Geometric Proportioning in Sixteenth-Century Fortifications: The Design Proposals of Italian Military Engineer Giovanni Battista Antonelli

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Abstract The geometry underlying the design of sixteenth-century fortifications is a subject of considerable interest among scholars of military architecture. Many treatises from the period emphasize the importance of using geometrical constructions for the design of defensive elements in proper proportion to the entire edifice. One treatise, the *Epitomi delle fortificationi moderne*, was written in 1560–1561 by Italian military engineer Giovanni Battista Antonelli (1527–1588), whose family had been in the service of the Spanish crown for nearly a century. In this paper, we investigate the methods set forth by Antonelli in his work, paying particular attention to the geometrical design of typical architectural elements in fortifications of the early modern period. We then provide a case study of the reconstruction of a bastion according to the engineer’s proposals.

Military Architecture and Geometry in the Late Sixteenth Century¹

By the end of the sixteenth century, numerous treatises on military architecture had been written in Italy and Spain to disseminate practical knowledge in the field of modern fortifications. These texts provide evidence of the socio-cultural context in

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¹ First and second paragraphs by Sandro Parrinello (“[Military Architecture and Geometry in the Late Sixteenth Century](#)”, “[Antonelli’s Contribution to Fortification Theory and Practice](#)”); third and fourth paragraphs (“[Geometrical Arguments in the Epitomi](#)”, “[Proportions of the Royal Bastion](#)”) and “[Conclusion](#)” by Silvia Bertacchi.

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which they were written, and the entire body of works constitutes a valuable framework for understanding the technical and scientific advances being made in warfare during the early modern period.

The treatises make reference not only to common technical arguments and widespread working practices, but also discuss novel defence solutions that reflect the evolving times. Early modern era engineers needed to be well-versed in a number of disciplines, and a solid grounding in mathematics, geometry and drawing were basic requirements for any rational reflection on modern fortification, as they were deeply linked to the design itself. In fact, the plans of fortresses were calculated according to the proportional allocation of the entire garrison, whose overall dimensions were dictated by the trajectories of the firearms to be employed.

Euclidean geometry and the study of plane figures were also crucial to the design of fortresses and citadels. Geometry had experienced a renaissance, and theorists and soldiers—often in fierce competition for supremacy in matters of war—were interested in how the mathematical system could be applied to military design.

It is no coincidence that the vast majority of war treatises were written by Italian engineers; the proliferation of treatises in Italy was fostered not only by the intellectual environment, but by the political climate as well, for despite its cultural supremacy over the rest of Europe, the country was being torn apart by war.²

Among the numerous sixteenth century works on modern fortification³ is a precious manuscript by Giovanni Battista Antonelli (1527–1588) that has fortunately survived to the present day and is now preserved in Spain.⁴

Antonelli was an engineer for King Philip II of Spain in the mid-sixteenth century,⁵ having received his early education in his native Italy. Little is known of

² On different periods of the history of fortification see Cobos Guerra (2011: pp. 181–189).

³ Several sixteenth-century manuscripts on fortification can also be consulted online: <https://archive.org>; Internet Archive; the Getty Research Institute; <http://www.internetculturale.it>; *Internet Culturale. Cataloghi e Collezioni Digitali delle Biblioteche Italiane*.

⁴ The manuscript is at present preserved at the *Instituto de Historia y Cultura Militar*, Toledo, Spain. Since 1960, it has been part of the collection of the *Museo del Ejército* in Madrid, Spain (De la Torre Echávarri 2007). A copy of the treatise by Antonelli was reprinted in its original form by Professor Mario Sartor, who also transcribed the text of the book (Sartor 2004a: pp. 201–367).

