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Michael Wolfe*

Urban Design Traditions and Innovations in France, 1200-1600**

Abstract. This essay will examine urban design in terms of the changing modalities between the « built » and the « viewed » in France from 1200 to 1600. The Italian Renaissance ideal of *disegno*, while important, did not displace enduring medieval traditions of urban design and innovation. Geometric theory and practice, long in separate realms, gradually merged after 1500 to create a new visual culture and directions of urban design brought about by improved projective mathematics, its use by surveyors and cartographers, and advances in etching and printing methods. Urban design and maps reflected new ideological values and ambitions embodied in the new bastioned trace and the rationalizing urbanism of the monarchical state. Innovative medieval craft practices combined with new technologies and evermore robust, bureaucratic forms of public governance to reshape urban life in the modern forms recognizable today.

Résumé. Traditions et innovations dans le dessin d'urbanisme en France, 1200-1600. Cet essai analyse les dessins et plans d'urbanisme du point de vue des changements de modalités survenus entre « construction » et « vision » dans la France des années 1200 à 1600. Bien qu'important, l'idéal du *disegno* de la Renaissance italienne ne remplaça pas les traditions durables du Moyen Âge en termes de plans d'urbanisme et d'innovation. Longtemps domaines séparés, théorie et pratique de la géométrie se mêlèrent peu à peu pour créer une nouvelle culture visuelle. L'amélioration de la projection mathématique, son utilisation par les arpenteurs et cartographes, ainsi que les avancées des méthodes de gravure et d'impression ouvrirent de nouvelles directions. Les cartes et plans urbains reflétaient de nouvelles valeurs et ambitions idéologiques incarnées par la nouvelle ligne des bastions et rationalisant l'urbanisme de l'état monarchique. Les pratiques artisanales innovantes du Moyen Âge se combinèrent aux nouvelles technologies et à des formes de gouvernement public de plus en plus bureaucratiques pour remodeler la vie urbaine, lui donnant les formes modernes qu'on reconnaît aujourd'hui.

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** I wish to express my gratitude to Professor Robert Carvais for his questions and commentary that forced me to rethink – hopefully successfully – portions of this essay.

« Give me a map: then let me see how much
Is left for me to conquer all the world... »¹

The history of urban design in the West has long identified the Italian Renaissance ideal of *disegno* as decisive in creating new ways to envision and thus reshape the world. While influential, this ideal mattered less in France than enduring medieval traditions of urban design and innovation. These traditions proved highly adaptive and necessary for the momentous transformation after 1500 in visual culture and urban design brought about by improved projective mathematics, its use by surveyors and cartographers, and advances in etching and printing methods. Chorographic descriptions of inhabited space gave way to a cartographic gaze bent on apprehension and possession. This ambition powerfully informed the new bastioned trace and rationalizing urbanism of the monarchical state. The changing modalities between the « built » and the « viewed » in France from 1200 to 1600 reflected enduring adaptability of indigenous design practices and traditions as well as the transformations brought by the development of early modern engineering and the state.

How individuals perceived and conceptualized urban space can be discerned in the built environment and its visual representation. Since ancient times, cityscapes offered idealized views of the world using symbolic spatial schemata that transformed natural space into inhabited place. These symbolic schemata took geometric form and displayed elements drawn from myth and metaphysics. Thus the symbol for city in ancient Mesopotamia was a simple « O », though the circle also in time signified the bounded cosmos, notions of infinity, and nothingness. Hellenistic mathematics, especially Euclidean geometry, further developed these abstractions of place referents. As a result, visual representations of place often juxtaposed the terrestrial to the cosmic, the imaginary to the real, and the sacred to the profane². These visual traditions changed after 1400 when cartography began to construe geographic space in mathematical ratios expressed geometrically and viewed from a single perspective, an approach that also became normative in architectural and urban design. Place images – be they towns or vast territories – also served powerful military ambitions, political agendas, and commercial interests. Creating and reading these images relied on a collaborative process of reduction, choice, abstraction, and final transformation; all this required, in turn, the ordering of distance, direction, scale and shape as well as meanings inscribed by the various literary, artistic, and scientific cultures of the time. Mapping also encouraged action, such as travel and war; they also connected, in a psychic sense, the map viewer with the mapped place in terms of its social and natural settings. Maps and

1. Christopher MARLOWE, *Tamburlaine*, Part II (v.iii.123-124).

2. PATRICIOS, N. N., 1973.

cityscapes thus combined mathematics, history, text, and aesthetics together to offer new ways to conceptualize and act upon space.

Western traditions of founding towns go back to ancient Rome when building a town began through inscribing upon the land the foundational surveying lines. These first drawn schematics of towns in dirt remain in the literal meanings of the words « geography » (writing on earth) and « geometry » (measuring the earth). Other media, such as stone, parchment, paper, engraving plates, or, more recent times, aerial and satellite photography, eventually displaced raw earth. From the initial intersection of the two axial lines – the *cardo* and *decumanus* – evolved the familiar orthogonal grid pattern of the urban interior that emphasized connective regularity. It was as much a religious endeavor as a practical one, undertaken by priests – the first engineers – who performed the necessary auspices and took the vital measurements. The sacrosanct boundary along the urban edge, known as the *pomerium*, further demarcated the settled place from its wilder surroundings. The orientation and aspect of buildings and open places arrayed along streets converted the town into a performance space that mediated, indeed at time intentionally choreographed, the flow and interaction of the town's inhabitants³. These basic characteristics of Western urbanism remain dominant to this day.

1. Theory and Practice in Medieval Geometry

Mathematics continued to shape design practices and modes of representing secular and religious place in medieval France⁴. Much like the ancient Egyptians and Pythagoreans, the English monk Matthew of Paris, for example, envisioned towns as circular forms that connoted geometric perfection and cosmological harmony⁵. Medieval treatises on geometry and surveying further betrayed their clerical origins by focusing on pictorial representations of Creation, the mathematical relationships found in the Trinity, and philosophical arguments about ontology using geometry. Geometry, of course, formed one of the seven classical liberal arts, defined by Isidore of Seville as the art of measuring the world; medieval mason handbooks later echoed this *topos* when discussing the tools used to shape the proportions of earthly materials for use in construction. Legends circulated in these texts about its biblical origins as part of the *prima theologia*. St. Thomas Aquinas described God as the *artifex principalis* of all Creation, whose use of the divine *scientia* of geometry – represented visually by Thierry of Chartres, for example – could only be apperceived in the architect's mind, not any

3. MACDONALD, W. L., 1986; VASALY, A., 1993.

4. HYDE, J. K., 1966.

5. LEWIS, S., 1987; LAVEDAN, P., 1954.

earthly form. Yet in medieval sermons, the sin of arrogance often became embodied in the figure of the brilliant master builder Daedalus, *doctor lathmorum*, *sapiens architectus*, *vir peritissimus*, as related by, for example, the Dominican preacher and writer, Nicolas de Biard, in 1261⁶. Whether master craftsmen in the building trades conceived of their buildings as reflections of the harmonic structure of the universe or as moral parables remain an open question, however.

The transmission of Hellenistic mathematics to medieval Europe is a vexed question. Latin translations of some of Euclid's *Elements* can be found in Boethius's *Consolation of Philosophy* and Pseudo-Boethius, for examples⁷. Fragments of Euclidean geometry could also be found in works of Roman encyclopedists and *agrimensores*, as well as Latin translations of Arabic works on science or directly from Greek manuscripts from Byzantium⁸. Some medieval monasteries apparently maintained these gromatic and Euclidean traditions⁹. The first Latin scholar to demonstrate any real understanding of Euclidean geometry was Gerbert of Rheims in the tenth century, though the *Geometria Gerberti* was likely not written by him¹⁰. These selected portions of Euclid's *Elements*, excerpts from Roman surveyor manuals, and bits of ancient metaphysics in early medieval geometrical texts reflected eclecticism, not an integration of theory and praxis.

Improved understanding of applied geometry first became evident in Hugh of St. Victor's *Practica geometriae*. Composed around 1120, this text encapsulated a late Roman and medieval computational tradition before it changed as a result of the influx of Greek and Arab science¹¹. Primarily a teaching manual, it showed that surveying practices remained little changed since Antiquity. In the first two parts, Hugh of St. Victor demonstrated useful techniques employing astrolabes and other surveying devices. The first, *altimetria*, dealt with heights and depths, while the second, *planimetry*, treated the properties of planes. The last, *cosmimetry*, took up measuring the terrestrial and heavenly spheres. Subsequent treatises on practical geometry invariably retained this tripartite schema. This part of the manual was mainly a scholastic exercise rather than a direct application of surveying techniques, however. In this respect, the manual echoes Hugh of St. Victor's broader interests in the relationship between technology and theology found in his better-known work, the *Didascalicon*.

6. MORTET, V. & DESCHAMPS, 1913, p. 290-291.

7. ZAITSEV, E. A., 1999; TANNERY, P., 1922; MORTET, V., 1904.

8. CLAGETT, M., 1953; CLAGETT, M., 1966.

9. ULLMAN, B. L., 1964.

10. BUBNOV, N. (ed.), 1899, p. 48-97, 310-313.

11. ST. VICTOR, H. (OF), 1991.

After the twelfth century, the theoretical approach to geometry in the universities and the more practical one in grammar schools and craft guilds parted ways even further. Leonardo Fibonacci's *Practica Geometriae* (1220), despite its title, reflects this separation as it treated primarily theoretical, not applied problems¹². On the other side, craft manuals evinced little understanding about the Euclidean foundations of classical Greek geometry. While the teaching of geometry as part of the *quadrivium* formed a key component of medieval *curriculum*s, masons did not gain their knowledge of it through formal schooling. For practical applications, constructive geometry only became based on Euclid later in the Renaissance, though that approach dominated in the scholastic geometry treatises. Two parallel systems, indeed cultures, of geometry thus existed until the sixteenth century.

Craft handbooks in Latin and the vernacular reveal how medieval craftsmen used practical geometry to deal with problems in Gothic design, such as pinnacles, gables, and window mullions. Practical geometry became further distinguished from theoretical explorations of Euclid in the schools by its use of instruments manually manipulated to measure proportions and then to relate them together in a design ensemble. After 1300, a further distinction set surveyors, who simply measured, apart from craftsmen, who applied measurements to remaking materials. Such specialization likely arose due to the increasing scale of constructing cathedrals and turreted stone enceintes. Surveyors and masons learned their skills through mastering the oral traditions of the craft as apprentices; writing down such knowledge before the age of print was quite exceptional. This explains the unique importance of the Picard artist Villard de Honnecourt's thirteenth-century sketchbook¹³. Villard's familiarity with the building trades did not mean he was mason. Even so, his sketchbook provides a privileged glimpse into the cognitive foundations of the applied geometry used by medieval masons¹⁴. The few notebooks, like Villard's, that survive reflect pedagogy more than construction techniques. In his preface, Villard emphasized that masons learn how to draw properly using geometry in order to make their work easier through these « techniques of forms » (*li force des traits*)¹⁵. His ideas fell in line with medieval *practica geometriae* that did not simply apply Euclid, but rather blended ancient methods of mensuration with craft

12. RIVOLO, M.T. & SIMI, A., 1998.

13. The portfolio consists of thirty-three parchment leaves and approximately 250 drawings, and it is preserved in Paris in the Bibliothèque nationale, ms. Fr. 19093. BARNES, J. & CARL, F., 1982.

14. SHELBY, L., 1972.

15. « Car en cest livre puet o(n) trover grant conseil de le grant force de maconerie (et) des engiens de carpenterie, (et) si troveres le force de le portraiture, les traits, ensi come li ars de iometrie le (com)ma(n)d(e) (et) ensaigne ». HANLOSER, H. R. (ed.), 1935, p. 11 and « Ci comence li force des trias de portraiture si con li ars de iometrie les ensaigne, por legierem(en)t ouvrir ». *Ibid*, p. 91. BRANNER, R., 1963.

training that substituted numerical examples based on metaphysically-informed ratios in lieu of actual demonstrations; they also emphasized convenient and manageable approximation over canonical precision using physical templates as well as compass and straightedge.

Figure 1. *Plan and Elevation of one of the Towers of the West Facade of the former Cathedral of Notre-Dame at Laon (Aisne), France**

*Villard de Honnecourt. Drawing (leadpoint, drypoint, and ink on parchment), made between *ca.* 1220 and *ca.* 1240 (Paris, Bibliothèque nationale de France, MS Fr 19093, Fols. 9v and 10r; photo: Bibliothèque nationale de France).

Later manuals approached problems in surveying and metrology more systematically than Villard. A late thirteenth-century French manual known as the *Pratike de geometrie*, written in the Picard dialect like Villard's sketchbook, for example, tackled basic problems such as calculating the area of a field, the circumference of a rounded city wall, and the volume of a barrel.¹⁶ The *Geometria deutsch* and *Büchlein* by the fifteenth-century German mason, Matthias Roriczer, showed the thought-processes of medieval masons by laying out the steps to construct a heptagon and octagon using a compass and straightedge¹⁷. He also treated how to determine the circumference of a circle using the practical method found in Gerard of

16. HENRY, C., 1882.

17. SHELBY, L., 1977.

Cremona's twelfth-century Latin translation of an original Arab treatise on the subject – a text that circulated widely in medieval European learned circles and contained elements of Archimedean mechanics¹⁸. None of these works, however, evidences any real understanding of actually how to use more sophisticated surveying instruments, such as the astrolabe or surveyor's quadrant, or recently introduced Arab advances in trigonometry, all of which casts doubt on their practical utility for practitioners¹⁹. The actual knowledge of geometry necessary for effective surveying thus did not lie in these manuscript manuals but instead remained in the craft's oral traditions of apprentice training²⁰. The attempt by Jordanus Nemorarius to formulate in his *Opusculum de ponderositate* a theoretical statics to account for structural problems and solutions found in Gothic architecture was thoroughly exceptional²¹.

These limits in craft manuals make the building they constructed the best sources of information about masons' understanding of mathematics. Well-established indigenous traditions of using geometric principles in construction existed throughout in Europe after 1100. Gothic cathedrals, in particular, served as sites of experimental practice. The simple templates based on scaled geometric ratios that masons and carpenters used come closest to revealing their theoretical grasp of geometry's underlying principles. The study of the simple templates based on scaled geometric ratios that masons and carpenters used to design these structures offers a place to begin. In its medieval form, the template served both an accounting function and as a design formula that integrated theory and practice. They also provided a sort of graphic functionalism that literally strove to create an image of heaven on earth, often in the form of the rose window of cathedrals²². Templates encapsulated all the essential information about design, while experience taught builders about the behavior of materials. Templates also had the advantage of portability, especially important for itinerant masons and carpenters who traveled from work site to work site²³.

