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Black Camels and Blazing Bolts: The Bolt-Projecting Trebuchet in the Mamluk Army

The Mamluks pioneered the use of gunpowder ordnance, but their principal piece of heavy artillery was ″the crushing, demolishing trebuchet″ (*manjanīq hādim haddād*).[1] In their campaigns of conquest, the Mamluks used substantial batteries of trebuchets, and Mamluk military science produced the only major technical treatise on the construction and operation of this form of artillery. The trebuchet (Arabic *manjanīq*, pl. *majāniq, manājīq, manājanīq,* and *majanīqāt*)[2] was the most powerful form of mechanical artillery ever devised. It consisted of a long tapering beam which pivoted near its butt-end around an axle mounted on top of a framework. At the end of the long arm of the beam, a sling was attached which held the missile. This was designed to open when the beam′s motion and position reached the desired state for discharge.

To launch a projectile, the beam—equipped with pulling-ropes at its short end—was set in a horizontal position. The operator of the machine readied the machine for launch by placing a projectile in the pouch of the sling. The sling had two ropes: one attached firmly to the end of the beam and the other looped over an iron prong extending from the tip of the beam. The alignment of the prong and the length of the sling were crucial to achieving maximum range. Human muscle force was applied to the pulling-ropes by a team of men—or, in some cases, women—while the operator guided the missile through the initial phase of the launch cycle. When the operator released the sling, a sudden surge of power was

[1]Muḥammad ibn Muḥammad Ibn Ṣaṣrá, *A Chronicle of Damascus, 1389–1397, by Muḥammad ibn Muḥammad Ibn Ṣaṣrá: The Unique Bodleian Library Manuscript of al-Durra al-Muḍīʾa fī′l-Dawla al-Ẓāhirīya (Laud Or. MS 112)*, ed. and trans. William M. Brinner (Berkeley, 1963), 1:118, 2:85. On the development of gunpowder artillery by the Mamluks, see David Ayalon′s classic study *Gunpowder and Firearms in the Mamluk Kingdom: A Challenge to a Mediaeval Society* (London, 1956). This study of the bolt-projecting trebuchet has been supported by a grant from the National Endowment for the Humanities, an independent federal agency.

[2]On the Arabic term *manjanīq* denoting a trestle-framed trebuchet, see Paul E. Chevedden, ″The Artillery of King James I the Conqueror,″ in *Iberia and the Mediterranean World of the Middle Ages: Essays in Honor of Robert I. Burns, S.J.*, ed. Paul E. Chevedden, Donald J. Kagay, and Paul G. Padilla (Leiden, 1996), 47–94, esp. 59–61. On the Arabic terms *ʿarrādah* and *luʿbah,* denoting a pole-framed trebuchet, see below note 4, and note 57 and text. Other Arabic terms for the trebuchet are discussed throughout the article.

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imparted to the beam, as the maximum force exerted by the pulling-crew took full effect. This action propelled the throwing arm skyward and allowed the looped end of the sling to fly free, thus hurling the missile from the sling.

In later versions of the trebuchet a weight was added to the butt-end of the beam. This weight was first used to counterbalance the weight of the long arm of the beam at discharge when the sling was loaded with a heavy stone shot. The horizontal counterbalancing of the two arms of the beam was an ergonomic innovation in artillery design that greatly improved the efficiency of the human-powered trebuchet. The human energy required to hold the beam in place at discharge was greatly reduced, thereby allowing a greater amount of force to be exerted by the pulling crew to accelerate the beam. The great turning point in the evolution of the trebuchet came with the introduction of the counterweight machine that utilized gravity power alone to accelerate the beam. The counterweight trebuchet replaced the pulling crew with a gravitating mass that was either fixed rigidly to the butt-end of the beam (Figs. 7, 8, 9, 11, 12) or was articulated to the beam′s end by means of a hinge in order to allow the counterweight to move freely (Figs. 5, 6, 10).[3]