⁵ The bibliography on the Antonellis is not very extensive, although there are some important studies on the whole family and especially on the most famous of them, Battista Antonelli (1547–1616). In the nineteenth century, Eugenio Llaguno y Amirola wrote a compendium on the most popular architects of the kingdom, at a later stage completed by Juan Augustin Céan Bermúdez (1829), that presents some interesting documents about Giovanni Battista's military works, and above all, on his career in hydraulic engineering and river navigation. Later, during Italian fascism, Leone Maggiorotti (1939) wrote an essay to emphasize Italian genius in warfare and extolling also the Antonellis' talents. Diego Angulo Íñiguez (1942) commented at length on Battista's personality and his key role in American military history. A growing number of studies have been published over the last decade, with works by scholars Mario Sartor (2004a, b), Graziano Gasparini (2007) and Alicia Cámara Muñoz (2004), taking account of the precious archival documentation preserved in Spain. In 2003, a conference held in Gatteo (FC, Italy), hometown of the Antonellis, celebrated the entire family and its contribution to fortifications all over the world: *Omaggio agli Antonelli, Primo Convegno Internazionale sull'Architettura Militare degli Antonelli da Gatteo*, Gatteo 3–5 Ottobre 2003, Oratorio di San Rocco. Since 2005, Professor Sandro Parrinello has been carrying out metric surveys of Battista Antonelli's fortresses, in particular in the Caribbean area, and in 2013, Ph.D. Silvia Bertacchi defended her doctoral thesis on the contribution of Giovanni Battista Antonelli in military theory and practice.

his early life, so it is not clear whether he had any army training, but later evidence shows that he took part in the Picardy military campaigns of 1557, when he was about 30 years old. The first-hand knowledge of fieldwork and army encampments that Antonelli received in Flanders provided him with the necessary expertise for his later works on fortified architecture. Not much can be said about Antonelli's professional career before he moved to Toledo in 1559 to serve the Spanish crown, taking advantage of a truce between France and Spain, the two major powers in Europe at the time.

The decade of the 1560s are rightly considered Giovanni Battista's most prolific: soon upon his arrival in Spain, he started work on his treatise on modern fortification to demonstrate his design expertise to the council; he was called immediately afterwards into the king's service to defend Spain's eastern coast from fierce pirate attacks in the Mediterranean. He was also placed in charge of a number of fortification projects, including new bastions to replace the old city walls around Alicante, the new fortified wall of Cartagena, not to mention the design and construction of the Fort of Bernia, Antonelli's major work (Parrinello and Bertacchi 2014a, b).⁶

Through his skills, Antonelli gained the king's utmost trust, so much so that other family members joined him in the Iberian Peninsula to help defend the kingdom and the Caribbean territories overseas. It is worth noting that Antonelli's younger brother Battista (1547–1616) also became a widely acclaimed military engineer. The success of Battista's fortresses overseas—still standing today—completely overshadowed the early success of his older brother, whose later military projects were almost all dismal failures that never got built. Giovanni Battista thereafter abandoned the field of military fortifications for a career in hydraulic engineering until his death in 1588.

Antonelli's Contribution to Fortification Theory and Practice

Antonelli's role and his treatise in the field of defence theory and practice have been the subject of in-depth studies (Bertacchi 2013: pp. 9–107) attempting to understand the logic underlying the architectural composition and geometrical models that the engineer used in his defensive projects in Spain and which later spread to the New World (Parrinello 2013).

Given the lack of solid information about the “school” in which Antonelli may have received his education, the existence of a manuscript copy containing evidence of his theoretical understanding is a precious font of information about the author and about the development of fortification theory and practice.

Antonelli's treatise, *Epitomi delle Fortificationi Moderne*, was written in a short space of time (1560–1561) and is a compendium of the engineer's background in the field of military practice. It is organized into the three main areas of interest at the time: modern fortification, artillery and army quartering.

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⁶ The history of the fort, located in the Valencian region in the Province of Alicante, and its geometrical features have been examined in depth in the doctoral thesis by Bertacchi (2013: pp. 185–222).

The surprisingly unique history of the manuscript deserves some mention. As explained in the text itself, the original work had already been completed by Antonelli before the military campaigns in Flanders, but was then stolen from General Captain Manrique de Lara, to whom it had been dedicated and presented (Antonelli 1560b: folio 2r).⁷ For this reason, Manrique de Lara, who was then a captain of artillery, solicited the engineer for a new, shorter version that would focus on the defence practices of modern fortified sites. This may explain both the brevity and the title of the surviving treatise: the term “epitome” refers to a summary of a broader work (Cámara Muñoz 2004: p. 169).

