation.[73] Corresponding to each *Mulstain* was a paper disk, and as each sighting was made, the angle recorded on the transit was drawn on the disk. Then the distances from each *Mulstain* to the other points were measured and recorded.[74] Sightings and measurements completed, Hirschvogel could pinpoint the location of each *Mulstain* on the finished plan by drawing to scale the angles and distances recorded in the field, following much the same procedure used by Leonardo half a century before. With these key points fixed, every building in the city could be located by the simple repetition of this process. Hirschvogel's plan of Vienna represents the major streets of the city and its principal civic monuments, but the individual buildings within the city blocks are not shown. In contrast, Wohlmuet's plan is much more detailed and appears to represent every house in the city—a difference of degree, but not of surveying methods.

view finds support in the inscription within one of the roundels of the 1552 edition of Hirschvogel's Vienna plan: *Feci ego laborum, tulit alter honorem.* The fact remains, however, that Wohlmuet's plan of Vienna is considerably more accurate than that of Hirschvogel, suggesting that technical as well as chronological primacy may actually belong to Wohlmuet. Archival research and further technical analysis may eventually clarify this point. Until then it seems best to accept the traditional primacy attributed to Hirschvogel in spite of the visual evidence, but with definite reservations.

71. A. Camesina, *Plan der Stadt Wien vom Jahre 1547, vermessen und erlaütert durch Augustin Hirschvogel von Nürnberg* (Vienna, 1863)—a facsimile edition. Cf. W. H. Ryff, *Zu rechtem Verstandt der Lehr Vitruvij* (Nürnberg, 1547), Bk. III, for contemporary surveying instruments, including a circular transit with a magnetic compass.

72. Camesina, *Plan der Stadt Wien*, pp. 15–22 (pages not numbered; citations numbered from the first facsimile sheet).

73. Wellish, "Die Wiener Stadtpläne," pp. 540 and 543, considers Hirschvogel's use of triangulation.

74. Camesina, *Plan der Stadt Wien*, pp. 23–35, lists distances and angles measured from each *Mulstain*.

Both Hirschvogel and Wohlmuet emphasized the walls of Vienna in their plans. Unlike any other portion of Hirschvogel's ichnographic plan, the entire circuit of Vienna's defenses is represented in perspective. Wohlmuet did not draw attention to the city walls in this way, but he did indicate the distances between the bastions[75] and projected the lines of enfilading fire that could be directed from them. This emphasis on the city walls is certainly a reflection of Vienna's position as the eastern bastion of Christendom, under the continual threat of Turkish attack. As recently as 1529 Vienna's walls had withstood a protracted siege,[76] and after that she strengthened her defenses, building bastions to withstand the concentrated fire of the new, more mobile artillery that was changing warfare and military architecture throughout Europe.[77] By 1547 the fortifications were complete, and Vienna's justifiable pride in her strong military position is clearly expressed by the plans of Wohlmuet and Hirschvogel.

The circular format of Hirschvogel's plan probably relates to the long tradition of circular city plans which we have traced back to the eighth century. Indeed, Einhart's description of the Carolingian plan of Rome inscribed on a round table may have influenced Hirschvogel's large Vienna plan. A fifteenth-century iconic plan of Vienna depicts the city as circular, and is worthy of comparison with contemporary iconic plans of Rome.[78] In Nicolaus Meldeman's large print of 1530, representing Vienna under siege, the city is also given a circular form.[79] It should be added that only two years before the first Turkish attack on Vienna, Albrecht Dürer published a treatise on fortifications which included designs for a number of ideal Christian defenses, among them a circular plan.[80] Hirschvogel's plan of Vienna thus unites the traditional circular format of city views with the most advanced techniques of precise topographical representation. Wohlmuet's rectangular plan, in contrast, represents the pure application of advanced surveying methods without any allusion to the artistic tradition of city plans with which Hirschvogel was familiar.