Trebuchets fall into three broad categories: (1) traction trebuchets, powered by crews pulling on ropes (Figs. 1 and 2); (2) hybrid trebuchets, powered by crews that received a gravity assist (Figs. 3 and 4); and (3) counterweight trebuchets, powered by gravitational energy (Figs. 5–12). The supporting framework for the axle of all three types of trebuchets adhered to two basic designs: (1) a pole framework; and (2) a trestle framework. Pole-framed machines required a fork-mounted beam. Two different mounting systems were used: (1) a fork mount, or pivot yoke, that surmounted the pole frame and held the axle (Figs. 1 and 3); and (2) a forked beam, looking like the letter Y, that attached its fork arms to the ends of the axle affixed atop the pole frame (Fig. 6). Pole-framed machines needed less material to construct than trestle-framed ones and had the great advantage of being able to discharge stone-shot in any direction without requiring the framework to be repositioned. Both mounting systems of the pole-framed trebuchet—pivot yoke and rotating axle—enabled the machine to be aimed instantly in any required direction. Trestle-framed machines pivoted the beam on an axle supported by the two triangular trusses of the framework (Figs. 2, 4–5, 7–12). They could only be aimed at a new target with great difficulty. To point such machines just a few degrees to the right or to the left required a change in position of the entire

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[3]An engineering analysis of the trebuchet that compares the principles of design and operation of traction-powered trebuchets with that of gravity-powered trebuchets is provided by Zvi Shiller in Paul E. Chevedden, Zvi Shiller, Samuel R. Gilbert, and Donald J. Kagay, ″The Traction Trebuchet: A Triumph of Four Civilizations,″ *Viator* 31 (2000): 433–86.

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framework, which necessitated the expenditure of considerable labor. Although trestle-framed trebuchets were cumbersome and expensive, and were difficult to line up on a new target, they had the advantage of being sturdy and reliable.

Development and Diffusion of the Trebuchet

The invention of the trebuchet was a unique discovery that was diffused from a single center of origin. China developed this powerful form of artillery between the fifth and fourth centuries B.C.E. From China, the two fundamental types of trebuchets—the traction-powered, pole-framed machine (Fig. 1) and trestle-framed machine (Fig. 2)—spread westward.[4] The new ordnance reached the eastern

[4]On the development and diffusion of the Chinese trebuchet, see Herbert Frankle, "Siege and Defense of Towns in Medieval China," in *Chinese Ways in Warfare,* ed. Frank A. Keirman, Jr., and John K. Fairbank (Cambridge, Mass., 1974), 151–201; Joseph Needham, "China's Trebuchets, Manned and Counterweighted," in *On Pre-Modern Technology and Science: Studies in Honor of Lynn White, Jr.,* ed. Bert S. Hall and Delno C. West (Malibu, Calif., 1976), 107–45; Sergei A. Shkoliar, "L'Artillerie de jet a l'époque Sung," in *Etudes Song: In memoriam Étienne Balazs,* series 1, *Histoire et institutions,* pt. 2, ed. Françoise Aubin (Paris, 1971), 119–42; idem, *Kitaiskaia doognestrelnaia artilleriia: Materialy i issledovaniia* (Moscow, 1980); Robin D. S. Yates, "Siege Engines and Late Zhou Military Technology," in *Explorations in the History of Science and Technology in China*, ed. Li Guohao, Zhang Mehgwen, and Cao Tianqin (Shanghai, 1982), 414–19; *Weapons of Ancient China*, ed. Yang Hong (New York, 1992); and Joseph Needham and Robin D. S. Yates, *Science and Civilization in China,* vol. 5, *Chemistry and Chemical Technology,* pt. 6, *Military Technology: Missiles and Sieges* (Cambridge, 1994). The Chinese developed an elaborate nomenclature for the trebuchet to identify many different types of trebuchets, but they divided all of these types into two basic categories according to the configuration of the framework of the machine: (1) the pole-framed machine, called a "Whirlwind" trebuchet *(xuan feng pao)* (Fig. 1); and (2) the trestle-framed machine, called a "Four-footed" trebuchet *(si jiao pao)* (Fig. 2). Thus, a binary nomenclature for the trebuchet was born. As the traction trebuchet was diffused across Eurasia and North Africa, a binary terminology, based on the framework of the machine, was used by all who adopted the new artillery. In Arabic, for example, the pole-framed trebuchet was designated an *ʻarrādah,* and later a *luʻbah* ("Plaything") (see below, note 57 and text); the trestle-framed trebuchet was called a *manjanīq* (see above, note 2). The employment of the *ʻarrādah* and the *manjanīq* by Islamic armies during the period 632 to 945 is examined by Hugh Kennedy in *The Armies of the Caliphs: Military and Society in the Early Islamic State* (London, 2001), 110–13, 133–36, 154, 155, 163, 184, 185, 189. In the Latin West, a variety of terms were used to refer to the trebuchet in both Latin and the European vernaculars, but a clear terminological dichotomy is evident prior to the introduction of gravity-powered artillery, based upon the configuration of the machine's framework. The most commonly used term to denote the pole-framed trebuchet was *manganellus* (mangonel), while the heavier trestle-framed machine was usually identified by the term *petraria* ("rock-thrower"). Scholars who have examined the nomenclature for artillery have erroneously concluded that the diversity of terms may reflect differences in the size of the machine, in the weight of the projectile discharged from it, or even fundamental differences in the kind of artillery employed (e.g., tension, torsion, or traction). In the era of human-powered artillery, the terminology was related to the most obvious design feature of the