It should be mentioned that even the original version of Antonelli’s text was far from complete: he had set out to produce a major work on conquest, military machinery, defence against siege and territorial surveying (Antonelli 1560b: folio 6r), but although started, these sections were unfortunately never completed.

The surviving document is handwritten; it is not an autograph, but was rewritten carefully in fair copy, probably as a bound reproduction prepared for its last revision before printing. The nearly 150 sheets of the treatise include 44 well-preserved coloured illustrations, in part attributed to the engineer himself (Sartor 2004a: pp. 46–49).

The treatise is organized into the following three sections:

Epitomi delle Fortificationi Moderne di Giovanbatta Antonelli (Antonelli 1560b) discusses the elements for the fortification of cities and citadels and the best sites for locating a fortress. This first section (folios 2–41r) was actually written after the third, and was completed by the end of 1560. Dedicated to the captain of artillery Manrique de Lara, it focuses specifically on the design of fortified posts and defensive elements according to the new theories of fortification in the early modern age (Figs. 1, 2), although it also includes some information about the best sites and building techniques for traditional rammed earth construction as applied to fortifications. This section contains Antonelli’s exposition of the geometrical construction of a bastion wall to protect the city.

Section two (folios 41v–122v), the *Epitomi del Trattato dell’Artiglieria* (Antonelli 1561), was actually the last to be completed and is divided into three books.⁸ This section focuses on artillery and carefully describes the production of firearms and gunpowder. Dedicated to King Philip II, this is the longest section of the treatise, although it does not cover all of the topics listed in the table of contents, and seems incomplete. It appears that many paragraphs are missing and even the figures are chaotically distributed throughout the text with no regard for any logic in their presentation. The illustrations related to firearms, however, are actually quite pleasing to the eye, showing a great level of attention to detail and skilful use of colours (Fig. 3).

⁷ According to the engineer, the Captain asked for another copy, but just a summary on the topic of fortifications. In the end, Antonelli wrote two additional essays, dedicating them to the Captain and to the King.

⁸ First book with sonnets and preface (folios 45v–68v); second book (folios 69r–99r): “Il secondo libro dell’artiglieria dove si tratta del finirla;” third book (folios 99r–122v): “Terzo libro. Dove si tratta della maniera di servirsi dell’artiglieria”.

Fig. 1 Illustration from the first section of the *Epitomi delle fortificationi moderne*, showing the plan of a cavalier raised behind the gorge of a bastion or far from a curtain (Antonelli 1560b: folio 22r, no. EMH_1534). Antonelli suggests building this platform to fire on enemies from a higher position. Reproduced by permission of the *Museo del Ejército*, Toledo, Spain

Fig. 2 Illustration from the *Epitomi delle fortificationi moderne*, showing the axonometric view of a cavalier raised behind the gorge of a bastion or far from a curtain (Antonelli 1560b: folio 22v, no. EMH_1689). See the corresponding plan in Fig. 1. Reproduced by permission of the *Museo del Ejército*, Toledo, Spain

Fig. 3 The detailed and colourful figure of a cannon is from the second book of artillery (folio 76r, Table 17, no. EMH_1588). Reproduced by permission of the *Museo del Ejército*, Toledo, Spain

Finally, the *Epitomi della Manera di Alloggiare un Campo* (Antonelli 1560a) suggests ten possible military camps suitable for a vast number of sites. This third and shortest section of the treatise (folios 123r–146v) was the earliest to be written, and its beautiful illustrations are attributed to Giovanni Battista (Figs. 4, 5).