More complex design schemas from the Romanesque to the late Gothic periods reflected the dynamic innovation of medieval craftsmen. Surviving medieval templates and, of course, the final built forms all demonstrate the use of a rational modular geometry to achieve a wide variety

18. CLAGETT, M., 1964.

19. CURTIZ, M., 1896; SHELBY, L., 1961 and 1965.

20. SHELBY, L., 1970.

21. Jordanus' treatise was finally edited and published by Nicolò Tartaglia in Venice in 1565 and served to further fuel the revival of Archimedean mechanics in the sixteenth century, culminating in the celebrated work of Galileo.

22. JAMES, J., 1982.

23. It was a dynamic, evolving set of practices, not the *frozen* one suggested by G. BACHELARD, 1964.

of forms and expressions²⁴. Medieval constructive geometry relied on techniques for deriving ratios and proportion through the division of squares and circles with compasses, all which then became materially manifested on the template. As in planning medieval new towns known as *bastides*, discussed below, the use of the square also formed the basis of the *ad quadratum* or *square schematism* approach typical in Romanesque architecture. Especially popular were the use of the *diagon* (right rectangle) and *auron* (golden-section rectangle) derived from Platonic theories of forms, which carried further Christian symbolic significance²⁵.

Figure 2. *Scaled Ratios in the Applied Geometry of the Triangle*

By the High Gothic period, these techniques had become so codified that builders increasingly departed from their norms using controlled irregularities or a forcible bending of established design procedures²⁶. This approach skewing the canonical practice of repetitively rotating the square 45° had its advantages and drawbacks as clerical patrons sought allegory in church design while craftsmen gave priority to practical building problems. Even so, the geometry informing the designs of medieval masons reveals symbolic thinking at work in terms of ratios and proportions. In fact, most building projects indicate that clerical patrons and craftsmen collaborated to create designs at once functional and analogical. Symbolic significance could also be coded into the design and coordinated in the realization of its construction²⁷. At once practical and symbolic, the basic rules of the *ad quadratum* method provided a highly flexible, economical, and effective

24. SHELBY, L., 1971; JAMES, J., 1989.

25. CONANT, K., 1968 and 1959.

26. BUCHER, F., 1972.

27. DAVIS, M. T., & NEAGLEY, L. E., 2000.

means of constructing large edifices that eventually spread across most of Western Europe by 1400 as a new international style.

A new departure in medieval design schema came with the use of the equilateral triangle and its derivations *ad triangulum*, along side the rotating square approach. A famous debate even occurred in fourteenth-century Milan over these two approaches when it came to deciding upon the design of the new *duomo*'s cross-section, a debate that touched on both practical matters of *ars* and deeper considerations of the *scientia* of geometry²⁸. The equilateral triangular schema became employed in fortification design at a variety of sites across Europe, including Poitiers, though only after 1400 did builders begin to realize the full potential of this approach²⁹. It also later served as the basis for designing the new bastioned *trace italienne* of the sixteenth century, though in point of fact its origins lay in the craft techniques of late medieval builders.

The projection method based on segments of circles as segment units, especially used for complex vault design, became the third important schematic approach in medieval architecture and the one that most fuelled the eventual development of projective geometry. The geometry of spherical solids, or stereometry, was the art of measuring and computing the cubical contents of bodies and figures, an essential skill for architects and stone masons. Scholarly treatises, such as Hugh of St. Victor's, first raised these issues when discussing cosmimetry, but not much beyond the rather elementary problem of calculating the earth's circumference³⁰. The earliest craft handbook to address stereometric problems is attributed to the so-called Magister 2 in the 1230 sketchbook of Villard. It used a fairly simple squaring technique consisting of uniformly excising triangular or curved wedges in order to realize the desired shape³¹. Villard's treatment clearly pointed the way to the more complex treatment of stereometry taken up briefly in Robertus Angelicus's *Tractatus quadrantis*, written sometime before 1276 in Montpellier³². Medieval masons solved stereometrical problems by the practical manipulation of geometrical forms in templates using tools and instruments to work materials, usually stone, wood, and glass³³. Indeed, some of the resulting geometric designs for towers, vaults,

28. PATETTA, L., 1987, especially on the arguments in favor of the triangular approach put forward by the mathematician Gabriele Stornaloco. See also Simi and Toti Rigatelli, 1993, for an examination of four manuscripts dedicated exclusively to practical geometry from Bologna, Siena and Florence, and five manuscripts containing a chapter on practical geometry from the same cities.

29. ACKERMAN, J. M., 1949.

30. BARON, R. (ed.), 1966, p. 17.

31. FRANKL, P., 1960, p. 35-48 and 48-54.

32. TANNERY, P., (ed.), 1897.

33. TURNBULL, D., 1993.

Figure 3. *Rose Window, Strasbourg Cathedral*

Figure 4. *Plan for Sforzinda, Antonio Averlino « Filarete »*

tracery, and profiles closely resemble the polygonal forms found in fifteenth-century ideal city design plans of Antonio Averlino, also known as Filarete, and celebrated bastioned enceintes of the sixteenth century. Continuities in medieval design thus persisted into the early modern period.

2. Applied Geometry and Medieval Urban Design Practices to 1550

Craft traditions of applied geometry found in architecture carried over into medieval urban design, especially evident in the new towns in southern France known as *bastides*. In fact, the underlying geometry of *bastides* derived from their ceremonial foundation with the *fixatio pali*, which consisted of planting a large pole on the spot, destined to become the market place. Affixed atop these poles were banners displaying the coats-of-arms of the king or great lord who sponsored the new town as laid out in the founding charter known as the *paréage*. The lord's agents then supervised the surveyors, known varyingly as *lotisseurs* or *arpenteurs*, as they traced the *bastide's* initial layout from this centrally fixed point to ensure conformity with the terms of the *paréage*³⁴. A more detailed process known as *perticatio* then ensued to delineate the building parcels (*local* or *ayral*), garden plots (*ort*, *casal*, or *casau*), and the surrounding arable for cereal cultivation and vineyards (*arpans*), separating each zone with ditches and earthen mounds. The measurements had to be done very precisely because they determined a person's tax rates. Beginning as a geometrical trace, a *bastide's* design became literally etched into the soil which then supported its growth.

While planned, *bastides* did not subscribe to any set, ideal scheme but rather responded to pragmatic considerations of site topography, the tension between orthogonal and radial features, and the placement of the parish church³⁵. Some *bastides*, such as the ones found in Quercy, became characterized by a single main avenue bisected by streets, much like rungs on a ladder. Another type found in Aquitaine usually consisted of eight residential blocks formed by longitudinal avenues bisected by streets to form an orthogonal grid. An additional type was an elongated yet still orthogonal grid laid out along a principal avenue flanked by two side streets. The use of right rectangular and golden-section rectangular schemas found in *ad quadratum* Romanesque church design occurred as well in *bastides*, such as Sainte-Foy-la-Grande and Grenade-sur-Garonne. Another type of *bastide* form found in Gascony possessed a central square formed by two sets of intersecting perpendicular avenues off of which went side streets to

34. These surveying techniques continued the practices established in Antiquity. See CAMPBELL, B., 2000.

35. LEBLOND, H., 1987; PULOL, F., 1991.

form the residential blocks³⁶. Some *bastides*, as seen below in the case of Montpazier, used the *ad triangulum* method to realize an orthogonal layout through the application of Pythagorean triangles or triples. The sides of such right-angled triangles were whole numbers, usually units of 3:4:5. The surveyors used a simple cord with twelve knots, all equally spaced in intervals called a *coudée* (« elbow-length »), to lay out the triangles. Each *coudée* was approximately 2.5 feet in length, which made the cord some thirty feet long. Using the Pythagorean Theorem ($a^2 + b^2 = c^2$), the surveyors could then easily extrapolate the larger overall dimensions of the planned *bastide* before they even walked onto the site. Besides its simplicity, this application of practical geometry to planning *bastides* also offered flexibility, for it could be readily adapted to fit just about any terrain.

Figure 5. *Bastide of Montpazier*

Source: <http://bastidess.free.fr/traceOrthogonal.htm>

The establishment of *bastides* continued fairly vigorously until the mid-fourteenth century, when the staggering population decline caused by the Black Death removed a powerful incentive to build new towns. With upwards of two hundred new towns founded in greater Occitania after 1200, the skills and mental outlook used to build these planned communities were quite ubiquitous, as was also the case in northern France, where

36. An extensive literature exists on individual *bastides*; however, for synthetic, comparative studies, consult F. DIVORNE, 1985; NÈGRE, V. & PETIT, M.-L., 1995; GARRIC, J.-P. & alii, 1992; ASSASSIN, S., 1994.

urban expansion and renewal projects proliferated through the Hundred Years War³⁷. Here, too, master masons and carpenters applied geometry to rework the existing physical fabric to accommodate huge new cathedrals and turreted enceintes³⁸.

An excellent source to trace their techniques is municipal account books. These records tend to be spotty until the fourteenth century, where after they assumed more regular and continuous form. Construction records from Amiens, a frontier town in Picardy, for example, again reveal the continuities in indigenous building and design practice into the sixteenth century. Admittedly, these books mainly tabulated the payments for goods and services rendered to the city, so recovering the practices of the builders must be inferred. Several different kinds of accounts existed. Up to 1500, masters of works (*maistres des ouvrages*) kept track of such payments. Master masons mainly served in these positions, though occasionally a master carpenter filled it. Masters of works oversaw contracts and accounts; among the skilled artisans they hired were visual artists (*peintres*)³⁹. They provided all this information to municipal tax receivers (*receveurs*) drawn from the urban elites who dominated municipal government. The *receveurs* actually kept the books to balance expenditures with available revenues. After 1500, a separate official, the comptroller (*contrerolleur*) representing the interests of the royal provincial governor, audited the accounts, a copy of which went to Paris for inspection. This new central oversight showed the rising influence of royal officials in directing local public works projects. While urban design practices remained essentially medieval, the changing composition of these records reflected the increasing bureaucratization of municipal government under the tutelage of the monarchy.

Judging from the built results, masons obviously used practical geometry to plan and execute the projects beyond cathedrals, such as fortifications. Master masons stood out as the unquestioned resident experts on urban design and construction until the mid-sixteenth century when Italian engineers begin to show up in the record. Yet the arrival of these supposed experts from the south, as discussed further below, complemented rather than supplanted these local experts. In 1565 in a ceremony akin to founding a *bastide* four hundred years earlier, municipal and royal officials assembled to watch the master mason, Jean Bullant, *dresser l'ouvrage* of a new bastion. He used stakes and rope to outline the royal state's imminent imprint upon this portion of urban space⁴⁰. Masters of works used these same techniques, sometimes with special chains made of one-inch links,

37. SALAMAGNE, A., 2001.

38. WOLFE, M., 1995. On Italy, see D. FRIEDMAN, 1988.

39. Municipal artists form the focus of F. BARON, 1969.

40. B.M. Amiens EE 270. See also M. WOLFE, 1998.

to verify the proper completion of contracted work, measuring it all out to the last *pouce* (inch) of each *toise*. Excavation projects occasionally offered calculations of volume, though not always⁴¹. Traditional practical mathematics comes through elsewhere in these records. Visits to nearby forests to select timber, quarries to choose stone, and even brick works required precise calculations to procure no more than was necessary. Cutting stone still utilized templates to ensure delivery of properly dressed stone⁴². While new techniques of practical geometry could be found in contemporary publications, the actual methods used to take measurements had changed little since the twelfth century.

This continuity thus confirms Pamela Smith's contention that from 1450 to 1650 the exploration and experience of nature in Europe was dominated by « artisanal epistemology », the conviction that practice, not theory, was the primary mode of engagement with the world⁴³. These artisans, who worked out of a longer medieval tradition, created what Smith calls a « vernacular science of matter », an immensely powerful and broad reaching engagement with nature rooted in the conviction that « knowledge is active and knowing is doing ». Rational modular geometry was part of this science and formed an essential point of continuity for design schemata – both in terms of conceptualization and representation – all the while new developments in projective mathematics and cartography got underway during the Renaissance. While construction practices still used applied mathematics in medieval ways, the novelty rested in the greater level of accountability to governmental authority and the emergence of new forms of pictorial representation. An embryonic royal fortification service certainly existed by 1500 composed of local experts, municipal officials, and an ascending hierarchy of royal officers and agents stretching from Amiens and other such towns to the Louvre⁴⁴.

41. B.M. Amiens CC 113 (1528), fol. 12v for an example of such a « *forme d'amendement* » contract for work « *lequel n'a esté compté ne mesuré* » in the original contract.

42. B.M. Amiens DD 568 (1573), fol. 273v: « ... *le grez preparez par les briseurs estans aux champs, pour estre employez à la massonnerie dudict bastion* ». See CC 681 (1584-1585) for mention of a template to guide the cutting of stone for the bastion de Longueville.

43. SMITH, P. H., 2004, p. 59. Smith largely concentrates on Flemish and German areas, though the culture she analyzes certainly existed in other areas of Europe. The new Baconian science of the seventeenth century, she argues, in effect appropriated the artisanal approach even as it gradually excised the artisans from the picture. Yet the artisans never became fully shunted aside, even though new forms and institutions of « knowledge legitimation » developed from roughly 1650 to 1850 to frame the new « Science of Nature ». The conclusion of this essay likewise confirms this finding.

44. On the development of the royal fortification service, see the first two chapters of H. VÉRIN, 1993, and all of D. BUISSET, 2000. Buisseret's account begins in the mid-sixteenth century, as opposed to the approach in this essay emphasizing the essential medieval continuities still at work at that time.

3. Renaissance Ways of Seeing Space and Place

Medieval constructive geometry and the new projective geometry were far from antithetical. Indeed, the eventual shift after 1500 to projective geometry – and with it, linear perspective in the visual arts – occurred because of craftsmen’s long familiarity with rudimentary Euclidean geometry. The first key change among master craftsmen was the eventual decision after 1450 to use drawings to express – and presumably solve – design problems. Indeed, novel forms of cognitive mapping joined new theories with older practices to spur new ways to build and depict cities and the wider world⁴⁵.

Before 1400, visual representations of townscapes tended to draw on generic, interchangeable conventions. Chorographic views distinguished a town’s identity by emphasizing the profile (0° or head on) defined by its walls, gates, and principal buildings. Like Villard’s mapping of human faces, chorographic views sought to reveal a place’s particular intrinsic character. They also underscored a town’s enclosed nature, its walls a barrier against a hostile world. Manuscript copyists and illuminators lacked the requisite mathematical expertise (namely, trigonometry) and knowledge of surveying methods to go beyond this external view. They also likely never even set eyes on most of the places they depicted, for their emblematic views situated a town in a cosmological rather than geographic setting. This metaphysical aspect informed the techniques of constructive geometry and came through most clearly in medieval *mappae mundi* centered on the axes of Rome, Jerusalem, and Paradise⁴⁶.