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Mediterranean during the sixth century C.E. and rapidly displaced the heavy artillery of the classical world. Widespread diffusion of the new artillery throughout the Mediterranean and the Middle East followed. Arabia was familiar with the pole-framed and trestle-framed trebuchet prior to the rise of Islam, and, during the century following the death of Muḥammad in 632, the armies of the Prophet carried the new artillery from the Indus to the Atlantic in a ballooning movement of conquests.[5] These conquests spurred innovations in weaponry that led to the

machine: its framework. Even with the introduction of the hybrid machine, trebuchet terminology underwent no fundamental change, since this terminology was based on the configuration of the framework of the machine, a component that remained unchanged regardless of whether the trebuchet was a traction or hybrid model. This explains why only a few languages—Armenian, Syriac, Latin, French, and Occitan—introduced new terms to identify the hybrid trebuchet. Arabic literary culture generally ignored the hybrid trebuchet, but Arabic oral culture did not. It was dubbed *al-ghaḍbān* (The Furious One), and this term for the hybrid machine entered both Armenian and Turkish (see below, note 60 and text). For a discussion of the terminology of the trebuchet and its meaning, see Chevedden, ″Artillery of King James I,″ 56-76; idem, ″The Hybrid Trebuchet: The Halfway Step to the Counterweight Trebuchet,″ in *On the Social Origins of Medieval Institutions: Essays in Honor of Joseph F. O′Callaghan,* ed. Donald J. Kagay and Theresa M. Vann (Leiden, 1998), 182, 198–212; idem, ″The Invention of the Counterweight Trebuchet: A Study in Cultural Diffusion,″ *Dumbarton Oaks Papers* 54 (2000): 71–116; and Chevedden et al., ″Traction Trebuchet,″ 433–86, esp. 452 (Table 3), 460–61, 474–84.