Despite this evident structuring of the content of the treatise, the general theoretical outline tends to be unclear and the information ambiguous. In other words, the treatise tends to be more of a practical manual than a rigorous contribution to the theoretical basis of the discipline. On the one hand, while more than one chapter may deal with the same topic, thus providing in-depth examination of some concepts and operating principles, on the other, the text sometimes leaves out information crucial for an understanding of the overall process and the logic of the different steps to be taken. It is not yet clear whether this lack of detailed description stems from the author's assumption that potential readers would already have a good understanding of the subject—thus making detailed and lengthy explanations superfluous—or from the author's own lack of in-depth knowledge about certain notions and thus the decision not to analyse them in further detail.

Although far from being a master treatise writer, Antonelli makes proper use of the language and includes some erudite quotes from the Classical tradition, revealing his cultural education and background. He writes in Italian, although some Spanish terms occasionally appear in the text.

There is no question that Antonelli's primary aim in writing the treatise was to promote himself in the eyes of the sovereign's close entourage and, to the work's detriment, he made frequent reference to other texts. As such, the treatise has often been considered a lesser work, for as has been said, mere imitations of existing

Fig. 4 Image of an army encampment from the *Epitomi della Manera di Alloggiare un Campo*, the third section of the treatise. Camp settlement for a regular site defended by geographical features, i.e., a basin and a river (folio 140r, no. EMH_1647). Reproduced by permission of the Museo del Ejército, Toledo, Spain

Fig. 5 Image from the *Epitomi della Manera di Alloggiare un Campo*: camp settlement for an irregular site protected by a river and a ravine (folio 141r, no. EMH_1648). Reproduced by permission of the Museo del Ejército, Toledo, Spain

treatises, particularly those dedicated to the king for promotional purposes, often proved to be unproductive and fruitless, insofar as they did not serve the purpose of advancing the discipline, managing only to steal others' ideas (De Castro Fernández and Cobos Guerra 2000: p. 246).

It is difficult to say what kind of relationship Antonelli had with other engineers, because of the lack of documentation. It is possible that he copied some models from his colleagues, whose treatises were circulating at the time and most likely influenced his work. This has been partially confirmed through stylistic analysis of some portions of the text, revealing their similarities to the works of other authors.⁹

However, in the matter of discussing fortifications, Antonelli ultimately proves to be a skilled expert, capable of elaborating competently on actions of war, as well as a good strategist and intelligent designer. He recommends that the reader analyse projects carefully, not leaving anything to chance. Regarding city defence, he repeatedly highlights how important it is to be familiar with both offensive and defensive techniques, as they are two complementary aspects of efficient design. It is a shame that Antonelli did not follow his own advice, for almost all of his defensive projects in the Spanish kingdom proved to be miserable failures.

Geometrical Arguments in the *Epitomi*

Among the many skills listed by the Roman author Vitruvius as being necessary for an architect, a knowledge of geometry is considered essential for design and measurement; even more so is competence in drawing, so that the final project can be depicted even before it is built, allowing full control of the effectiveness of the idea prior to its execution (Gros 1997: p. I, I).

Centuries later, in the light of renewed sixteenth-century interest in the art of combat, geometry was still considered to be the “master of all arts” and essential for designing excellent fortresses (Cámara Muñoz 1981: p. 260), because the proportions required between the fortified building as a whole and its individual parts could be verified by geometry. This is mentioned again and again in the literature: Pedro Luis Escrivá (1490–unknown),¹⁰ author of the first text on the great Spanish fortification of the early modern era, considered geometry as the science for drawing; the important Italian mathematician and engineer Giacomo Lanteri (unknown–1560) stated that an architect expert in geometry and mathematics could easily outclass a soldier talented with practical ability, since only by combining theory and practice can one deal with the complex matter of fortification (see Lanteri 1559: pp. I, I, 3; Lanteri 1557: II, 53); Giovanni Battista de' Zanchi (1515–1586), another military engineer working at the time, asserted that geometry

⁹ See Cattaneo (Cattaneo and 1554) and Zanchi (1554), whose works had probably been consulted by the compatriot engineer. Pietro Cattaneo (1510–1574) was an Italian architect and Giovanni Battista de' Zanchi (1515–1586) an Italian military engineer.