Later in the sixteenth century, the instruments and surveying techniques essential to the preparation of ichnographic city plans were made available to an increasingly large circle of northern artists and topographers through a number of publications.[81] One of the most interesting of these books is Daniel Speckle's treatise on fortifications, published in 1589. Speckle's method of surveying, which permitted a ground plan of "any building, city or castle" to be drawn, is closely related to Hirschvogel's procedure.[82] Unlike Hirschvogel's confusing description of his own inventions, however, Speckle's chapter on surveying is a model of clarity and verbal economy. Speckle's straightforward and step-by-step exposition of surveying techniques parallels those of Tartaglia and Bartoli earlier in the century. It permitted any interested artist or architect to learn and apply them easily. Due to the publication of such books, by the end of the sixteenth century the preparation of ichnographic city plans was no longer a mysterious art, but a clearly defined scientific operation.

Johannes Praetorius (1537–1616) is generally credited with the invention of the modern surveyor's transit, or *mensula praetoriana* as it has been called after him.[83] Considering what we know of Hirschvogel's transit, not to mention Leonardo's and Bufalini's, it seems clear that Praetorius merely standardized the component elements of instruments already in use. It is true that the earliest surviving instruments of advanced design seem to date from around the turn of the century.[84] The proliferation of surveying instruments at this time may be attributed, at least in part, to their application in warfare, especially in determining trajectories and distances to targets.[85] The design and precision of surveying instruments began to improve rapidly toward the end of the sixteenth century, and continued to do so throughout the seventeenth century, but did not substantially alter the plans made with them. The German mapmaker Paul Pfinzing's

75. In this respect it is similar to Bufalini's plan of Rome.

76. E. Tomek, "Die Bedeutung Wiens als Vorort der Christenheit in den Turkenkriegen," *Wien, sein Boden und seine Geschichte* (Vienna, 1924), pp. 268–282.

77. H. de la Croix, "Military Architecture and the Radial City Plan in Sixteenth-Century Italy," *Art Bulletin*, XLII (1960), 263–290. Hirschvogel and Wohlmuet both participated in building Vienna's new fortifications.

78. A. Kutzlnigg, "Das Befestungs- und Kriegswesen," *Geschichte der Stadt Wien*, II (1900), 284–351, tav. XIV, for a facsimile reproduction of this plan of ca. 1438–1455, now in the Historisches Museum der Stadt Wien.

79. Eisler, *Historischer Atlas*, tav. II. The earliest engraved plans of towns frequently appeared in connection with military events: cf. E. Pognon, "Les plus anciens plans de villes gravés et les evenements militaires (1552–1567)," *Imago Mundi*, XXII (1968), 3–19.

80. A. Dürer, *Etliche Underricht von Befestigung der Stett, Schloss und Flecken* (Nürnberg, 1527).

81. A few of the more important titles are: J. Chauvet, *Instruction et usage de cosmometre* (Paris, 1585); P. Danfrie, *Déclaration de l'usage du graphomètre* (Paris, 1597); O. Finaeus, *De re et praxi geometrica libri tres, figuris et demonstrationibus illustrati, ubi di quadrato geometrico* (Paris, 1556); and D. Speckle, *Architectura von Vestungen* (Strassburg, 1589).

82. Speckle, *Architectura*, part I, chaps. 1 and 2.

83. D. Schwenter, *Geometria practica nova* (Nürnberg, 1641), tractatus III; and *Allgemeine Deutsche Biographie* (Berlin, 1970), XXVI, 519–520.

84. G. von Bezold, "Wissenschaftliche Instruments im germanischen Museum: Die Mensula Praetoriana und das Winkelinstrument des Andreas Albrecht," *Mitteilungen aus dem Germanischen Nationalmuseum* (1897), pp. 3–14, and other installments which follow. Augustin Hirschvogel's surveying instruments, illustrated in his treatise and preserved in the Historisches Museum der Stadt Wien, are a notable exception to this observation.

85. Ryff, *Zu rechtem Verstandt der Lehr Vitruvij*, Bk. II, demonstrates the effectiveness of surveying instruments in directing artillery fire in numerous illustrations. As early as 1450, Alberti observed that the surveying disk was useful in range finding: cf. Bonucci, *Opere*, IV, 429–430.

1594 plan of Nürnberg, for example, resulted from essentially the same surveying methods as Hirschvogel's and Wohlmuet's.[86] As in Hirschvogel's plan of Vienna, the city walls are represented in perspective, while the rest of the city is drawn in ground plan.