[5]On the development and diffusion of the trebuchet outside of China, the following studies are of fundamental importance: Guillaume Dufour, *Mémoire sur l′artillerie des anciens et sur celle du Moyen Age* (Paris, 1840), 87–112; Louis-Napoléon Bonaparte, *Études sur le passé et l′avenir de l′artillerie* (Paris, 1848–71), 2:26–61; Eugène-Emmanuel Viollet-le-Duc, *Dictionnaire raisonné de l′architecture du XI^e^ au XVI^e^ siècles,* (Paris, 1854–68), 5:218–42; Alwin Schultz, *Das höfische Leben zur Zeit der Minnesinger* (Leipzig, 1889), 2:363–93; Gustav Köhler, *Die Entwickelung des Kriegswesens und der Kriegführung in der Ritterzeit von Mitte des II. Jahrhunderts bis zu den Hussitenkriegen* (Breslau, 1886–89), 3:139–211; Sir Ralph Payne-Gallwey, *The Crossbow, Mediaeval and Modern, Military and Sporting: Its Construction, History and Management, with a Treatise on the Balista and Catapult of the Ancients* (London, 1903); Rudolf Schneider, *Die Artillerie des Mittelalters* (Berlin, 1910); Marco Polo, *The Book of Ser Marco Polo, the Venetian, Concerning the Kingdoms and Marvels of the East,* 3d ed., trans. and ed. Colonel Sir Henry Yule (London, 1926), 2:161–69; Bernhard Rathgen, *Das Geschütz im Mittelalter* (1928; repr., Düsseldorf, 1987), 578–638; Kalevero Huuri, ″Zur Geschichte des mittelalterlichen Geschützwesens aus orientalischen Quellen,″ in *Societas Orientalia Fennica, Studia Orientalia*, 9/3 (Helsinski, 1941); Claude Cahen, ″Un traité d′armurerie pour Saladin,″ *Bulletin d′études orientales* 12 (1947–48): 103–63; José Frederico Finó, ″Machines de jet médiévales,″ *Gladius* 10 (1972): 25–43; idem, *Forteresses de la France médiévale: construction, attaque, défense*, 3d ed. (Paris, 1977), 149–63; Donald R. Hill, ″Trebuchets,″ *Viator* 4 (1973): 99–115; Carroll M. Gillmor, ″The Introduction of the Traction Trebuchet into the Latin West,″ *Viator* 12 (1981): 1–8; D. J. Cathcart King, ″The Trebuchet and other Siege-Engines,″ *Chateau Gaillard* 9–10 (1982): 457–69; Randall Rogers, ″The Problem of Artillery,″ Appendix III of *Latin Siege Warfare in the Twelfth Century* (Oxford, 1992), 254–73; Peter Vemming Hansen, ″Experimental Reconstruction of a Medieval Trébuchet,″

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development of the hybrid trebuchet (Figs. 3–4). The Byzantine Empire soon acquired this advanced piece of artillery, and by the second half of the ninth century it was being used in northern Europe.[6]

Another conquest movement, or more exactly an enterprise of reconquest, is likely to have led to the development of the counterweight trebuchet. In his efforts to reconquer Anatolia from the Saljuq Turks, Alexios I Komnenos (1081–1118) constructed large trebuchets, referred to as ἑλεπόλεις (*helepoleis,* "city-takers"), of several types, "but most of them were fashioned according to an unprecedented design of his own devising which amazed everyone."[7] The Byzantine emperor supplied the new artillery to the Latin Crusaders in 1097 to aid in the conquest of Nicaea in western Anatolia. During the twelfth century, the dynamics of conflict and contact quickly diffused the counterweight trebuchet throughout the Mediterranean and the Middle East. New terms arose to identify the machine that had started the gravity-powered revolution in artillery—the trestle-framed counterweight trebuchet. Arabic sources designated it a "big" trebuchet *(manjanīq kabīr),* a "great" trebuchet *(manjanīq ʿaẓīm),* or as a "huge" or "frightful" trebuchet *(manjanīq hāʾil).* During the thirteenth century, it was given a new Arabic name, the "Western Islamic" trebuchet *(manjanīq maghribī or manjanīq gharbī),* perhaps reflecting a design improvement.[8] Syriac sources named the machine a "great"

Acta Archaeologica 63 (1992): 189–208; Paul E. Chevedden, Les Eigenbrod, Vernard Foley, and Werner Soedel, "The Trebuchet: Recent Reconstructions and Computer Simulations Reveal the Operating Principles of the Most Powerful Weapon of its Time," *Scientific American* (July 1995): 66–71; Chevedden, "The Artillery of King James I"; idem, "Hybrid Trebuchet"; George T. Dennis, "Byzantine Heavy Artillery: The *Helepolis,*" *Greek, Roman and Byzantine Studies* 39 (1998): 99–115; Paul E. Chevedden, "Fortifications and the Development of Defensive Planning during the Crusader Period," in *The Circle of War in the Middle Ages*, ed. Donald J. Kagay and L. J. Andrew Villalon (Woodbridge, Suffolk, 1999), 33–43; idem, "Invention of the Counterweight Trebuchet"; and Chevedden et al., "Traction Trebuchet."