¹⁰ On Escrivá as treatise writer and his dissertation *Apología* (1538), see among others Sánchez Gijón (1995: pp. 109–145).

and mathematics are essential to the design of fortresses (Zanchi 1554: p. 57), as did Spanish engineer Cristóbal de Rojas (1555–1614).¹¹

Civil and military architecture of the sixteenth century evoked classical tradition, although it only adhered to the first two aspects of the Vitruvian notions of *firmitas*, *utilitas* and *venustas*,¹² which referred to the structural resistance (*firmitas*) and effectiveness (*utilitas*) of a building. Engineers generally did not advise any form of embellishment for the design of strongholds, as it was considered far more important for them to appear intimidating than aesthetically pleasing (*venustas*) (Tartaglia 1554: p. 69v; Maggi and Castriotto 1564: p. 26v).¹³

Of course, since the plan of a fortress was modelled through the use of basic geometrical rules (straight lines representing firearm trajectories, parallel and perpendicular lines, straight angles) and simple shapes (regular quadrilaterals such as the square, plane figures such as the pentagon or many-sided polygons), a knowledge of Euclidean geometry was extremely common among engineers. Thus, some coeval or later military treatises devote ample discussion to the different types of angles and polygons (Lanteri 1559: pp. II, XI, 92–94; Cattaneo 1564: pp. 3v–15v; Rojas 1598: pp. 4r–29v] (Fig. 6), encouraging the advanced study of postulates and definitions from Euclid's *Elements* (Fig. 7).¹⁴

Antonelli's *Epitomi*, instead, may seem to completely lack any such deference to the geometrical rules for drawing, given that none of the sections is dedicated exclusively to geometrical compositions; however, this is not actually the case: the basic geometry is implicit throughout, as can be seen by indirect clues.

Antonelli believed that a kingdom can be protected by natural features (for example, if the site is surrounded by a river or a sea, by mountains or forests) or by human strategy (such as the construction of fortresses to defend strategic points and outposts on the boundaries against external attacks), or by a combination of both (Antonelli 1560b: folio 5r).¹⁵ Through clever engineering, even a kingdom devoid of natural features of defence could be protected. In terms of the engineer's activity, Antonelli points out that, on the one hand, one should consider that “artificial protection” is contingent on the shape of a fortified place, and on the other, that it depends on the construction techniques and materials employed (the so-called “*materia*”).¹⁶

¹¹ “La Primera de las tres cosas que han de concurrir en el Ingeniero, es la Geometria,” (Rojas 1598: p. II, 1v). The engineer transcribes in his treatise a summary of the lessons taught at the *Academia de Matemáticas de Madrid*.

¹² Latin terms indicating durability, utility and beauty of a building.

¹³ Nicolò Tartaglia (1449–1557), an Italian mathematician, states in clear terms that “dove è necessario la fortezza, non si debbe far conto di bellezza” (Gionta del libro sesto, quesito I) and Castriotto approves some decoration if not too costly, even though solidity is the most important feature.

¹⁴ Gerolamo Cattaneo (1520–1580) was an Italian treatise writer, mathematician and architect.

¹⁵ Explanations are given in *Qualità de Regni*, folios 4v–5r and also in *Fortezza de' siti*, folios 8r–9r, where, after a dedicatory introduction, the text clarifies the choice of the best location for a fort.

¹⁶ The term used by Antonelli was “*artificio*” or “*industria*,” referring to what has been created by human activity, as opposed to nature. See Giovanni Battista's opinion in *Quello che fa forte una Città*, folios 11r–11v. On this topic see also Tartaglia (1554: p. VI, 62v), who instead considers the shape as the most important feature of a fortification.