New ways to visualize urban space in France began not with the master masons, but rather the men referred to as *peintres* (painters). Since the late Middle Ages, these artists performed an eclectic mix of services for towns, from banners and elaborate stagecraft for public festivals and ceremonial entries to depictions of patron saints and coats-of-arms on walls, towers, and gates. They also created tableaux of written public prohibitions and exhortations to citizens to do their duty. They even prepared images for public display of criminals executed either in person or in effigy⁴⁷. Municipal artists in Amiens, and presumably other urban areas in France, did not need to await the arrival of linear perspective techniques from Italy to create such images. To be effective, painting in public places required optimal sight lines and proper plotting. These tasks, in turn, required the use of some basic geometry and further suggest that the artist had to conceive of the actual townscape as a kind of canvas on which to leave his mark.

45. See D. TURNBULL, 2000, on these different visual cultures.

46. This is a vast subject. See D. WOODWARD, 1985; SMITH, C. T. & HAWTHORNE, J. G., 1974; CHEVALIER, B., 1981, who argues that people in Middle Ages identified towns by the aspect of their ramparts and walls; LILLEY, K. D., 2000; FRUGONI, C., 1991.

47. B.M. Amiens CC 221 (1585), fol. 88v, for example.

It was then only a short step to devising a design plan for discrete features of the townscape. A celebrated example is the collection of exquisite images in the *Armorial* of Guillaume Revel. Revel was a herald from Auvergne who served Charles VII. Its 400 drawings, most left unfinished, depicted the places with the coats-of-arms of lords in Auvergne and Forez under the king's suzerainty⁴⁸. Cadastral surveys from the early nineteenth century attest to the rough accuracy of Revel's townscapes, situating notable public buildings, plazas and residential areas in a proper ensemble. Amateurish, but still effective, techniques of draftsmanship and color lent these portraits a sense of perspective within the confines of the walls and in relation with the hinterland. While Revel evidently did not use practical mathematics to execute his views, he clearly demonstrates a rudimentary understanding of geometrical space.

Figure 6. View of Montrond-les-Bains, from Guillaume de Revel's *Armorial*

Another well-known example is Jacques Le Lieur's *Livre des fontaines* for Rouen. Composed in the 1520s, it also reflects the shift from chorographic profiles to visual depictions of a town's interior. Le Lieur was city counselor who prepared a study plan to bring fresh water to Rouen. His images of the town and plans for aqueducts mainly served utilitarian purposes, but left room for aesthetic expression. He attests in the copy he presented to the city that it « had been researched, viewed, measured, portrayed and edited in the present book by the hand of me, Le Lieur »⁴⁹. The accompanying narrative provided vital information about the slopes and heights of geographic

48. FOURNIER, G., 1973.

49. « avoit esté chairché, veu, tézé, pourtraict et rédigé par escript en ce présent livre de la main de moy dict Le Lieur [...] », in J. LE LIEUR, 2005, p. 11.

features critical for this gravity-fed water system. The use of practical mathematics can thus clearly be inferred from the texts and its image as well as the technological prerequisites of the project itself.

Figure 7. *View of Rouen (detail), from Le livre de fontaines*

Municipal account books in Amiens refer to such images of the town in a 1520 entry about a payment to Adrieu de Moncheaux, a local artist, for preparing design schematics of Amiens' fortifications⁵⁰. Yet this shift toward projective geometry to depict and refashion urban space began even earlier. Extensive records on roofing and gabling projects from the late 1400s, for example, indicate the use of at least rudimentary geometry to calculate the area and pitch of surfaces. Inspection teams not only visited the walls and towers, but actually traveled outside the fortified periphery to higher ground to gain « *les veus par dehors* » – a perspective that soon dominated graphic representations of towns⁵¹. Pragmatic considerations outweighed aesthetic ones until the 1540s when special presentation drawings to official patrons of the city began to be made. After 1550, builders began to use these images to guide construction projects. Until then, they still principally served to communicate basic design information to city officials⁵². Local artists

50. B.M. Amiens, CC 97 (1520), fol. 198v: « A Adrieu de Moncheaux, peintre, la somme de *LXIII s.*, pour avoir tiré et pourtret en parchemin le signe de la forteresse ceste ville ». (my emphasis).

51. B.M. Amiens, CC 86 (1509), fol. 86.

52. B.M. Amiens, CC 98, (1521), fol. 90 and CC 99 (1521), fol. 15v.

became increasingly mentioned in the group who visited and consulted about Amiens' fortifications.

During the Renaissance, modes of representing urban places, together with geographical and cosmological space, underwent profound change but still retained these earlier emblematic, metaphysical features. Neoplatonic ideas informed the Vitruvian figure and images of the ideal city, capturing a vast place in a composite image with few words⁵³. New secular meanings gradually overlaid these metaphysical ones as more scenographic representations situated towns in « real time and real space »⁵⁴. Not coincidentally, new levels of mathematical expertise as well as improved surveying techniques became attained as the Renaissance notion of *diseño* moved from the studio into the world at large. Yet the governing geometric logic for artists remained rooted in medieval practical mathematics, even though improved techniques of measurement led to subsequent abstraction⁵⁵. As a result, first in Italy and then in France around 1500, images of towns quite literally came down to earth as interest in their physicality and history became more pronounced⁵⁶. In a sense, the artistic ability to integrate specific places into a broader geographic, as opposed to metaphysical, setting provided a political analog and reinforcement of the process of state formation and territorial consolidation already underway.⁵⁷

Claudius Ptolemy's *Geographia*, composed in the second century, played a central role in the change. It circulated widely in manuscript form after it arrived from Byzantium in 1400 and was eventually published in the 1480s. Use of the Ptolemaic system of coordinated axes in cartography offered a new way to abstract space⁵⁸. As a result, the terrestrial globe became increasingly considered as both a physical sphere and as a human *oekoumène*, a place to live⁵⁹. These two approaches took their cue respectively from Ptolemy and then Strabo, Pomponius Mela, and Pliny, all of whose texts became published by 1500. The first, more mathematically and astronomically oriented one, mainly concerned measuring the size of the planet, determining its position in the universe and accurately locating place according to latitude and longitude. The second, both literary and descriptive in its style and historical and encyclopedic in its scope, looked at the men

53. FIRPO, L., 1974; LANG, S., 1952; ROSENAU, H., 1983; LE MOLLÉ, R., 1972.

54. That said, religious symbolism continued to be important in visual representations of Renaissance cities. See A. CHASTEL, 1954.

55. KEMP, M., 1990, p. 9-52.

56. BARKAN, L., 1999, explores this new impulse to come into physical contact with both a place and its past.

57. BUISSERET, D., 1992.

58. PELLETIER, M., 1989.

59. EDSON, E., 2007.

who live on the planet, at their environment, their traditions, beliefs, and forms of government. Yet Ptolemaic geography and Straboian chorography steadily converged in sixteenth-century cartography, as mapmakers sought to meld their mathematical and aesthetic features into accurate, yet visually pleasing forms in such works as Sebastian Münster's influential *Universal Cosmography*, published in 1544⁶⁰. The quest to create these new maps proved difficult to realize. Ptolemy demonstrated a method to project space using a grid and basic geometry to represent territory. While mathematical precision only lay in the future, visual artists could use an array of illusionist techniques to lend perspectival verisimilitude to new-style maps⁶¹.

These innovations in cartography affected depictions of towns after 1450 first in Italy and then elsewhere. New modes of portraying urban space include ichnography, or plan; orthography, or section; and scenography, or view. Scenography was furthermore divided into two types: classical profile and military axonometric views. Each view held advantages and limits in urban design, especially used in fortifications, depending on which basic perspective it employed: profile (0°), equestrian (10°), oblique view (30°), bird's eye view (45°), cartographic (60°), and ichnographic (90°). Reconciling the new ichnographic and older profile modes required using multiple points of view and the elaboration of new ways to symbolically represent space and the objects found in it.⁶² Take singly, each form of visual depiction could easily rely upon on medieval traditions of applied geometry; combining different points of view, however, created challenges only solvable by more advanced mathematical theory.

Changes in urban design theory and practice sprang from new directions in Renaissance mathematics and metaphysics. Renewed interest in Neoplatonic and Hermetic philosophies posited mathematics as a manifestation of God's immanence in the world, revealing harmony and proportion at every level of creation. This flowering of Euclidean geometry gradually opened up new ways of « physical » thinking that linked harmonic consonances perceived in visual art and heard in music. New forms of notation and graphic representation broadened and transformed the means of mathematical communication which, in turn, reshaped mathematical thinking and practice, including pictorial representations based on perspective and surveying. The crowning achievements of Renaissance mathematics in these domains were the revival of Archimedean mechanics to explain motion

60. BESSE, J.-M., 2003.

61. On the connection between optics and these new forms of visual representation, see M. KEMP, 1990.

62. BARTOLI, M. T., 1978; NUTI, L., 1994; PINTO, J., 1976; FRANGENBERG, T., 1994.

and the development of algebraic geometry to solve problems related to complex three-dimensional forms⁶³.

The relationship between mathematics and visual art deepened in its sophistication in the late 1400s. Piero della Francesca's *Libellus De Quinque Corporibus Regularibus*, composed in the 1490s, brought a very high level of mathematical rigor to perspective techniques that became popularized, with some error, in Luca Pacioli's *De Divina Proportione*, published in 1509⁶⁴. Subsequent work on three-dimensional geometry developed in the later writings of other Italian mathematician theorist-practitioners who strove, with varying degrees of success, to graft the complex mathematics of three-dimensional geometry onto the practical roots of the artist's procedure⁶⁵. Most of them had extensive experience in ateliers and formal, if not very extensive, training in Euclidean geometry. They also evinced a keen interest in the physiology of sight. Cartography was an area of especial interest for such applications, as were ballistics and fortification design. These works exerted extensive and enduring influence on design theory and practices in France not long after their original publication in Italy⁶⁶.

The reception of these ideas and techniques in France relied upon the already well-established interest there in Euclidean geometry. Euclid's *Elements* was only surpassed by the *Bible* in terms of editions published during the late fifteenth and sixteenth centuries. The initial 1482 Latin publication in Venice by Erhard Ratdolt was quickly followed by numerous re-printings. An edition appeared as a French imprint in Paris in 1516 when Jacques Lefèvre d'Étaples, though better known now for his biblical commentaries, edited a Latin edition. Lefèvre d'Étaples was closely connected to erudite circles affiliated with the Valois court⁶⁷. A French translation of Euclid's *Elements* finally appeared in 1564 by Pierre Forcadel of Béziers, who was *lecteur du roy ès mathématiques*⁶⁸. Forcadel had spent time in Italy before returning to Paris where Pierre Ramus had him named professor of mathematics at the Collège Royal in 1560. His translation included long

63. ROSE, P. L., 1975.

64. DAVIS, M. D., 1977.

65. These published practitioners included Daniele Barbaro, Giovanni Zamberto, Federico Commandino, Egnatio Danti, Giovanni Paolo Lomazzo, Giovanni Battista Benedetti and Guidobaldo del Monte.

66. See in general J. V. FIELD, 1997 as well as the more specialized work of P. DUBOURG GLATIGNY, 1999 and 2003.

67. It should be mentioned that Charles de Bouelles published a mathematical treatise in Latin in 1510 in Paris, that included, among other subjects, Euclidean geometry entitled « De geometricis corporibus » and « De geometricis supplementis ». On C. de Bouelles, see below.

68. PIERRE FORCADEL, 1564 and, 1565. Forcadel also translated several works on mechanics and hydraulics by Archimedes in P. FORCADEL 1565. On P. Forcadel, see J. FONTÈS, 1895-1897.

commentaries from the courses he taught, thus suggesting it was intended for his students. Forcadel already had an established reputation, having published in French several books on arithmetic in the mid-1550s.

Much more sophisticated mathematical theory became inspired by the publication of the thirteenth-century mathematician, Johannes Sacrobosco's *De Sphaera*. This work elucidated the spherical geometry underlying the mathematical astronomy of Ptolemy. It first appeared in print in Ferrara in 1472 and then in a Latin edition in Venice in 1485, again edited by Erhard Ratdolt. As with Euclid, a Paris edition was published in 1507, again edited by Lefèvre d'Étaples. A French translation appeared in Paris in 1546. A woodcut of a medallion in this last edition suggested a connection between Sacrobosco's ideas and townscapes. The works of the fifteenth-century German mathematician-astronomers, Georg von Peurbach and Johannes Müller, also known as Regiomontanus, contributed further advances to projective techniques; their works underwent much the same publication track as those of Ptolemy, Euclid, and Sacrobosco. Numerous editions of all these essential works disseminated a new projective mathematics across Europe that only became superseded a century later by the powerful new algebraic geometry of Girard Desargues and René Descartes⁶⁹.

This new projective mathematics first became applied in France to cartography, not townscapes, in the 1520s in the work of Oronce Finé, a mathematician and cosmographer from Briançon who held a chair in mathematics at the Collège de France. Finé fell back on geometric terms, depicting France as a diamond or a square (*carré*), a form rife with symbolic import, as later would be the hexagon.⁷⁰ Finé's *carte gallicane* of 1525 reflected France's Italian ambitions at the time in its inclusion of Piedmont and Lombardy. Finé drew inspiration from the map of Gaul published in Florence in 1481-1482 by the Florentine humanist Francesco Berlinghieri (1440-1501), who extracted his *Gallia Novella* from Ptolemy's *Geographia*, which he translated into Italian verse. Subsequent maps of France include the *Frantia*, published in Ulm in 1482, and the *Moderna tabula Galliae*, which appeared in Strasbourg in 1513. The latter encompassed the left bank of the Rhine in « modern Gaul ». These maps also replaced ancient place names with their contemporary equivalents and employed information from portolan charts to depict coastlines.

Finé found inspiration in these maps for his map of Gaul, which went through five editions between 1525 and 1557. It incorporated the left bank

69. On these developments, see P. L. ROSE, 1975. Rose evinces little interest in the applications of the new projective mathematics. For that subject, see M. J. VOSS, 1994.

70. Oronce FINÉ, 1532. This work appears in Italian as *Della geometria* sometime shortly thereafter. In 1536, O. Finé published in Latin the first six books of Euclid, along with Bartolomeo Zamberti's commentaries on Euclid.

of the Rhine and northern Italy as parts of « greater Gaul », with the Alps as little more than mole hills. His map improved upon Ptolemy's trapezoidal projections by using longitudinal and latitudinal calculations based on his new measuring instruments, such as the « méthroscope géographique », an astrolabe modified by the addition of a compass. In his 1530 work *Cosmographie*, Finé provided the coordinates of 180 French towns, some taken from Ptolemy and others from his own direct observations or corrections of Ptolemy. He included both ancient and contemporary toponyms. His cordiform map of the world employed the new forms of projective mathematics discussed in his *De Mundi Sphere*, published in 1542, using optics and conics to transcribe geometrically in two dimensions any object in space⁷¹.