[6]On the development and diffusion of the hybrid trebuchet, see Chevedden, "Hybrid Trebuchet"; and Chevedden et al., "Traction Trebuchet."

[7]Anna Komnena, *Alexiade: Règne de l'empereur Alexis I Comnène (1081–1118)*, ed. and trans. Bernard Leib, Collection byzantine publiée sous le patronage de l'Association Guillaume Budé (Paris, 1937–45), 11.2.1. The learned monk Euthymios Zygabenos, a close associate of Alexios, ranks the emperor's new artillery with the works of Archimedes, the most famous inventor of ancient Greece. This suggests that an important breakthrough in the design and construction of the trebuchet was achieved at Nicaea. Given the imminent appearance of gravity-powered artillery, this breakthrough is most likely to have been the development of the first counterweight trebuchet (Euthymios Zygabenos, *Panoplia*, in *Patrologiae cursus completus, Series graeca*, ed. J.-P. Migne [Paris, 1857–66], 130:20). On the introduction of the counterweight trebuchet, see Chevedden, "Invention of the Counterweight Trebuchet."

[8]On the *manjanīq maghribī/gharbī,* a trestle-framed, gravity-powered trebuchet with a hinged counterweight, see Najm al-Dīn Ayyūb Aḥdab al-Rammāḥ, *Al-Furūsīyah wa-al-Manāṣib al-*

trebuchet *(manganīqē rawrbē),* and a Greek source called it a "great siege-engine" (μεγάλη μηχανή, *megalē mēkhanē*). In the Latin West, the new artillery was designated by the term "trebuchet," a diminutive form derived from the medieval Latin word *trabuc[h]us*. The term first appeared as *trabuchellus* in 1189, and a decade later *trabuchus* entered the record (Fig. 5).[9] Today the term "trebuchet" is used to refer to the entire class of artillery that draws its energy from a beam pivoted around an axle.

By the end of the twelfth century the diversification of the counterweight trebuchet into different forms had begun. In the Latin West, a pole-framed machine was introduced that had a bifurcated beam with two counterweights suspended from its fork arms. Its pivoting shaft and paired counterweights earned it its name, the *bricola,* or the "Two-Testicle" machine (Fig. 6), from the combination of the prefix *bi-,* "having two," and the Latin *coleus,* meaning testicle (Fr. *bricole,* It. *brìccola,* Oc. *bricola*, Catal. *brigola,* Cast. *brigola,* late L. *bric[c]ola,* Gk. *praikoula* or *prekoula*). In 1242 Emperor Frederick II of Hohenstaufen sent *bricola*s to the Levant, and soon thereafter (post 1250) the Mamluks incorporated this versatile piece of artillery into their siege arsenal, calling it the "Frankish" or "European" trebuchet (*manjanīq ifranjī* or *manjanīq firanjī*). Muslim engineers employed by the Mongols brought the *bricola* to China, where it was designated the "Muslim" trebuchet *(hui-hui pao).* Batteries of *bricola*s (sing. *manjanīq firanjī*) rained