Fig. 6 A few geometrical constructions from the fifth chapter of the treatise by Cristóbal de Rojas (1598), where the engineer explains plane figures and Euclid's prepositions

Fig. 7 A method for tracing angles of a figure starting from the number of its sides. In commenting on Euclid's postulates, the author says to subtract four right angles (*square shape*) from twice the number of sides of the figure and then to divide the result by the number of sides. For example, for a pentagon: 5×2 sides $- 4 = 6$ right angles, to be divided by the same number of sides (5), so $6/5 = 1$ right angle $+ 1/5 = 90^\circ + (90^\circ/5 = 18^\circ) = 108^\circ$, which is the value of the internal angle of the pentagon (Lanteri 1559: p. 93: *Pratica di formare gli angoli*)

When considering the best shape for fortification, a few sixteenth-century treatises (Zanchi 1554: p. 24; Lanteri 1557: p. I, 28) preferred many-sided plans tending to a circular shape (Fig. 8). Antonelli was among those who believed it was best to build as many bastions as possible on a many-sided fortification, using “five, six, seven, eight or more angles (...) and the more there are, the better they are, and the less they are, the worse they are” (Antonelli 1560b: folio 11r).

Thus, whereas 10- and 12-sided curtains were suggested for determining obtuse-angle bastions that would be extremely resistant to attacks by artillery, triangular- and quadrilateral-shaped plans ought to be avoided (Fig. 9). This notion was frequently expressed by engineers of the time (Tartaglia 1554: pp. 6,

Fig. 8 Best regular polygons for fortifications. *Top* Cattaneo (1554: pp. 12v, 13v, 14v). *Bottom* Rojas (1598: pp. 43r, 43v, 44r)

Fig. 9 Shapes unsuitable for fortifications (*square and triangle*) because of their sharp and non-obtuse bastions (Rojas 1598: p. 40v, 42r)

IV; Zanchi 1554: pp. 23, 34–39; Maggi and Castriotto 1564: pp. I, III, 7v and II, III, 43r–v; Theti 1569: pp. 5, 18–19),¹⁷ even though the square fort—despite the bastions’ sharp angles—was often adopted for smaller outposts (Rojas 1598: pp. III, 38v).

The choice in shape is actually quite limited, since complex many-sided shapes are unlikely to be adopted for real fortifications because of constraints in terms of geographical features and cost. Nevertheless, once the shape has been chosen, the effectiveness of a fortified post can be enhanced through the addition of specific architectural elements, such as bastions, curtains, ramparts, cavaliers (Fig. 10), tenailles (Fig. 11), moats or ditches, earthworks, or casemates, chosen according to the type of firearm being protected against.

If protecting the defenders from attacks was their primary aim, fatally damaging the enemy was not far behind. Antonelli strongly believed that a good offence (knowing how to damage) required a good defence (Antonelli 1560b: folio 2r). In all likelihood, the section of the book devoted to firearms (Antonelli 1561) reflects his notion that to become a skilled expert, one must have had experience in the field of artillery.

Artillery is generally divided into two categories based on weight (Figs. 12, 13): “royal” when cannonballs exceed eight pounds (cannons, culverins and demi-culverins), or not “royal” if they are lighter (arquebuses, etc.); the terminology for bastions follows the same classification, according to whether or not they can resist royal enemy fire or not (Antonelli 1560b: folio 9v).

Proportions of the Royal Bastion

According to Giovanni Battista Antonelli, bastions were the most important elements in a fortification (Antonelli 1560b: folio 6v).¹⁸ As already mentioned, only obtuse-angle bastions allowed safe protection due to their proportions against cannon shot (Fig. 14).¹⁹

In most military treatises, the authors include figures and even scale drawings to illustrate the distinctive features of their own innovations or to show the graphic proportions between elements. Yet it must be remarked that all of Antonelli’s illustrations are out of scale, with no graphic scale or annotations to help interpretation. However, among the 12 figures of the first book on fortifications, two images representing the “royal” bastion provide interesting material for analysis, especially when combined with the dimensions listed in the table at folios 17 recto and verso.²⁰

¹⁷ Carlo Theti (1529–1589) was an Italian architect and military engineer.

¹⁸ “*I baluardi sono i membri più importanti che vi siano*”.

¹⁹ *Baluardo in particolare*, folios 12r–v. On this topic see also others famous coeval engineers Tartaglia (1554: p. 71v); Zanchi (1554: p. 23); and Lanteri (1557: pp. I, 25).