Finé's work soon inspired imitators and contributed to the first atlases, known as *Theatrum*s. His map of Gaul, for example, was reprinted in Sebastian Münster's celebrated *Das gantz Frankreich*, printed in Basel in 1545⁷². These maps tended to be much less abstract than the two-dimensional maps of today, replete with symbols for water, forestland, built-up areas, etc. Instead, cartographers depicted areas from a 45° bird's-eye-view, using a slanting projection to overlook a particular panorama. The same techniques also became used in townscapes, which appeared in these atlases. Such a view easily allowed rendering of prominent features, such as towns, buildings, and other landmarks three-dimensionally.

Applications of the new projective mathematics to cityscapes began with the famous early sixteenth-century image of Venice by Jacopo da Barbari (1440-1515), while the Dutch artist-cartographer Cornelis Anthonisz (c. 1500-1553) produced a bird's-eye-view of Amsterdam, first as a painting and then in 1544 as a woodcut⁷³. In France, cityscapes from an ichnographic perspective developed alongside maps of territories. Guillaume Gueroult's *Épitomé de la corographie d'Europe*, published in Lyon in 1553, together with Antoine Du Pinet's *Plantz, pourtraitz et descriptions*, printed in Lyon eleven years later, contain several dozen woodblock prints of major cities by Jean d'Ogerolles that utilize this dual perspective⁷⁴.

The 1550 plan of Paris by Truschet and Hoyau printed in Basel offered a richly detailed visual representation of the metropolitan area, as viewed from the west (church facades head on), depicting the allotments, buildings, and streets in the city and adjoining suburbs. Accompanying texts embedded in the maps identify specific places; other texts inscribed in cartouches

71. Oronce FINÉ, 1525; BROU, N., 1983.

72. Sébastien MÜNSTER, 1545; DRAPEYRON, L., 1889.

73. SCHULZ, J., 1978; D'Ailly, A. E., 1934.

74. Jean d'OGEROLLES, 1553, p. 11. J. d'Ogerolles reused many of his woodcut blocks in A. DE PINET, 1564.

celebrate the city grandeur, antiquity, and noble inhabitants.⁷⁵ Georg Braun's copper etching of Paris, published in 1572 in his *Civitates orbis terrarum*, assumed the same western view and closely followed the format of the Basel plan with a few differences. Most noticeable is the prominent coat-of-arms of the city that stands in lieu of the royal one. The Braun plan also makes considerably less of an effort to portray the suburbs, except the important one of Saint-Germain-des-Prés. The delineation between inside and outside the city thus becomes sharper, even though the fortified periphery again seems excessively conventional and indistinctive⁷⁶.

Figure 8. Jean d'Ogerolles's plan of Lyons in Guérout's *Epitome* (Lyons, 1553)

Although the application of trigonometric measurements became more common by 1550, thus making it technically possible to create geometrically accurate maps, the custom of rendering elevations in slanting projection continued, largely because viewers expected such images. The conventions of the bird's-eye-view allowed artist-cartographers to tackle a variety of compositional and perspective problems by striking a balance between orthogonal exactitude and the comforting familiarity of the profile

75. DERENS, J., 1980; BOUTIER, J., 2002.

76. BRAUN, G. & HOGENBERG, F., 1572. A modern edition of this work is J. GOSS (ed.), 1992. On plans of Paris, see A. PICON & J.-P. ROBERT, 1999. A catalog for an exhibit at the Arsenal of maps of Paris since 1250 to the present, it emphasizes the technical, political and cultural factors shaping their formats and uses; J.-F. COULAIS & al., 2003 traces through archaeology and cartography the growth and development of Paris from its origins down to the present, emphasizing its progressive transformation – indeed colonization – of the adjoining hinterland; and P. PINON, & al., 2004 presents fifty different plans, with accompanying commentaries, that show the historical evolution of representations of Paris and the different motives that shaped them.

view. It also injected a sense of volume in the otherwise « flat » two-dimensionality of the orthogonal and profile views. In the seventeenth century, all three views became commonly used in representations of cities, sometimes combining all three viewpoints in one print—a technique pioneered in the illustrations commissioned by Braun and Hogenberg. The demand for this variety of topographical material grew after 1600, especially as the royal fortification and engineering service developed⁷⁷. These perspective renderings of maps and cityscapes, as well as the construction of new-style fortifications *à la trace italienne*, all relied upon a long, complex series of surveys of the place to be depicted or built. Thus, visual depictions of urban space in France prior to 1600, mainly intended for commercial distribution and official consumption, bear ample evidence of the impact of the new projective mathematics as well as the abiding influence of long-established surveying techniques.

Figure 9. Geometrical Theory and Design Practice in Renaissance France

While printed maps and townscape tell us much, questions still remain about the actual practices of builders and designers on the ground. How and to what extent did the new bookish approaches in mathematical theory find their way into the world of builders and surveyors of urban space? How did they conceptualize and represent physical space differently as a result? How, in turn, was the built environment affected? Theory and practice must not be distinguished too sharply. After all, many Renaissance theorists, who wrote on perspective also were versed in the surveying and building trades. Changes in design practices in France after 1500 emerged from the easy mingling of theory and practice to create new ways to conceptualize and alter physical space.

Innovations in surveying and design can be found in the many arithmetic primers and geometry manuals printed after 1500. Without denying Italian influences, French works on applied mathematics provided sources

77. HARVEY, P. D. A., nd. See also the vital work another sixteenth-century cartographer, Abraham Ortelius in R. W. KARROW, 1998 and C. KOEMAN, 1964.

which builders could readily consult. Most of these works contained sections on solving common surveying problems. While Italians certainly blazed new trails on perspective geometry, the context in which perspective was taken up in France exhibited a less abstract nature than in Italy or Germany at the time, and was instead more closely associated with the representation of realistic architectural space. This difference can be seen in the work of an obscure canon from Toul, Jean Pélerin (1435-1524), who wrote under the name *Viator* (voyager). In 1505, he published the first French work exclusively devoted to Euclidean geometry, *De Artificiali perspectiva*. In it, he offers perspectival renderings ranging from the grandiose interiors of Notre-Dame de Paris and the Palais de Justice in Rouen to the mundane interior of his own home. These illustrations hold no relationship with the perspective geometry discussed in the text, however⁷⁸. Pélerin's method represented a much simpler approach to linear perspective than the ones already developed in Italy. He presented a formulaic but effective three-point system using a series of pyramids with the apexes along the horizon (or « pyramidal ») line. Indeed, Pélerin made no effort to maintain the illusion of a vanishing point in the rear of the picture. His form of perspective image thus did not record the objective world but instead reproduced it through a specific method of construction. Pragmatic applications mattered more for him than theoretical accuracy.

Advances beyond Pélerin's method came from the influence of Italian painters brought to France in the 1530s to work on Fontainebleau. They include Rosso Fiorentino, Francesco Primaticcio, and Giacomo Barrozi da Vignola, all proficient perspectivists whose work can still be seen today in the palace. Most important, however, was Sebastiano Serlio, whose books on architecture became so popular in France that he became François I's chief architect in the early 1540s. Serlio devised another easily accessible technique to render perspective for stage scenery. He provided particularly good guidance for properly using a compass to delineate curved lines in ovoid spaces⁷⁹.

Subsequent draftsmen in France, such as Philibert de l'Orme and Jacques Androuet du Cerceau, the latter of whom wrote a stand-alone work on perspective, expanded further upon Pélerin's approach. Androuet du Cerceau's *Leçons de perspective positive*, published in 1576, complemented his earlier collection on architecture and the building trades, *Excellents bâtimens de France*. In it, he presents sixty lessons in a do-it-yourself format, complete with easy-to-follow illustrations to guide the student or

78. FRANGENBERG, T., 1986; BRION-GUERRY, M., 1962, gives a French translation of the 1505 Latin text on p. 217-227.

79. HART, V. & HICKS, P., 1996; 2001. Serlio relied in particular on the earlier work of Baldassare Peruzzi, concentrating on geometry and perspective in books one and two of volume one.

builder⁸⁰. Du Cerceau purposely omits mention of Euclidean geometry in his primer, as he strove for readers to master applied technique rather than bookish knowledge. By contrast, the application of more advanced perspective geometry comes through in the work – both built and written – of Philibert de l'Orme.

A close look at the *trompe* that L'Orme built at the château of Anet between 1549 and 1551, which became featured in his *Premier tome de l'architecture* sixteen years later, reveals the ongoing innovations possible in the craft tradition.⁸¹ As the name suggests, a *trompe* aimed to appear to flout the laws of gravity. The techniques featured by L'Orme grew out of the stone-cutting traditions of the masons; his father, in fact, was a master mason.⁸² In the introduction to the *Premier tome*, L'Orme insists on the importance for both architects and master masons to know geometry. Indeed, no built work can begin without the fundamental—and foundational—act of squaring up. In a clumsy nod to the metaphysical tradition, he supplemented his pragmatic advice with banal musings on the symbolic meaning of geometric forms.

Design continuities stand out, with slight innovation. L'Orme's *trait* for a star vault, for example, was transitional in both styles – flamboyant to Renaissance – and combined the earlier, more limited technique of projection with a more geometrically sophisticated one. Yet late Gothic masons must surely have known of this difficult technique in practice given the complicating ribbed and fan vaulting often found in fourteenth and fifteenth-century churches, especially pendant fan vaults. The difference now was the appearance of this artisanal knowledge in print.

The major theorist of perspective in sixteenth-century France who perfected the three-point linear technique was Jean Cousin. In his 1560 *Livre de perspective* in Paris, he achieved complex results using fairly simple means long used by craftsmen. Originally from Sens before taking up residence in Paris, Cousin was an artist who worked in a number of media – fabric, glass, and engravings – all of which benefited from his knowledge of perspective and basic Euclidean geometry. In fact, Cousin bridged the craft world of applied mathematics and the learned culture of court, much as Du Cerceau and L'Orme did⁸³. What Cousin's treatise lacked

80. While there is no modern edition of *Leçons*, a modern edition of Du Cerceau's work on architecture appeared with D. THOMSON (ed.), 1988. See also F. BOUDON, 1988.

81. J.-M. PÉROUSE DE MONTCLOS, 2000 surpasses A. BLOUNT's 1958 study.

82. RYKWERT, J., 1996, p. 364-376.

83. Cousin's son, Jean, followed in his father's trade as an artist-writer, publishing a short work on portraiture in 1595, based in part on the perspective methods employed by Jean Cousin senior.

in originality was made up for in clarity of expression and practicality of application⁸⁴.

Figure 10. Title page, Jean Cousin, 1560

Works devoted mainly to mathematical theory also contained much practical information readily applicable to problems encountered by builders and merchants. The first such book printed in French was *Larismetique* by Étienne de La Roche, published in Lyon in 1520. From Villefranche, La Roche studied under Nicolas Chuquet, known for his work in algebraic notation, and taught commercial mathematics for twenty-five years in Lyon. Lyons offered a well established book market which introduced mathematical work by Italians to a French audience⁸⁵. *Larismetique* was essentially a pastiche of basic algebra drawn from Chuquet, Luca Pacioli and Philippe Frescobaldi, a banker in Lyon⁸⁶. It included solutions using algebra for problems familiar to merchants and builders, such as calculating volumes.

True advances in geometry only came in 1542 when Charles de Bouelles published his *Géometrie pratique*. Bouelles was a canon at Noyons and humanist savant who had studied mathematics and theology at the University of Paris in 1493, where he became a close associate of Lefèvre d'Étaples.⁸⁷ Reprinted four times in the next twenty years, he

84. Jean COUSIN, 1560 [1974]. AUCLAIR, V., 2003.

85. VAN EGMOND, W., 1988. On Chuquet, see G. FLEGG, C. HAY & B. MOSS (eds.), 1985.

86. Étienne DE LA ROCHE, 1520. Pacioli was known for *Summa de arithmetica geometria proportioni e proportionalita*, 1494 and his edition of Piero della Francesca's work on linear perspective. Little is known of Frescobaldi.

87. Charles DE BOUELLES, 1542, reprinted in 1547 as *Géométrie pratique*.

aimed to teach his readers the rudiments of Euclidean geometry, covering general principles, angular figures, angular figures with circles, the quadrature of the circle, dimensions of solids, the cubification of the sphere, the properties of sound, wind and water, the proportions of the human body and the uses of geometry in astrology. Oronce Finé provided the book's many woodcuts, visually illustrating principles logically notated in the text. Bouelles provided a much more powerful combination of advanced projective geometry focused on a variety of practical problems.

Another important contributor was Jacques Peletier, who wrote a primer on arithmetic in 1549, a short introduction to algebra in 1554, and later translated several of Finé's manuals on practical geometry. Peletier hailed from Le Mans and had studied at the College de Navarre, where his brother Jean was a professor of mathematics. He frequented the literary circle of Marguerite de Navarre and had served as René du Bellay's private secretary in the mid-1540s. In 1573, he composed his own work on geometry, *De l'usage de géométrie*, explicitly aimed at practitioners. After a brief résumé of basic Euclidean geometry, Peletier provides several dozen examples of practical applications for surveyors, such as measuring a building, a plot of land, or a mountain⁸⁸. He also brought to bear a more probing acumen by pointing out flaws in some of Euclid's original proofs. The noted Flemish fortification expert, Simon Stevin, published a French version of his own treatise on arithmetic and algebra in Leiden in 1585⁸⁹. His work on perspective looks at a number of innovations, such as the case of calculating the perspective for making a drawing on a canvas which is not perpendicular to the ground, and the case of inverse perspective.

Treatises on advanced instrumentation further demonstrated this conjunction of mathematical theory and design practice. A Fleming named Valentin Mennher, for example, wrote a short work on practical geometry in French in 1565 detailing, among other matters, how to use geometry to prepare account books – an important task as procedures became more bureaucratic.⁹⁰ Surveying formed a main topic in manuals on the use of astrolabes, mainly for astrological charts of the heavens, by Jacques Focard and Auger Ferrier⁹¹. Abel Foullon published another guide to a holometer, an

88. Jacques PELETIER, 1549, with numerous editions in French and Latin. His other mathematical works include *L'algèbre*, 1554, *In Euclidis elementa geometrica demonstrationum libri sex*, 1557, *De occulta parte numerorum, quam algebra avocant, libri duo*, 1560, *Commentarii tres*, 1563; and *De usu geometriae, liber unus...*, 1572. This last piece included Oronce Finé's 1555 *De arithmetica practica libri quatuor*. J. Peletier also published widely on poetry, rhetoric, and medicine, introducing the works of Girolamo Cardano to the French.