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Ḥarbīyah: al-Barūd, al-Nīrān al-Ḥarbīyah, al-Taqṭīr, al-Nīranjāt, ed. Aḥmad Yūsuf al-Ḥasan, Maṣādir wa-Dirāsāt fī Tārīkh al-'Ulūm al-Taṭbīqīyah, vol. 8 (Aleppo, 1998), 118, Fig. 71; Chevedden, "Artillery of King James I," 62–63, Figs. 7–9; idem, "Invention of the Counterweight Trebuchet," 106, Fig. 3; and below, note 32 and text. Since the *manjanīq maghribī* had a hinged counterweight, it is likely that the feature which distinguished it from earlier counterweight trebuchets was the hinged counterweight box or a new method for hanging the counterweight box with a hinge. It should be noted that the earliest extant illustration of a gravity-powered trebuchet, the double-propose machine described and illustrated by al-Ṭarsūsī, had a "hinged" counterweight consisting of a rope sack filled with stones held by three strong cords (Murḍī ibn 'Alī ibn Murḍī al-Ṭarsūsī [d. 589/1193], "Tabṣirat Arbāb al-Albāb fī Kayfīyat al-Najāh fī al-Ḥurūb min al-Aswā' wa-Nashr A'lām al-I'lām fī al-'Udad wa-al-Ālāt al-Mu'īnah 'alá Liqā' al-A'dā'" [Instruction of the masters on the means of deliverance in wars from disasters, and the unfurling of the banners of information: equipment and engines which aid in encounters with enemies], Bodleian MS Hunt. 264, fols. 133v–135r [hereafter cited as "Tabṣirah fī al-Ḥurūb"]); idem, "Tabṣirah fī al-Ḥurūb," Süleymaniye Library MS Ayasofya 2848 mü, fols. 100r–102r; idem, *Mawsū'at al-Asliḥah al-Qadīmah: al-Mawsūm Tabṣirat Arbāb al-Albāb fī Kayfīyat al-Najāh fī al-Ḥurūb min al-Anwā'* [sic] *wa-Nashr A'lām al-A'lām* [sic] *fī al-'Udad wa-al-Ālāt al-Mu'ayyanah* [sic] *'alá Liqā' al-A'dā'*, ed. Karin Ṣādir [Beirut, 1998], 168–69, 256–57 [Fig. 12]; Cahen, "Traité," 119, 120, Pl.. 3, Fig. 14; and Chevedden, "Invention of the Counterweight Trebuchet," 87–90, 115–16, Fig. 1).

[9]For a discussion of the nomenclature of the counterweight trebuchet, see Chevedden "Artillery of King James I," 61–63, 68–76; Chevedden, "Invention of the Counterweight Trebuchet"; and Dennis, "Byzantine Heavy Artillery."

destruction on the cities of Fancheng (1272) and Xiangyang (1273), on the Han River in northwest Hubei province, and broke the power of the Song Empire (960–1279). On the high seas, the *bricola* was mounted on the poops of ships and was used to bombard coastal cities and fortresses.[10] Human ingenuity and engineering skill combined to produce yet another type of gravity-powered trebuchet. This new machine extended the capabilities of the trebuchet enormously; it enabled the machine to do what it had never done before: discharge immense bolts.

THE BOLT-PROJECTING TREBUCHET

The improved performance of the counterweight trebuchet presented new possibilities for artillery. Two additional contrivances, the counterweight and the elongated sling, enabled artillery to break free of many of the limitations of the traction-powered trebuchet. The high rotational velocity reached by the beam of a counterweight trebuchet and the wider range of rotation that was utilized to accelerate