²⁰ The synoptic table lists the dimensions of architectural elements of fortification both in Italian and Spanish feet, revealing Antonelli’s military background.

Fig. 10 A plan of a cavalier situated on the outer side of a curtain (Antonelli 1560b: folio 18v, no. EMH_1685). Reproduced by permission of the *Museo del Ejército*, Toledo, Spain

Fig. 11 A scheme of a tenaille, a low work to protect the curtain wall, usually built in the ditch between bastions (Antonelli 1560b: folio 21r, no. EMH_1533). Reproduced by permission of the *Museo del Ejército*, Toledo, Spain

Fig. 12 Depictions of culverins (Antonelli 1561, folio 54v, no. EMH_1720) with their balls from the first book of the *Epitomi del trattato dell'Artiglieria*, the second section of the treatise. Reproduced by permission of the *Museo del Ejército*, Toledo, Spain

In his first illustration (Fig. 15), Antonelli uses a simple sketch to depict the basic geometrical rules provided in the text to design a bastion through a compass-and-straightedge construction (Fig. 16): “in order to design a bastion, one must start from the angle of the plan shape (point A) with a dimension from 120 to 130 ft. from the vertex of the angle, (space necessary) for the higher and lower parade grounds; at the end (point B), to determine the flank, a right angle to the curtain is necessary, with the length noted in the table (BC); at the extremity, the flank side of the proper dimension will be drawn towards the opposite bastion (CD); a parallel line to the flank helps determine its width (DE); a continuous straight line passing through this end (point E) and the beginning of the opposite flank must be drawn, and by doing the same on the other side of the angle, the two infinitely-extended lines will intersect (point F)” (Antonelli 1560b: folio 12v).

When the two straight lines cross, only one point of intersection is determined, which in turn indicates the two faces of the obtuse-angle bastion, as depicted in Antonelli’s second illustration (Fig. 17). This illustration shows the detailed plan of a “royal” bastion, whose dimensions are specified by the author in the table summarizing the proportions—in Spanish and Italian feet—of the most relevant elements forming a bulwark.

Fig. 13 Depictions of cannons and demi-cannons (Antonelli 1561, folio 52r, no. EMH_1564) with their balls from the first book of the second section, dedicated to artillery. Reproduced by permission of the *Museo del Ejército*, Toledo, Spain

This method of line drawing is not restricted to the bastion alone, but serves as a rule that can be applied to any given plan shape, and infinitely-extended lines can also be used to create the moat (again, see Fig. 16): “In order to design the ditch, we draw a parallel line to the flank, and starting from the flank side, which is 100 ft. (or the required distance) away, do the same from the other bastion. Then, draw a continuous line from this point (E) towards the inner corner of the opposite flank, extending it towards the countryside. Do the same thing on each single side: those lines will intersect at different points, one in front of the middle point of the large curtain (point 3), and the other in front of the end of each bastion (point 2), whose intersection represent the boundaries of this moat” (Antonelli 1560b: folio 28r).

Detailed analysis of the sketch reveals an inconsistency between the description in the text and the drawing: the continuous straight line that determines the faces of the bastion does not actually start from the beginning of the opposite flank, as stated within the pages of the treatise, but from an unspecified point on the curtain; as the text proceeds, it is unclear whether Antonelli intended to draw a second flank, as was fashionable at the time, or not. He merely states “... (the engineer) is free to

Fig. 14 Ballistics studies by Tartaglia (1554: pp. 14v–16r)

choose this point (to start the line) even far from the flank, on the large curtain, always avoiding too sharp a bastion” (Antonelli 1560b: folio 12v).

Another important problem solved through architectural drawings following the rules of geometry is that of planning a defensive wall with a scarp [*Scarpa*, see Antonelli (1560b: folios 13r–v)]. The geometrical construction proceeds as follows, considering a 35 Spanish foot high (or 40 ft.) wall: the face of the stone bastion will have a slope up to 25 Spanish foot in height (or 30 ft.) with a 5:1 ratio, that is to say, losing 1/5 foot in plan each foot in height (1/4 ft. for rammed earth fortifications). Consequently, the rampart at the end of the scarp will decrease by 5 ft. in all, and this must be taken into account when starting construction.