Although the theoretical basis of the ichnographic city plan and the instruments which made it possible had been perfected by the end of the sixteenth century, this kind of plan was drawn only rarely until the middle of the eighteenth century.[87] The frequent presence of at least some element of relief in sixteenth-century ichnographic plans reflects the fact that most city plans were still bird's-eye views. In much the same way today, tourist maps often combine a measure of an ichnographic plan's accuracy, particularly in the representation of the street system, with the city's principal attractions magnified in isometric projection. Bird's-eye city views could be drawn with relative ease, while an accurate survey preparatory to an ichnographic plan required a significant degree of technical expertise, as well as considerably more time, effort, and financial investment.[88] Another explanation for the relative scarcity of ichnographic plans involves the public for which city plans were made, which as late as the eighteenth century were still primarily composed of pilgrims, as well as a more diffuse educated public of armchair travellers. The immediacy and versatility of bird's-eye views served the needs of this public much better than the highly specialized image of ichnographic plans. Thus, the more general appeal of bird's-eye views as souvenirs and tourist maps insured their continuing popularity, while ichnographic plans were only occasionally made for planners, civic administrators, and armies.[89]

The immediate significance of the ichnographic city plan is closely bound up with the changing form and structure of cities in the Renaissance. A more accurate means of representing cities was perfected at the very time that military technology and urban design were being revolutionized by the introduction of mobile artillery. The development of improved instruments and techniques of surveying and the graphic abstraction of cities which they permitted also coincided with renewed interest in the city as an ideal architectural form. Once the various organs of civic life began to be structured according to overriding principles of defense, communication, and visual coordination, a new means of representing cities which met specific functional requirements came to be formulated. Certain Renaissance topographers began to view cities with detachment, from without rather than within. They sought a coherent framework for depicting cities into which they could insert the smallest details while retaining an image of the city in its totality. The ichnographic plan provided an accurate delineation of a city's general layout, as well as its component elements—buildings, streets, and squares.

The ability to visualize the world in abstract terms was essential to the development of the exact sciences, and constitutes one of the most remarkable achievements of the Renaissance. The most advanced Renaissance illustrations, such as the anatomical and botanical studies of Leonardo or the architectural drawings of Sangallo and Peruzzi, were achieved primarily through the formulation of new conventions of graphic representation. The ichnographic plan not only constituted a new conceptual approach to the depiction of cities, but also stimulated the development of scientific instruments designed to bridge the gap between the direct observation of the environment and its subsequent graphic abstraction. It is rare that one can point to such a clear example of the sympathetic interaction of scientific technology and artistic endeavor.

86. E. Gagel and F. Schnelbögl, *Pfinzing, Der Kartograph der Reichstadt Nürnberg, 1554–99* (Hersbruck, 1957), cat. no. 24. Pfinzing's treatise on map-making entitled *Methodus Geometrica* (MS version 1590, published 1598) illustrates his instruments and explains their use.

87. Only one true iconographic plan of Rome was drawn in the course of the seventeenth century: Matteo Gregorio de Rossi's of 1668. Cf. Frutaz, *Le piante*, III, tav. 350. The ichnographic plan was not popular in Venice either: cf. J. Schulz, *The Printed Plans and Panoramic Views of Venice (1486–1797)* (Venice, 1970).

88. Melchoir Lorichs's 1559 view of Constantinople illustrates this point. In the foreground Lorichs has depicted himself, elegantly dressed, in the act of drawing the city spread out before him. The artist is assisted by a Turk who holds an inkwell and unrolls a long scroll on which the finished view is being directly recorded. Cf. E. Oberhummer, *Konstantinopel unter Sultan Suleiman dem Grossen* (Munich, 1902), tav. XI.

89. An accurate ichnographic plan of Ferrara was drawn in 1597, however the engraved plan by Matteo Florimi Formis printed in the following year is a perspective view: cf. B. Zevi, *Biagio Rossetti, architetto ferrese* (Turin, 1960), figs. 191 and 192. Nolli's ichnographic plan of Rome (1748) was prompted in part by the reorganization of the city into new administrative quarters, the boundaries of which he precisely indicated.