89. HOOYKAAS, R. & MINNAERT, M. G. J. (eds.), 1970. ANDERSEN, K., 1990.

90. Valentin MENNHER, 1565.

91. Jacques FOCARD, 1555 & Auger FERRIER, 1559. Oronce FINÉ, 1551, published a short treatise on astrology entitled *Briefve & isagogique Introduction sur la Judiciaire Astrologie*.

instrument used to measure all sorts of angles, which appeared in the 1550s. Foullon served as director of the royal mint under Henri II and later held the title of *ingénieur du roy*. Foullon even claimed he could teach the basics of measuring distances to persons lacking any mathematical training⁹². In 1573, Jean des Merliers, a mathematics teacher in Amiens, published a short manual describing the proper use of the square to solve practical geometry problems, a subject he further explored in another short tract in 1575. Another work by him, though only published posthumously in 1608 in a revised edition of Bouelles's *Geométrie pratique*, explicitly demonstrated the Euclidean underpinnings of surveying⁹³. This same edition also contained a short piece by Jean Pierre des Mesmes on calculating heights, distances, and volumes⁹⁴. Dominique Jacquinot and Jacques Bassantin collaborated on a manual, *L'usage de l'astrolabe*, published in Paris in 1573, which described how to use an astrolabe and calculate the mathematical properties of spheres. Jacques Chauvet, about whom little is known, wrote a short manual in 1585 describing how to use a new surveying gadget called the *cosmomètre* as well as a manual on arithmetic⁹⁵. Finally, Alexandre Guybert published a tract in 1580 to help masons calculate more exactly the work involved in large excavation and construction projects⁹⁶.

Advances in etching led to finely detailed illustrations of new tools, occasionally in exploded views, to accompany step-by-step guides of how to use them. The work of Jacques Besson stands out. From Grenoble, he entered French royal service under Charles IX as an *ingénieur du roy*. He wrote several manuals on practical geometry and mathematical instrumentation, though his masterpiece, *Théâtre des instrumens mathématiques et mechaniques*, appeared posthumously in Lyon in 1578.⁹⁷

In 1598, Henri de Suberville published a treatise on a new surveying device that he named after the first Bourbon king⁹⁸. The accompanying il-

92. Abel FOULLON (1513-1563), 1555 [1561]. Foullon's manual was translated into Italian in 1564. As it stated in the preface, this work was « [n]ecessaire a ceus qui veullent promptement, & sans aucune subiection d'arithmetique, sçavoir la distance des places, arpanter terre, & faire cartes topographiques » It also acknowledges the assistance of Jean Maignan in the « demonstrations » (i.e. diagrams).

93. Jean DES MERLIERS (1575). Merlier's piece in the Bouelles' 1608 edition is entitled *L'art de mesurer toute superficies rectilignes tiré des élémens d'Euclide*.

94. Jean Pierre DES MESMES (1560).

95. Jacques CHAUVET, 1585 and 1585.

96. Alexandre GUYBERT, Paris, 1580. It was subsequently republished in the seventeenth century in various collections.

97. Jacques BESSON, 1567-1569 and 1571. Edited by Béroalde de Verville, the *Théâtre* (BESSON, J., 1579) went through many subsequent editions and translations into Latin, Italian, Spanish and German over the next fifty years. On Besson, see L. DOLZA & H. VÉRIN, 2004. HILLARD, D., 1979 and 1981. KELLER, A. G., 1965; 1973 and 1976.

98. Henri DE SUBERVILLE, 1598.

illustration showed its use in laying out the periphery of a bastioned trace. Again, this method did not essentially differ from the one used in founding medieval *bastides*.

Figure 10. *Illustration from Henri de Suberville's L'Henry-metre, 1598*

One work actually brings us close to design practices at the time in Amiens. It was the *Petit traité de geometrie et d'horologigraphie pratique* by Jean Bullant (1515-1578), published in Paris in 1562. Perhaps born in Amiens, Bullant was likely related to Jehan Bullant, master mason of Amiens⁹⁹. He served as an architect for the constable, the Anne de Montmorency, and then Catherine de Médicis; his design commissions included castles at Écouen and La Fère in the 1540s and the Château de Chenonceaux in 1566. He traveled extensively in Italy and helped to introduce the five classical Vitruvian orders – and thus classicism – to France in his *Reigle generale d'architecture*, published in Paris in 1568. The practical bent of this work came through particularly in the instructions that he addressed to stonemasons working in the quarries of Écouen, a chief supply source of stone for Amiens.

There thus developed in sixteenth-century France a substantial body of publications on practical mathematics that offered merchants and builders new – and sometimes not so new – techniques to solve age-old practical problems. These printed works opened up new ways to conceptualize and express changes in design that accompanied the « chorographic shift » of the 1500s. While university-trained mathematicians predominated in printed works on practical mathematics until 1550, artisans steeped in traditional building practices increasingly came to the fore thereafter both in print and

99. See Y. PAUWEL, 2002, on Bullant's role at Chenonceaux.

the emerging professions of architects and engineers. This mix of old and new in design practice becomes even more apparent in municipal account books on construction projects in Amiens and presumably elsewhere. These continuities in indigenous design practices only began to merge with Italian innovations in fortification science in the late 1500s. Until then, masons still dominated most phases of design formulation and execution¹⁰⁰.

Representing design practices fell, however, to visual artists employed on public commissions. The most important such person in sixteenth-century Amiens whose career reflected these evolving techniques was the painter, Zacharie Le Sellier (or Cellier), whose career spanned from 1530 to the 1570s.¹⁰¹ Le Sellier took part in site visitations, where he worked with the master of works to render « *le tout réduct au certain* »¹⁰². Although it may still have included narrative elements from the medieval tradition, this phrasing suggests a perspectival drawing based on measurements taken by the master mason, in this case Jehan Bullant, who headed up public works. Yet Le Sellier did more, much more, than simply provide a visual representation of what the masons measured. He also used his knowledge of practical mathematics to calculate volumes and building materials – and thus costs – for specific projects. His methods remained essentially medieval¹⁰³. In 1543, for example, he contributed his expertise to calculate in cubic *toises* the amount of earth to move to widen the ditch between the Porte de Haultoie and the Porte de Beauvais. He also collaborated with the master of works to determine the most cost-effective manner to remove this earth. This collaboration included the building of a customized machine (*engin*) for which Le Sellier provide the technical design plan¹⁰⁴. In 1548, Le Sellier even traveled to Boulogne to prepare site drawings of the two principal forts guarding this vital port, which the English had recently occupied¹⁰⁵.

100. B.M. Amiens, CC 60 (1480), fol. 49v; CC 106 (1524), fol. 90v; CC 138 (1541), fol. 143v; CC 141 (1543), fol. 77; and CC 643 (1577), fol. 33v. In the 1570s, for example, as officials in Amiens contemplated building a massive new bastion outside the Porte de Paris, Julien Louvel, the master of works, and Jehan Bullant, a master mason long involved in such projects, traveled to Péronne and Corbie to study artillery platforms, particularly their sight lines. B.M. Amiens CC 643 (1577), fol. 33v.

101. B.M. Amiens CC 126 (1535), fol. 97. The first mention of him is for a payment for writing the names of neighborhood officials on those parts of the walls for which they were responsible.

102. B.M. Amiens CC 623 (1539), fol. 48.

103. CAILLEUX, P. & LARDIN, P., 2001.

104. B.M. Amiens CC 141 (1543): « ...pour enquérir de luy la manière comment on pourroit besongner pour avoir les terres du fonds dudit fosse sur les rampars à la plus grand diligence que faire se pourroit, et à moins de fraiz » and « il a faict devise de ung engin pour tirer lesdictes terres et d'icelluy faict ung pourtraict ». For Augusto Ramelli, see his *Le diverse et artificiose machine*, 1588.

105. B.M. Amiens CC 151 (1548) fol. 74. On the siege of Boulogne, see P. GRESSIER, 1977.

Zacharie Le Sellier thus demonstrated most of the essential knowledge sets and designs skills of an engineer prior to the actual appearance of such experts from Italy who sported this title. The first Italian engineer to appear in Amiens in these records was Girolamo Marini, who arrived in 1548 to consult about building a bastion between the Porte of Haultoye and the Porte de Beavais¹⁰⁶. Although usually referred to as a Bolognese, Marini was actually from the vicinity of Modena. He began service for the French during François I's 1537 campaign in the Piedmont and the 1542 siege of Perpignan. He also provided the French advice on rebuilding the city of Luxembourg after its capture in 1543, overseeing work by some 100 to 120 Italians specially sent to upgrade its defenses. Marini had most recently participated in defending places in Champagne against a series of Imperial sieges in 1544. Marini also received the celebrated commission to build a new town, Vitry-le-François, incorporating the new-style *trace italienne*¹⁰⁷. Blaise de Monluc, in fact, described him as « le plus grand homme d'Italie pour assiéger une place ».

By almost any reckoning, Marini was among the most accomplished, cutting-edge engineers of his day, yet his role as consultant to Amiens essentially consisted of one single visit to meet with Zacharie Le Sellier to go over a building project that lasted for the better part of six years. Le Sellier's standing as principal designer of this bastion can be seen when he traveled in 1549 to Paris to show his *pourtraict de bolevert* to Henri II himself¹⁰⁸. Other itinerant engineers made periodic visits to Amiens over the next several decades. These included a certain sieur Vincent in 1555 and two men, seigneur Fredau, possibly a German, and Bartholomée, all of whom visited at the behest of the provincial governor. An unwelcome inspection occurred in 1572 when municipal authorities arrested a certain maistre Henry, a Flemish engineer, on charges of espionage. Poor Henry was caught conducting measurements of the city's bastions and also reputedly tried to steal brick making secrets, a local specialty¹⁰⁹.

In the eyes of local officials, Le Sellier certainly served in a subordinate status to Italian engineers sent by the king. In 1564, for example, he received a payment for assisting Bernardino Bellarmato who spent eight days examining Amiens' defenses, especially a bastion project destined

106. B.M. Amiens CC 151 (1548), fol. 69. Marini's title in this entry is « maistre ingénieur du Roy ». In general, see « La patria et la famiglia di Girolamo Marini, ingegnere militare del secolo XVI », in *Atti e memorie della R. Deputazione di storia patria per le provincie di Romagna* (1927).

107. Marini became involved in designing the defenses of Saint-Dizier. See C. PAILLARD & G. HÉRELLE, 1884 and A. ROZET & J. F. LEMBEY, 1910. Vitry-le-François was built upon the ruins of Vitry-en-Perthois. Monluc, *Commentaires*, p. 76.

108. B.M. Amiens CC 152 (1549), fol. 23.

109. B.M. Amiens CC 196 (1572), fol. 83v.

for the Porte des Rabuissons. The entry underscored Le Sellier's humble readiness to follow Bellarmato's commands¹¹⁰. Unlike earlier Italian engineers, Bellarmato visited Amiens on a fairly regular basis over the next five years; indeed, his title explicitly specified his duties and corresponding authority as royal engineer of Picardy. During this time, Jean de l'Orme, now an « *architecte des bastimens du Roy* », visited Amiens during a tour of Picardy, where he presented to the lieutenant general a set of specific defensive recommendations, together with five plans and accompanying drawings¹¹¹. These technical experts, brought in from the outside by the budding royal fortification service, increasingly dominated the design process of urban fortifications after mid-century.

This change continued in 1572 with the arrival of Bernardino's son, Aineas Bellarmato, who held the same royal title. Aineas, however, seemed to spend more time in Paris than in the province. He, too, worked on the bastion at Rabuissons, now named Longueville after the new provincial governor. He provided not only technical advice, but also design drawings for casemates sent after his visit¹¹². By the next year, officials in Amiens sent letters to the provincial governor, the marquis de Crèvecœur, asking him to send his engineers, led by the younger Bellarmato, to the city so that they could precisely mark out the dimensions of the new curtain walls joining the bastion de Longueville to the city¹¹³. Aineas spent a sufficient amount of time in 1574 to prepare for Crèvecœur a comprehensive design plan of Amiens' entire circuit of fortifications. This rendering presumably superseded the one created by Le Sellier six years earlier¹¹⁴. Three years later, Aineas stayed three weeks in the city to ensure that the initial construction of the bastion de Longueville scrupulously followed his design. This kind

110. B.M. Amiens CC 180 (1564), fol. 17: « ... pour ester tousjours plus prestz à faire qu'il plaisoit...audict ingénieulx de leur commander ». The master mason, Jehan Bullant, assisted Bellarmato as well. Bellarmato was likely related to Girolamo Bellarmato (1493-1555), who had served as a royal engineer for the French monarchy from the mid-1530s until his death at the siege of Siena. His most noteworthy project was the design of the new port of Le Havre in Normandy. See R. HERVAL, 1960 and P. LARDIN, 2003.

111. B.M. Amiens CC 635 (1569), fol. 40v-42. Apparently William of Orange threatened to invade the region at time to support local Huguenot forces. Jehan de l'Orme was the father of the celebrated French architect, Philibert de l'Orme. While now outdated, A. BLOUNT's *Philibert de l'Orme*, 1958 still contains useful information, though for a more recent study see P. POTIÉ, 1996.

112. B.M. Amiens CC 638 (1572), fol. 29 and EE 272 (1572-1577).

113. B.M. Amiens CC 199 (1573), fol. 11.

114. B.M. Amiens CC 201 (1574), fol. 14v. « ... du dessin et pourtraict que le sieur Belarmat le jeune, ingénieulx, avoit encommenché du circommuniqué du circuyt et forteresse de ladicte ville d'Amiens... ».

of close, sustained supervision suggests that Bellarmato wished to forestall any changes by the master masons of his original vision for the work¹¹⁵.

Finally in 1582, Bellarmato returned from Paris to conduct another full inspection which yielded a detailed report together with design drawings for municipal officials, while another copy of the report presumably went back to Paris with him. However, the next year a separate such inspection, this time conducted by the master of works and local master masons, re-examined Bellarmato's recommendations. It appears the city received two separate streams of information about the state of its municipal fortifications, one from a representative of the provincial governor and ultimately the crown, while the other came from resident experts of long standing¹¹⁶. Urban design practices were clearly in transition to a system increasingly dominated by the central government and its experts. It remains open to question whether the new-style *trace italienne* was a foreign import or, as seems more likely in this scenario, a home-grown adaptation.

Disentangling the respective areas of expertise of these outsiders from Le Sellier's is difficult, though Le Sellier's consistent involvement suggests he handled both the drafting and technical aspects of these sundry projects. As a result, his stature seemed to rise in the 1550s as he again went to Paris to present his plans before the king's *conseil privé*, including in 1554 a high quality (but now lost) vellum portrait of the Amiens showing all its fortifications and principal buildings, together with a listing of the militia companies responsible for its defense¹¹⁷. Significantly, an account from 1555 detailing expenses associated with a new bastion fronting the Porte de Noyon identifies Le Sellier as the « *architecteur de ladite ville* »¹¹⁸. He often thereafter received this appellation when he worked on building projects, but was designated as a mere *peintre* when took more humble commissions.

Mastery of new perspectival techniques in cartography also became evident when Le Sellier and the master mason Jehan Bullant collaborated over two weeks in 1568 to create a double portrait of the entire city. Using a compass, theodolite and surveyor's rods, they laid out a series of traversal lines that served as the base for triangulating various important places inside the city's walls. These measurements then enabled Le Sellier to create a proportional plan of Amiens, containing « *les distances, longueurs et largeurs des fosses, rampars, moyneaulx, bolvartz et autres forteresses,*

115. B.M. Amiens CC 643 (1577), fol. 34v. ... pour donner ordre à conduire l'ouvrage et observer plus seurement son dessein ».