As a tool for determining the proper slope, Antonelli recommends using a “quarto bono”, a right-angled piece of board whose base must be in direct proportion to the decreasing quantity in plan and whose other side is in direct proportion to the height of the scarp; the hypotenuse obtained will represent the correct inclination for the required scarp (Fig. 18). Once designed using this simple instrument, it might seem difficult to create the correct slope in reality, but Antonelli suggests using the hypotenuse of the triangle as a guide: after having driven wooden pickets into the ground (on each vertex of the plan shape), and with the help of the plumb line for verticals, small ropes function as reference lines for building the walls (Fig. 19). Afterwards, the counterscarp in the outer side of the ditch will almost completely hide the curtains, protecting them from direct cannon fire, and

Fig. 15 Sketch illustrating the design of a bastion (Antonelli 1560b: folio 16r)

the covered street will be drawn parallel to the base side of the wooden instrument measuring up to the end of the scarp (rising to the level of the parapet of the bastion).

The author then moves on to deal extensively with designing all of the other architectural elements composing the bastion (the moat, the gate, the ramparts and

Fig. 16 Scheme of the design of a bastion based on Antonelli's text. In his sketch, he starts the continuous lines from the curtain (see Fig. 15). Drawing by Silvia Bertacchi

so on), but other than providing the measurements for the correct dimensioning, the manuscript includes no other detailed descriptions for the design of additional constructions (Figs. 20, 21).

Fig. 17 Plan of a royal bastion with sectioned buttresses and walls (Antonelli 1560b: folio 16v, no. EMH_1683). Reproduced by permission of the *Museo del Ejército*, Toledo, Spain

Conclusion

Some scholars (De Castro Fernández and Cobos Guerra 2000: p. 246) hold that Antonelli's *Epitome* is ultimately a mere pastiche of other treatises of the time, and that it provides little in the way of original or innovative solutions. However, while much of the work is in fact substantiated by nothing but vague and shallow reasoning, it does formulate a number of precious recommendations, especially concerning the use of rammed earth for fortification (Antonelli 1560b: folios 33r–41r).

A lack of documentation makes it difficult to definitively determine whether Antonelli's contribution can be considered innovative for its time. It is reasonable to surmise that his work shows connections with other contemporaneous writers, with whom he could have exchanged ideas, directly or indirectly, while active in the military.

Assuming that the work, for the most part, might not be original in terms of content, the question remains as to whether it contributed to promulgating Antonelli's notions of fortification. Because the treatise remained unpublished, we

Fig. 18 The wooden tool described by Antonelli for use in determining the inclination of the scarp (image from Maggi and Castriotto 1564: p. 42r)

can assume that, unfortunately, Giovanni Battista's ideas were relatively unknown outside of his own circle of family and friends. His younger brother Battista, however, succeeded in becoming one of the most important experts in the field of modern fortification in the service of the king, and it is interesting to ask to what extent he was informed by his elder brother's expertise.

Unfortunately, in his *Epitomi*, Antonelli neglected to provide explicit articulation of the geometrical rules for design underpinning his compositional models, possibly

Fig. 19 Ropes serving as reference points for the building of the scarp and counterscarp (image from Maggi and Castriotto [1564](#): p. 43r-v)

Fig. 20 Comparison of some of the sections of the fortified system. From the *top*: hypothesis by Antonelli (drawing by Silvia Bertacchi), Maggi and Castriotto (1564: p. 32r), Lanteri (1559: p. 99) and Rojas (1598: p. 69v)

Fig. 21 Reconstruction of the bastioned fortress according to Antonelli's precepts on modern military architecture and interpreting his sketches. Drawing by Silvia Bertacchi

because he was making use of design methods that were common at the time and assumed he was addressing an informed audience. This should not detract from his theoretically innovative contribution. Giovanni Battista Antonelli remains one of history's most important promoters of Italian military tradition, first in Spain and then overseas.

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