116. B.M. Amiens CC 215 (1582), fol. 66v and EE 273 (1583-1585).

117. B.M. Amiens CC 162 (1554), fol. 20v.

118. B.M. Amiens CC 164 (1555), fol. 29-29v.

avec les retours, coulds et jaretz y estans »¹¹⁹. The plans described here entailed a *double pourtraict*, one to guide the masons on site and another to present to Gaspard de Coligny, the provincial governor of Picardy at the time¹²⁰. An even more ambitious cartography commission came in the form of five maps of Picardy which Le Sellier prepared in 1572 as a presentation gift to visiting dignitaries¹²¹.

Le Sellier's was not the only local painter-architect to demonstrate mastery of these techniques of projective geometry. A certain Jehan de l'Abbaye regularly shows up in the record during this same period. In 1570, for example, he received a commission to prepare a *pourtraict* of various properties at dispute in a lawsuit between the cathedral canons and local inhabitants. He presumably used, or had someone assist him in using, surveying instruments in order to realize a true delineation of the property lines¹²². There is even mention of a payment to him for a design plan for a new roof of the Tour de Beffroy, containing exact dimensions and a calculation of the timber necessary for the project, prepared by a master mason and master carpenter. The plan's practicality became evident when local merchants and carpenters used it to guide their purchase of lumber in nearby forests¹²³. Another set of local experts who demonstrated these same skills were the surveyors or *mesureurs jurés*. One of them, Nicholas Gargualt, for example, occasionally became hired by the city to help deal with land expropriations and excavation projects¹²⁴. In 1582, the *mesurier* Pierre Norman submitted two copies of a design plan for iron doors intended for the bastion de Longueville, together with a precise cost estimate of all necessary materials and a model¹²⁵.

119. B.M. Amiens CC 634 (1568), fol. 30. « ... pour avoir toizé, mesuré, faict calcul et reduction... ».

120. B.M. Amiens CC 180 (1564), fol. 15: « ... pour y employer grand nombre des habitans oisifs et mendiants qu'ilz avoient à quoy eulx employer... ».

121. B.M. Amiens CC 196 (1572), fol. 87v. Further work remains to be done to determine what relationship, if any, exists between these maps – none of which apparently survived – and the one of Picardy created by Jean (or Jacques) Surhon in 1579 which appeared in *Ortelius, Cartographica Neerlandica*, n°. 46. See P. H. MEURER, 1995.

122. B.M. Amiens CC 192 (1570), fol. 80v.

123. B.M. Amiens CC 640 (1574), fols. 58-58v, 59v: The artisans involved were Jehan Bullan, Jehan Maroeul, Léon Masse mel, Jehan Martin, and Bastien Huimarcq « ... pour farie le pourtraict de la charpenterie du comble du Beffroy et du beffroy des cloches, et pour avoir calculé et prisé le menu les pieces de bois quy y entreront ».

124. B.M. Amiens CC 196 (1572), fol. 81v and CC 202 (1575) fol. 96. For more on this case, which dragged on for over three years, see my unpublished paper « Peripheral Matters: Contesting Civic Space on the Militarized Edge ». For *mesuriers jurés*, see the account in CC 201 (1574) fol. 18v, for example.

125. B.M. Amiens CC 216 (1582), fol. 18. « ... pour avoir... faict deux pourtraicts en pappier... faict le calcul par le menu combine elle pouvait couster, mesmes au faict ung modelle d'un pied carré ».

And then there were the masons and carpenters, long fluent in medieval traditions of practical geometry. Jean de Maoeul, a master mason and frequent master of public works, and his colleague Jehan Bullant received similar mention as *expert en le mesure et bastimens* and *catisseur juré*. In fact, Bullant prepared on-site drawings of artillery platforms in Péronne and Corbie to guide the design of the bastion de Longueville in 1577, while in 1589 another master mason, Anthoine Pasturon, rendered a scale drawing of the city's ramparts from the Tour de la Haye to the Porte de Beauvais at the behest of the provincial governor, the Duc de Nevers¹²⁶. Pasturon, who appeared regularly in the municipal account books since the early 1570s, receives mention in a 1590 account not as master mason but as *architecte de ceste ville*, thus filling the professional role originally played by Le Sellier. The lack of any further references to Italian engineers visiting Amiens during these years may have contributed to Pasturon's elevation in stature, as did the fact that in that instance he served as part of a team of officials sent from Amiens to Conti to oversee the demolition of a castle¹²⁷.

In the 1590s, the indigenous traditions of municipal construction and practical mathematics in Amiens became increasingly subject to direct monarchical control with the emergence of a more formal royal fortification service under Henri IV. The near disastrous seizure of Amiens in 1597 by the Spanish proved a key factor in precipitating this crucial change¹²⁸. The episodic visits of Italian engineers typical under the Valois now became replaced by more permanent missions to the city, as elsewhere in the kingdom, by French experts who practiced and published these new design techniques. In 1591, example, Ambroise Bachot, identified in this account simply as *ingénieur en Picardi*, inspected Amiens' fortifications and prepared several design plans for their improvement. Ambroise Bachot was originally trained as an engraver; however, he had been active in fortification design and engineering since at least the early 1580s. His *Le Timon*, published in 1587, relates albeit somewhat confusedly, different practical applications of mathematics to solve basic problems of calculating scale and distance in perspective. It also offers what Bachot claims are several newly invented machines for moving earth and constructing fortifications. A number of the plates, however, were reminiscent of Agostino Ramelli's justly celebrated *Diverse e artificiose machine*, published the next year in 1588. While Bachot extensively lauded Ramelli in his book, Ramelli bitterly accused Bachot of plagiarism and theft. It should be pointed out that

126. B.M. Amiens CC 643 (1577), fol. 32. These phrases came in reference to the ongoing repairs of the city's belfry. On Bullant's drawings, see CC 643 (1577), fol. 33v, while for Pasturon see CC 229 (1589), fol. 35v.

127. B.M. Amiens CC 655 (1590), fol. 58v.

128. See M. WOLFE, 2000, p. 61-79.

Bachot, if guilty as charged, was not all that unique in the world of early modern engineering and engraving¹²⁹.

Bachot serves as an important transitional figure because he arguably became the first Frenchman to head a post in the nascent royal fortification service when Henri IV appointed him in 1596 to serve as director of fortifications at Melun, a key town in the Seine valley. Two years later, Bachot issued, using his own press, it seems, a revised and expanded version of *Le Timon* under the new, more exalted title of *Le gouvernail* (the rudder), a nautical image usually associated with the king, who directed the ship of state.¹³⁰ This work further demonstrated Bachot's weak grasp of basic mechanical engineering and entirely derivative ideas about fortification design.

After recapturing Amiens in 1597, Henri IV sent not Bachot but rather Jean Errard from Bar-le-Duc to the city to oversee repairs and begin design of a royal citadel – a structure that symbolized for the city, and in time, the rest of the kingdom, the monarchy's heightened ambitions. He served the Duke of Lorraine before entering French royal service after 1594.¹³¹ Errard is generally credited, along with Claude de Flamand, with creating the first truly French school of fortification science¹³². Both men also wrote on practical geometry and the art of war like earlier theorist-practitioners. Flamand's guide to fortifications derived from his own study of Italian and Dutch treatises on the subject as well as his own war-time experience¹³³. Errard's publications and actual built structures, though shaped by the same influences, proved much more original.

Along with the emergence of a French school of fortification design came the enhanced use of linear perspective and new cartography techniques to depict advances in fortification design¹³⁴. The work of Jean de Beins and Claude Chastillon stand out in particular, providing designs for the revamped royal administration of fortifications, which underwent significant change under the leadership of the Duc de Sully. In 1599, Sully united in his hands the offices of Superintendent of Finances, Artillery, and Buildings and Fortifications. He was also royal governor of the citadels of Amiens, Calais, Ponthieu, and the Trois-Évêchés in Lorraine. One of the expressed purposes for this administrative consolidation was to improve

129. Ambroise BACHOT, ?-1599, 1587. See M. T. GNUDI, 1974.

130. Ambroise BACHOT, 1598.

131. Jean ERRARD, 1584; 1598; 1605; 1600.

132. In general, see D. BUISSET, 2000.

133. Claude FLAMAND, 1597 (reprinted in 1612, German edition in 1613). His other works on practical geometry, which also included a piece on surveying, only appeared in 1611 (C. FLAMAND, 1611a et 1611b).

134. VÉRIN, H., 1998 and 2002.

royal military performance. In 1601, Sully proposed to the king the goal of strengthening frontier fortifications by applying recently developed theories of Errard. Three years later came a survey of the condition of all these places, along with the *grand règlement* of 1604, in which Sully proposed organizing military engineers, who numbered between eighteen and twenty-four along with local *contrôleurs des fortifications*, by defining their duties and assigning them to specific territories. He ordered them to make regular inspections of fortifications in their areas and report recommended construction or demolition. He appointed a chief engineer to direct inspections and construction projects for Picardy, Champagne, Dauphiné, and Provence. It became general practice under Henri IV for the crown to assume the initial construction costs for new urban fortifications, leaving maintenance costs thereafter as the responsibility of municipal authorities. In this manner, the crown gained much greater control over deciding where and how to modernize fortifications. The emerging fortification service became the means by which this general policy became enacted.

Similar developments in civil construction took place in the late sixteenth century. The *Chambre des Bâtiments*, for example, which since the thirteenth century had essentially been a corporate tribunal representing craft guilds under the *prévôt* of Paris received *lettres patentes* in 1574 that placed it directly under the crown, which appointed a judge to serve as *Maître général des œuvres de maçonnerie*¹³⁵. Another major innovation occurred in 1597 when the crown reformed the statutes of the corporations of masons and carpenters in Paris. These reforms grew out of longstanding conflicts between the crown and masons, on the one side, and the Parlement of Paris and the urban notability, on the other. The new statutes affirmed through royal prescription the power of the guilds by extending them the right of appeal from its tribunal directly to the Parlement, thus bypassing the *prévôt*. The crown essentially confirmed the traditional hierarchy within the guilds, reaffirming the authority of the master over his apprentices and journeymen. The king also laid out rules governing salaries, work conditions, arbitration of disputes, theft from building sites, and guild elections. In time, the crown extended these new standards by decree to the rest of France. In 1607, it issued a decree that enhanced the rights and functions of the *Grand-Voyer de France* in an attempt to create a more centralized system of administrative control over urban planning and construction. This move sharpened tensions between masons and royal building administrators into the next century.¹³⁶ Controlling the urban fabric of the walled towns required not only a growing royal monopoly over fortification design and construction, but also greater royal regulation of the building trades. Crown

135. See R. CARVAIS, 2001. This work will soon be published by Droz.

136. See J.-L. HAROUEL, 1993.

control over municipal fortifications and the guilds involved in construction thus proceeded in tandem¹³⁷.

By 1600, the momentous changes affecting the built environment in France principally sprang from the merging of innovative craft traditions of urban design and building practice with more robust, bureaucratic forms of public governance, first in town governments and then the monarchy. Ongoing improvements in projective mathematics, instrumentation, and illustration continued into the future as French walled towns became situated into a broader cartographic landscape that reflected their creeping integration into the fabric of the monarchical regime erected by the Bourbons. These adaptive continuities in the world of work and social life persisted far into the future and played vital roles in defining the modern city and modern culture.

Bibliography

- ACKERMAN, James S., « 'Ars sine scientia nihil est'. Gothic theory of Architecture at the Cathedral of Milan », *Art Bulletin*, xxxi, 1949, p. 84-111.
- AILLY, A. E., D', *Catalogus van Amsterdamsche plattegronden*, Amsterdam, R. Anslo, 1934.
- ANDERSEN, K., « Stevin's Theory of Perspective: The Origin of a Dutch Academic Approach to Perspective », *Tractrix*, ii, 1990, p. 25-62.
- ANDROUET DU CERCEAU, Jacques, *Leçons de perspective positive*, Paris, 1576.
- , *Les Plus Excellents Bastiments de France*, D. Thomson, ed., Paris, Sand & Conti, 1988.
- ASSASSIN, Sylvie, *Les bastides de l'Agenais*, Toulouse, Diagram édition, 1994.
- Atti e memorie della R. Deputazione di storia patria per le provincie di Romagna*, « La patria et la famiglia di Girolamo Marini, ingegnere militare del secolo XVI », 3rd series, v. XIX, 1927, p. 188-203.
- AUCLAIR, V., *La Compétence du dessinateur en France au XVI^e siècle. La copie et la perspective comme instruments de l'invention*, thèse de doctorat, Université de Paris-IV, 2003.
- BACHELARD, Gaston, *La poétique de l'espace*, Paris, PUF, 1964.
- BACHOT, Ambroise, *Le Timon du capitaine A.-B. Bachot, lequel conduira le lecteur parmi les guerrières mathématiques sur la reduction des unes aux autres figures géométriques et instrumens de mesurer toutes distances et représenter en perspective joint un traité fort utile des fortifications machines de guerre et aultres particularitez inventees par l'auteur*, Paris, 1587.
- , *Le gouvernail d'Amroise Bachot capitaine ingénieur du Roy lequel conduira le curieux de geometre en perspective dedans l'architecture des fortifications, machines*

137. CARVAIS, R., 2005 and 2005.

- de guerre et plusieurs aultres particularitez y continues*, Melun, 1598.
- BARKAN, Leonard, *Unearthing the Past: Archaeology and Aesthetics in the Making of Renaissance Culture*, New Haven, Conn., Yale University Press, 1999.
- BARNES, Jr., Carl F., *Villard de Honnecourt, the Artist and His Drawings. A Reference Publication in Art History*, Boston, G. K. Hall, 1982.
- BARON, F., « Enlumineurs, peintres et sculpteurs parisiens des XIII^e et XIV^e siècles d'après les rôles de la taille », *Bulletin archéologique du Comité des travaux historiques et scientifiques, nouvelle série*, IV, 1969, p. 37-121.
- BARON, Roger (ed.), *Hugonis de Sancto Victore Opera Propaedeutica : Practica geometriae, De grammatica, Epitome Dindimi in philosophiam*, Notre Dame, Ind., University of Notre Dame Press, 1966.
- BARTOLI, M. T., « Orthographia, Ichnographia, Scaenographia », *Studi e Documenti di Architettura*, VIII, 1978, p. 197-208.
- BESSE, Jean-Marc, *Les grandeurs de la terre: aspects du savoir géographique à la renaissance*, Lyon, ENS, 2003.
- BESSON, Jacques, *Le cosmolabe, ou, Instrument vniuersal: concernant toutes obseruations qui se peuuent faire par les sciences*, Paris, 1567-1569.
- , *Description et vsaige du compas euclidien : contenant la plus part des obseruations qui se sont en la geometrie perspectiue, astronomie, & corographie*, Paris, 1571.
- , *Theatre des instrumens mathematiques & mechaniques de Iaques Besson dauphinois doctemathematicien*. Lyon, 1579.
- BLOUNT, Anthony, *Philibert de l'Orme*, London, A. Zwemmer Ltd, 1958.
- BOUDON, F., « Les livres d'architecture de Jacques Androuet du Cerceau », in Jean GUILLAUME (ed.), *Les Traités d'architecture de la Renaissance*. Actes du colloque tenu à Tours du 1^{er} au 11 juillet 1981, Paris, Picard, 1988, p. 367-396.
- BOUELLES, Charles DE, *Que hoc volumine continentur*, Paris, 1510.
- , *Livre singulier et utile, touchant l'art pratique de geometrie, composé nouvellement en françoys*, Paris, 1542, reprinted in 1547 as *Géométrie pratique*.
- BOUTIER, Jean, *Les plans de Paris des origines (1493) à la fin du XVIII^e siècle*, Paris, Bibliothèque nationale de France, 2002.
- BRANNER, Robert, « Villard de Honnecourt, Reims, and the Origin of Gothic Architectural Drawing », *Gazette des Beaux Art*, LVI, 1963, p. 129-46.
- BRAUN, Georg & HOGENBERG, Franz, *Ciuitates orbis terrarum. Liber primus/Auctorum aere et impensis*, Antwerp, 1572.
- BRION-GUERRY, M., *Jean Pélerin, Viator, sa place dans l'histoire de la perspective*, Paris, Les Belles Lettres, 1962.
- BROC, Numa, « Quelle est la plus ancienne carte 'moderne' de la France ? », *Annales de Géographie*, XCII, 1983, p. 513-530.
- BUBNOV, Nicolaus, (ed.), *Gerberti postea Silvestris II papae opera mathematica*, Berlin, 1899, rpt., Hildesheim, Olms, 1963.
- BUCHER, François, « Medieval Architectural Design Methods, 800-1560 », *Gesta*, XI, 2,

- 1972, p. 37-51.
- BUISSERET, David, « Monarchs, Ministers, and Maps in France before the Accession of Louis XIV », in *Monarchs, Ministers, and Maps: The Emergence of Cartography as a Tool of Government in Early Modern Europe*, Chicago, Ill., University of Chicago Press, 1992, p. 99-123.
- , *Ingénieurs et fortifications avant Vauban. L'organisation d'un service royal aux XVI^e-XVII^e siècles*, Paris, CTHS Géographie, 2000.
- CAILLEUX, Philippe & LARDIN, Philippe, « Les mesures dans les bâtiments en Normandie à la fin du Moyen Âge », *Histoire & Mesure*, XVI, 3/4, 2001, p. 245-260.
- CAMPELL, Brian, *The Writings of the Roman Land Surveyors*, London, Society for Promotion of Roman Studies, 2000.
- CARDINALI, Philippe, *L'invention de la ville moderne : variations italiennes, 1297-1580*, Paris, Éditions de la Différence, 2002.
- CARVAIS, Robert, *La Chambre royale des Bâtiments. Juridiction professionnelle et droit de la construction à Paris, sous l'Ancien Régime*, 3 volumes, thèse d'État droit, Paris-II, 2001.
- , « L'ancien droit de l'urbanisme et ses composantes constructive et architecturale, socle d'un nouvel *ars* urbain aux XVII^e et XVIII^e siècles. Jalons pour une histoire totale du droit de l'urbanisme », *Revue d'histoire des sciences humaines*, special issue, « Discipliner la ville. L'émergence des savoirs urbains (XVIII^e-XX^e siècle) », Stéphane Van Damme (ed.), XII, 2005, p. 17-54.
- , « Les statuts des métiers de la construction et l'économie de l'industrie du bâtiment: premiers résultats d'une enquête en cours dans la France moderne », in S. CAVACIOTTI, (ed.), *L'Edilizia prima della Rivoluzione industriale secc. XIII-XVIII*, Atti della "Trentaseiesima Settimana di Studi", Istituto Internazionale di Storia Economica "F. Datini", Prato, Le Monnier, 2005, p. 137-65.
- CHASTEL, André, « Un épisode de la symbolique urbaine au XV^e siècle : Florence et Rome Citées de Dieu », in *Urbanisme et architecture. Études écrites et publiées en l'honneur de Pierre Lavedan*, Paris, H. Laurens, 1954, p. 75-79.
- CHAUVET, Jacques, *Instruction et usage du cosmometre. Ou Instrument uniuerfel pour les dimensions, tant geometriques que optiques, astronomiques & geographiques*, Paris, 1585.
- , *Méthodiques institutions de la vraye et parfaite arithmétique*, Paris, 1585.
- CHEVALIER, Bernard, « Le paysage urbain à la fin du Moyen Âge. Imaginations et réalités », in *Actes du Congrès de la Société des historiens médiévistes, Lyon, Juin 1980*, Lyon, 1981, p. 7-21.
- CLAGETT, Marshall, « The Medieval Latin Translations from the Arabic of Euclid's *Elements*, with Special Emphasis on the Versions of Adelard of Bath », *Isis*, XLIV, 1953, p. 16-30.
- , *Archimedes in the Middle Ages*, Madison, University of Wisconsin Press, 1964.
- , « *Euclides Graeco-Latinus*: A Hitherto Unknown Medieval Latin Translation of the Elements Made Directly from the Greek », *Harvard Studies in Classical Philology*, LXXI, 1966, p. 249-270.
- CONNANT, Kenneth, *Carolingian and Romanesque Architecture, 800-1200*, Harmondsworth, Penguin Books, 1959.

- , « The After-life of Vitruvius in the Middle Ages », *Journal of the Society of Architectural History*, xxxvii, 1968, p. 33-38.
- COULAIS, Jean-François, BLUMENFELD, André, DUGÉNY, François & PINON, Pierre, (eds), *Paris et l'Île-de-France*, Paris, Belin, 2003.
- COUSIN, Jean, *Livre de Perspective*, Paris, *Livre de Perspective*, Paris, Jehan le Royer, 1560 (éd. fac-similé, Verlag Walter Uhl, 1974) .
- CURTZE, Maximilan, « Über die im Mittelalter zur Feldmessung benutzten Instrumente », *Biblioteca Mathematica*, x, 1896, p. 65-72.
- DAVIS, Margaret Daly, *Piero della Francesca's Mathematical Treatises*, Ravenna, Longo Editore, 1977.
- DAVIS, Michael T. & NEAGLEY, Linda E., « Mechanics and Meaning: Plan Design at Saint-Urbain, Troyes and Saint-Ouen, Rouen », *Gesta*, xxxix, 2, 2000, p. 161-82.
- DERENS, Jean, *Le plan de Paris par Truschet et Hoyau, 1550*, Zürich, Editions Seefeld, 1980.
- DIVORNE, Françoise, *Les Bastides d'Aquitaine, du Bas-Languedoc et du Béarn : essai sur la régularité*, Bruxelles, Aux Archives d'architecture moderne, 1985.
- DOLZA, Luisa & VÉRIN, Hélène, « Figurer la mécanique : l'énigme des théâtres de machines de la Renaissance », *Revue d'Histoire Moderne et Contemporaine*, li, 2, 2004, p. 7-37.
- DRAPEYRON, Ludovic, « L'image de la France sous les derniers Valois (1525-1589) et sous les premiers Bourbons (1589-1682) », *Revue de Géographie*, xxiv, 1889, p. 1-15.
- DUBOURG GLATIGNY, Pascal, « La merveilleuse fabrique de l'oeil : anatomie et perspective à la fin du xvi^e siècle » *Roma moderna e contemporanea*, vii, 3, 1999, p. 369-394.
- , *Les deux règles de la perspective pratique de Vignoble, 1583*, Paris, CNRS, 2003.
- EDSON, Evelyn, *The World Map, 1300-1492: The Persistence of Tradition and Transformation*, Baltimore, Md., The Johns Hopkins University Press, 2007.
- EGMOND, Warren van, « How Algebra Came to France », in Cynthia HAY, (ed.), *Mathematics from Manuscript to Print 1300-1600*, Oxford, Clarendon Press, 1988, p. 127-144.
- ERRARD, Jean, *Le premier livre des instruments mathématiques*, Nancy, 1584.
- , *Les six premiers livres des elements d'Euclide*, Paris, 1598.
- , *Les neuf premiers livres des elements d'Euclide*, Paris, 1605.
- , *La fortification reduite en art et demonstrée*, Paris, 1600.
- FERRIER, Auger, *L'usage de l'astrolabe*, Paris, 1559.
- FIELD, J. V., *The Invention of Infinity: Mathematics and Art in the Renaissance*, Oxford University Press, Oxford, 1997.
- FINÉ, Oronce, *Nova Totius Galliae Descriptio*, Paris, 1525.
- , *Protomathesis*, Paris, 1532.
- , *In sex priores libros geometricorum elementorum Euclidis Megarensis demonstrationes. Quibus ipsius Euclidis textus graecus, suis locis insertus est : vnà cum interpretatione latina Bartolomaei Zamberti..., ad fidem geometricā per eundem Orontium recognita*, Paris, 1536.

- , *Briefve & isagogique Introduction sur la Judiciaire Astrologie*, Paris, 1551.
- , *De arithmetica practica libri quatuor*, Paris, 1555.
- FIRPO, L., *La città ideale del Rinascimento*, Turin, 1974.
- FLAMAND, Claude, *La guide des fortifications et conduite militaire pour bien se fortifier et deffendre*, Montbéliard, 1597.
- , *Les mathematiques et geometrie departies en six livres contenant ce qu'est le plus necessaire, pour l'utilité de la vie humaine*, Montbéliard, 1611a.
- , *La pratique et usage d'arpenter et mesurer toutes superficies de terre*, Montbéliard, 1611b.
- FLEGG, G., HAY, C. & MOSS, B. (eds), *Nicolas Chuquet, Renaissance Mathematician*, Dordrecht, Reidel, 1985.
- FOCARD, Jacques, *Paraphrase de l'astrolabe, contenant les principes de geometrie: la sphere, l'astrolabe, ou declaracion des choses celestes, le miroir du monde, ou exposition des parties de la terre*, Lyon, 1555.
- FONTÈS, Joseph, *Pierre Forcadet, lecteur du roy ès mathématiques (1560-1573)*, Toulouse, 1895-1897.
- FORCADEL, Pierre, *Les six premiers livres des Elements d'Euclide*, Paris, 1564.
- , *Les septième, huitième et neuvième livres des Éléments*, Paris, 1565.
- , *Le livre d'Archimède des pois qvi avssi est dict des choses tombantes en l'hvmide*, Paris, 1565.
- FOULLON, Abel, *Usaige et description de l'holometre pour scavoir mesurer toutes choses qui sont sous l'estanduë de l'oeil : tant en longueur et largeur, qu'un hauteur et profondeur*, Paris, 1555.
- FOURNIER, Gabriel, *Châteaux, villages et villes d'Auvergne au xv^e siècle, d'après l'Armorial de Guillaume Revel. Bibliothèque de la Société Française d'Archéologie*, 4, Droz, 1973.
- FRANGENBERG, Thomas, « The Image and the Moving Eye: Jean Pélerin (Viator) to Guidobaldo del Monte », *Journal of the Warburg and Courtauld Institutes*, XLIX, 1986, p. 150-171.
- , « Chorographies of Florence: The Use of City Views and City Plans in the Sixteenth Century », *Imago Mundi*, XLVI, 1994, p. 41-64.
- FRANKL, Paul, « Villard de Honnecourt and Magister 3 » and « Magister 2 and the Secret of the Lodges » in *The Gothic: Literary Sources and Interpretations through Eight Centuries*, Princeton, N.J., Princeton University Press, 1960, p. 35-48 and p. 48-54.
- FRIEDMAN, David, *Florentine New Towns: Urban Design in the Late Middle Ages*, Cambridge and London, The MIT Press, 1988.
- FRUGONI, Chiara, *A Distant City: Images of Urban Experience in the Medieval World*, William McCuaig, trans., Princeton, N.J., Princeton University Press, 1991.
- GARRIC, Jean-Philippe & al., *Les bastides d'Armagnac*, Toulouse, Diagram édition, 1992.
- GNUDI, M. T., Agostino Ramelli and Ambroise Bachot », *Technology and Culture*, xv, 4, 1974, p. 614-625.
- GOSS, John (ed.), *The City Maps of Europe: Sixteenth-century Town Plans from Braun & Hogenberg*, Chicago, Ill., Rand McNally, 1992.

- GRESSION, Philippe, « Le siège de Boulogne (1544) », *Dossiers d'histoire boulonnaise*, 1-2, 1977, p. 21-26, p. 21-28.
- GUYBERT, Alexandre, *Traicte familier, pour toiser, mesurer & exactement calculer toute maçonnerie tant en quarré & superfice : que cube & massiue, comme aussi les plates formes, turcies & leuees de riuieres, fossez & vuidanges de terres*, Paris, 1580.
- HANLOSER, Hans R. (ed.), *Villard de Honnecourt: Kritische Gesamtausgabe des Bauhüttenbuches ms. fr 19093 der Pariser Nationalbibliothek*, Vienna, Anton Schroll & Co., 1935.
- HAROUËL, J.-L., *L'embellissement des villes. L'urbanisme français au XVIII^e siècle*, Paris, Picard, 1993.
- HART, Vaughan & HICKS, Peter (eds) and trans., *Sebastiano Serlio on Architecture*, Vol. 1, New Haven, Conn., Yale University Press, 1996 and Vol. 2, 2001.
- HARVEY, P. D. A., « The Spread of Mapping to Scale in Europe, 1500-1550 », in *Imago et mensura mundi*, Carla Marzoli, ed., Rome, n.d., 2 volumes, v. II, p. 473-477.
- HENRY, Charles, « Sur les deux plus anciens traités français d'algorithme et de géométrie », *Bulletino di bibliografia e di storia delle scienze matematiche e fisiche*, xv, 1882, p. 53-70.
- HERVAL, René, « Un ingénieur siennois en France au XVI^e siècle : Girolamo Bellarmati [sic] et la création du Havre », *Études normandes*, xl, 1960, p. 33-43.
- HILLARD, Denise, « Jacques Besson et son *Théâtre des instrumens mathématiques* », *Revue française de l'Histoire du Livre*, xxii, 1979, p. 5-38.
- , « Jacques Besson et son *Théâtre des instrumens mathématiques* », *Revue française de l'Histoire du Livre*, 30, 1981, p. 47-69.
- HOOPYKAAS, R. & MINNAERT, M. G. J. (eds), *Simon Stevin: Science in the Netherlands around 1600*, The Hague, Martinus Nijhoff, 1970.
- HYDE, J. K., « Medieval Descriptions of Cities », *Bulletin of the John Rylands Library*, XLVIII, 1966, p. 308-340.
- JAMES, John, *Chartres: The Masons who Built a Legend*, London and Boston, Routledge & Kegan Paul, 1982.
- , *The Template-Makers of the Paris Basin*, Leura, Australia, West Grinstead Publishing, 1989.
- KARROW, Robert W., *Mapmakers of the Sixteenth Century and Their Maps: Bio-bibliographies of the Cartographers of Abraham Ortelius, 1570: Based on Leo Bagrow's A. Ortelii Catalogus cartographorum*, Chicago, Ill., Speculum Orbis Press, 1993.
- KELLER, Alexander Gustav, *A Theatre of Machines*, New York, The Macmillan Company, 1965.
- , « The Missing Years of Jacques Besson, Inventor of Machines, Teacher of Mathematics, Distiller of Oils, and Huguenot Pastor », *Technology and Culture*, xiv, 1973, p. 28-39.
- , « A Manuscript Version of Jacques Besson's Book of Machines, With His Unpublished Principles of Mechanics », in Bert S. HALL & C. DELNO (eds), *On Pre-Modern Technology and Science: A Volume of Studies in Honor of Lynn White, Jr.*, Malibu, Cal., Undena Publications, 1976.
- KEMP, Martin, *The Science of Art: Optical Themes in Western Art from Brunelleschi to*

- Seurat, New Haven, Conn., Yale University Press, 1990.
- KOEMAN, Cornelius, *The History of Abraham Ortelius and his Theatrum Orbis Terrarum*, New York, 1964.
- LANG, Susan, "The Ideal City », *Architectural Review*, CXII, 1952, p. 91-101.
- LARDIN, Philippe, *Entre tradition et modernité: Les premières années du Havre (1517-1541)*, Presses universitaires de Rouen, Rouen, 2003.
- LA ROCHE, Étienne DE, *Larismetique*, Lyon, 1520.
- LAVEDAN, Pierre, *Représentation des villes dans l'art du Moyen Âge*, Paris, Van Oest, 1954.
- LEBLOND, Hervé, « Recherches métrologiques sur les plans des bastides », *Histoire & Mesure*, II, 1987, p. 55-88.
- LE LIEUR, Jacques, *Le Livre des Fontaines, Connaître Rouen* IV, Édition de point de vue, Paris, 2005.
- LE MOLLÉ, R., « Le mythe de la ville idéale à l'époque de la Renaissance italienne », *Annali della Scuola Normale Superiore di Pisa*, II, 1972, p. 275-310.
- LEWIS, Suzanne, *The Art of Matthew Paris in the Chronica majora*, Berkeley, University of California Press, 1987.
- LILLEY, Keith D., « Mapping the Medieval City: Plan Analysis and Urban History », *Urban History*, XXVII, 2000, p. 5-30.
- MACDONALD, William L., *The Architecture of the Roman Empire*, v. II, *An Urban Appraisal*, New Haven, Conn., Yale University Press, 1986.
- MENNHER, Valentin, *Practicque povr brievement apprendre à ciffrer, & tenir liure de comptes avec la regle de Coss, & geometrie*, Antwerp, 1565.
- MERLIERS, Jean DES, *L'vsage dv qvarré geometrique amplement décrit et démontré*, Paris, 1573.
- Merlier, Jean des, *La practique de geometrie descripte et démontrée*, Paris, 1575.
- MESMES, Jean Pierre DES, « Traicté des mesures géométriques, des hauteurs accessibles, ou inaccessibles, & de toutes choses pleines ou profondes, selon leur longueur, largeur, & profondeur », Paris, 1560.
- MEURER, Peter H., « De verboden eerste uitgave van de Henegouwen-kaart door Jacques de Surhon uit het jaar 1572 », *Caerta Thresoor*, XIII, 1995, p. 81-86.
- MORTET, Victor, « Note historique sur les emploi des procédés matériels et d'instruments usités dans la géométrie pratique au moyen âge (x^e-xiii^e siècles) », *Congrès international de philosophie*, 2nd session, Geneva, Kundig, 1904, p. 925-942.
- MORTET, Victor & DESCHAMPS, Paul, *Recueil de textes relatifs à l'histoire de l'architecture et à la condition des architectes en France au Moyen Âge*, 2 vols., Paris, A. Picard, 1911-1929.
- MÜNSTER, Sebastien, *Das gantz Franckreich so vor zeiten Gallia Narbonensis, Lugdenensis, Belgica und Celtica ist genent worden*, Basel, 1545.
- MURATORE, G., *La città rinascimentale. Tipi e modelli attraverso i trattati*, Milan, Mazzotta, 1975.
- NÈGRE, Valéri & PETIT, Marie-Laure, *Les bastides du Quercy*, Toulouse, Diagram éditions, 1995.

- NUTI, Lucia, « The Perspective Plan in the Sixteenth Century: The Invention of a Representational Language », *Art Bulletin*, LXXVI, 1994, p. 105-128.
- OGEROLLES, Jean D', *Épitomé de la corographie d'Europe, illustré des pourtraitz des villes plus renommées d'icelle, mis en françoys, par Guillaume Gueroult*, Lyon, 1553.
- ORME, Philibet DE L', *Traité d'architecture*, Jean-Marie PÉROUSE DE MONTCLOS (ed.), Paris, Laget, 1988.
- PACIOLI, Luca, *Summa de arithmetica geometria proportioni e proportionalita*, Venice, 1494.
- PAILLARD, Charles & HÉRELLE, G., *L'invasion allemande en 1544 : fragments d'une histoire militaire et diplomatique de l'expédition de Charles Quint*, Paris, Champion, 1884.
- PATETTA, Luciano, *L'architettura del Quattrocento a Milano*, Milan, Co-operativa Libreria Universitaria del Politecnico, 1987.
- PATRICIOS, N. N., « Concepts of Space in Urban Design, Architecture and Art », *Leonardo* VI, 1973, p. 311-318.
- PAUWEL, Yves, *L'architecture au temps de la Pleiade*, Paris, G. Monfort, 2002.
- PELETIER, Jacques, *L'arithmétique de Jacques Peletier du Mans, départie en quatre livres*, Poitiers, 1549.
- , *L'algèbre*, Lyon, 1554.
- , *In Euclidis elementa geometrica demonstrationum libri sex*, Lyon, 1557.
- , *De occulta parte nümerorum, quam algebra avocant, libri duo*, Paris, 1560.
- , *Commentarii tres. I. De dimensione circuli. II. De contactu linearum: & de duabus lineis in eodem plano neque parallelis, neque concurrentibus. III. De constitutione horoscopi*, Basel, 1563.
- , *De usu geometriae, liber unus...*, Paris, 1572.
- PELLETIER, Monique, *Géographie du monde au Moyen Age et à la Renaissance*, Paris, Éditions du CTHS, 1989.
- PÉROUSE DE MONTCLOS, Jean-Marie, *Philibert De l'Orme : Architecte du roi (1514-1570)*, Paris, Mengès, 2000.
- PICON, Antoine & ROBERT, Jean-Pierre, *Un atlas parisien. Le dessus des cartes*, Paris, Picard, 1999.
- PINET, Antoine DE, *Plantz, pourtraitz et descriptions de plusieurs villes et forteresses tant de l'Europe, asie d'Afrique, que des Indes et terres neuves*, Lyons, 1564.
- PINON, P., LE BOUDEC, B. & CARRÉ, D. (eds), *Les plans de Paris. Histoire d'une capitale*, Paris, Le Passage, 2004.
- PINTO, John, « Origins and Development of the Ichnographic City Plan », *Journal of the Society of Architectural Historians*, xxxv, 1976, p. 35-50.
- POTIÉ, P., *Philibert de l'Orme. Figures de la pensée constructive*, Marseilles, Parenthèses, 1996.
- PULOL, Florence, « L'élaboration de l'image symbolique de la bastide », *Annales du Midi*, ciii, 195, 1991, p. 345-67.
- RAMELLI, Agostino, *Le diverse et artificiose machine*, Paris, 1588.

- RIVOLO, M. T. & SIMI, A., « Il Calcolo delle Radici Quadrate e Cubiche in Italia da Fibonacci a Bombelli », *Archive for History of Exact Sciences*, LII, 2, 1998, p. 161-93.
- ROSE, Paul Lawrence, *The Italian Renaissance in Mathematics*, Geneva, Droz, 1975.
- ROSENAU, Helen, *The Ideal City, Its Architectural Evolution in Europe*, 3rd edition, Methuen, London, 1983.
- ROZET, A. & LEMBAY, J. F., *L'invasion de la France et le siège de Saint-Dizier par Charles-Quint en 1544*, Paris, Plong, 1910.
- RYKWERT, Joseph, *The Dancing Column: On Order in Architecture*, Cambridge, Mass., MIT Press, 1996.
- SAINT-BLANQUAT, Odon DE LINGU DE, « Comment se sont créés les bastides du Sud-ouest de la France », *Annales E.S.C.*, IV, 1949, p. 278-289.
- SAINT VICTOR, Hugh OF, *Practical Geometry*, Frederick A. Homann, trans., *Mediaeval Philosophical Texts in Translation*, 29), Milwaukee, Wis., Marquette University Press, 1991.
- SALAMAGNE, Alain, *Construire au Moyen âge. Les chantiers de fortification de Douai, Villeneuve-d'Ascq*, Presses universitaires du Septentrion, 2001.
- SCHULZ, Juergen, « Jacopo Barberi's View of Venice: Map Making, City Views, and Moralized Geography before the year 1500 », *Art Bulletin*, LX, 1978, p. 425-474.
- SHELBY, Lon, « Mediaeval Masons' Tools: The Level and the Plumb Rule », *Technology and Culture*, II, 1961, p. 127-130.
- , « Mediaeval Masons' Tools, Compass and Square », *Technology and Culture*, VI, 1965, p. 72-81.
- , « The Education of Medieval Master Masons », *Medieval Studies*, XXXII, 1970, p. 1-26.
- , « Medieval Mason's Templates », *Journal of the Society of Architectural Historians*, XXX, 1971, p. 140-52.
- , « The Geometrical Knowledge of Medieval Master Masons », *Speculum*, XLVII, 1972, p. 34-53.
- , *Gothic Design Techniques: The Fifteenth-Century Design Booklets of Mathes Roriczer and Hanns Schmuttermayer*, Carbondale and Edwardsville, Ill., University of Southern Illinois Press, 1977.
- SIMI, A. & RIGATELLI, L. Toti, « Some Fourteenth- and Fifteenth-Century Texts on Practical Geometry », in M. FOLKERTS & J. P. HOGENDIJK (eds), *Vestigia mathematica: Studies in medieval and early modern mathematics in honour of H.L.L. Busard*, Amsterdam, Rodopi, 1993, p. 453-470.
- SMITH, Cyril Stanley & HAWTHORNE, John G. (eds.) and trans., *Mappae Clavicula: A Little Key to the World of Medieval Techniques*, Transactions of the American Philosophical Society, n.s. 64, pt. 4, 1974.
- SMITH, Pamela H., *The Body of the Artisan: Art and Experience in the Scientific Revolution*, Chicago, Ill., University of Chicago Press, 2004.
- SNYDER, John P., *Flattening the Earth: Two Thousand Years of Map Projections*, Chicago, Ill., University of Chicago Press, 1993.
- STÖFFLER, Johann, *Traité de la composition et fabrique de l'astrolabe, & de son usage avec les preceptes de mesures geometriques*, Jean Pierre des Meses, trans., Paris, 1560.

- SUBERVILLE, Henri DE, *L'Henry-metre, instrument royale, et universal, avec sa theorique, usage et pratique demonstree par les propositions elementaires d'Euclide, & regles famillieres d'arithmetique: & aussi sans arithmetique lequel prend toutes mesures geometriques, & astronomiques, qui luy sont circulairement opposées tant au ciel, qu'en la terre, sur une seule station, par un seul triangle orthogone...*, Paris, 1598.
- TANNERY, Paul (ed.), « Le Traité du quadrant du Maître Robert Anglès (Montpellier XIII^e siècle). Texte latine et ancienne traduction grecque », *Mémoires Scientifiques*, v, 188. Reprinted from *Notice et extraits des manuscrits de la Bibliothèque Nationale*, xxxv, pt. 2, 1897, p. 561-640.
- , « La géométrie au XI^e siècle », *Mémoires scientifiques*, J. L. HEIBERG & al. (ed.), Paris and Toulouse, E. Privat, 1922, p. 7-102.
- TURNBULL, David, « The Ad Hoc Collective Work of Building Gothic Cathedrals with Templates, String, and Geometry », *Science, Technology, and Human Values* xviii, 3, 1993, p. 315-340.
- , *Masons, Tricksters and Cartographers: Comparative Studies in the Sociology of Scientific and Indigenous Knowledge*, Amsterdam, Harwood Academic Publishers, 2000.
- ULLMAN, B. L., « Geometry in the Medieval Quadrivium », *Studi di bibliografia e di storia in onore di Tammaro de Marinis*, Verona, Stamperia Valdonega, 1964, v. 4, p. 263-285.
- VASALY, Ann, *Representations: Images of the World in Ciceronian Oratory*, Berkeley, University of California Press, 1993.
- VÉRIN, Hélène, *La gloire des ingénieurs*, Paris Albin Michel, 1993.
- , « La réduction en art et la science pratique au XVI^e siècle », in R. SALAIS, E. CHATEL & D. RIVAUD-DANSET (eds), *Raisons pratiques, « Institutions et conventions »*, ix, 1998, p. 119-144.
- , « Généalogie de la réduction en art. Aux sources de la rationalité moderne », in T. GAUDIN & A. HATCHUEL (eds), *Les nouvelles raisons du savoir*, Paris, Édition de l'Aube, 2002, p. 29-41.
- VOSS, Mary J., « Between the Cannon and the Book: Mathematicians and Military Culture in Sixteenth-Century Italy », Ph.D. dissertation, The Johns Hopkins University, 1994.
- WOLFE, Michael, « The *Bonnes Villes* of France during the Hundred Years' War », in IVY CORFIS & Michael WOLFE (eds), *The Medieval City Under Siege*, Woodbridge, UK., Boydell & Brewer, 1995, p. 63-87.
- , « Building a Bastion in Early Modern Amiens », *Proceedings of the Western Society for French History*, xxv, 1998, p. 36-48.
- , « Prélude à la paix : le siège d'Amiens (1597) et ses conséquences militaires et diplomatiques », in Jean-François LABOURDETTE, Jean-Pierre POUSSOU & Marie-Catherine VIGNAL, *Le Traité de Vervins*, Paris, Presses de l'Université de Paris-Sorbonne, 2000, p. 61-79.
- WOODWARD, David, « Reality, Symbolism, Time and Space in Medieval World Maps », *Annales of the Association of American Geographers*, LXXV, 1985, p. 510-521.
- ZAITSEV, Evgeny A., « The Meaning of Early Medieval Geometry: From Euclid and Surveyors' Manuals to Christian Philosophy », *Isis*, xc, 3, 1999, p. 522-553.