[10]On Frederick II's dispatch of *bricola*s to the Levant, see Caffaro, *Annali genovesi di Caffaro e de' suoi continuatori*, ed. Luigi T. Belgrano and Cesare Imperiale di Sant'Angelo, Fonti per la storia d'Italia pubblicate dall'Istituto storico italiano, Scrittori, Secoli XII e XIII, nos. 11–14bis (Rome, 1890–1929), 3:128: "Et cum inimici mari et terra cum machinis, prederiis (= *petrariis*), bricolis, scalis et aliis hedifficiis eorum infortunio ad locum Levanti pervenissent." On the Muslim engineers who brought the *bricola* to China and the role these machines played in forcing the surrenders of Fancheng in 1272 and Xiangyang in 1273, see Rashīd al-Dīn Faḍl Allāh Ṭabīb, *Jāmi' al-Tavārīkh,* ed. Bahman Karīmī (Tehran, 1338/1960), 1:651–52; idem, *Jāmi' al-Tavārīkh,* trans. John Andrew Boyle, *The Successors of Genghis Khan* (New York, 1971), 290–91; Arthur C. Moule, *Quinsai: With Other Notes on Marco Polo* (Cambridge, 1957), 70–78. Both Rashīd al-Dīn (1247?–1318) and Chinese historian Zheng Sixiao (1206–83) provide details on the heavy artillery used at the sieges of Fancheng and Xiangyang (modern-day Xiangfan). Rashīd al-Dīn identifies the most powerful pieces of artillery as "European" trebuchets (sing. *manjanīq firangī*), or *bricola*s (*Jāmi' al-Tavārīkh,* 1:651; *Successors of Genghis Khan,* 290), and Zheng, who calls the machines "Muslim" trebuchets *(hui-hui pao),* indicates that, "in the case of the largest ones, the wooden framework stood above a hole in the ground" (quoted in Needham and Yates, *Science and Civilisation in China*, 5:6:221). Since the *bricola* was the only counterweight piece of artillery that had a framework capable of being mounted in a hole in the ground and was commonly set up in this fashion, there is little doubt that Zheng is referring here to the *bricola*. The stone-shot launched by these machines weighed 150 *jin,* or 94.5 kilograms (208 lb) (Moule, *Quinsai,* 76), and Zheng states that, "the projectiles were several feet in diameter, and when they fell to the earth they made a hole three of four feet deep. When [the artillerists] wanted to hurl them to a great range, they added weight [to the counterpoise] and set it further back [on the arm]; when they needed only a shorter distance, they set it forward, nearer [the fulcrum]" (Needham and Yates, *Science and Civilisation in China*, 5:6:221). On the development and diffusion of the *bricola* and the *manjanīq ifranjī/firanjī,* see Chevedden, "Artillery of King James I," 62–63, 68, 71–76, 79, 84, Fig. 11; idem, "Invention of the Counterweight Trebuchet," 102–3, 106–10, Fig. 5; and below, notes 33, 34, 35, and 36, and text. *Elegant Book* (see note 13) includes two illustrations of the *bricola* ("Anīq," fols. 20r, 22r; *Anīq*, ed. 'Abd al-'Azīz, 47, 51; *Anīq*, ed. Hindī, 97–98).

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the beam made it possible to increase the length of the sling. By using a longer sling that was now driven by a constant or rotating load, the shooting potential of the machine was greatly improved, both in terms of the size of the projectile thrown and the range of the shot. The increased rotational velocity and greater rotational range of the beam also made it possible to substitute the standard trebuchet release mechanism—the sling—for a new release mechanism that enabled it to hurl projectiles never before launched by this type of artillery. With a few structural modifications, a stone-projecting, trestle-framed, counterweight trebuchet could be converted into a bolt-projecting machine and employed to discharge flaming bolts. A large blazing bolt hurled from a trebuchet was particularly suited for setting alight the wooden siege engines of an attacking army or burning the protective screens that shielded fortifications from bombardment.[11]

[11]The evolution of the trebuchet from stone-projector to bolt-projector follows in reverse order the development of the ancient catapult. The catapult, which developed from the hand-bow, was originally designed to launch bolts. It was eventually scaled up in size and adapted to hurl stone-shot. On the development of the catapult, see Erwin Schramm, *Die Antiken Geschütze de Saalburg* (1918; repr., Bad Homburg, 1980); E. W. Marsden, *Greek and Roman Artillery: Historical Development* (Oxford, 1969); idem, *Greek and Roman Artillery: Technical Treatises* (Oxford, 1971); Nicolae Gudea and Dietwulf Baatz, "Teile Spätrömischer Ballisten aus Gornea und Orsova (Rumänien)," *Saalburg Jahrbuch* 31 (1974): 50–72; Dietwulf Baatz, "The Hatra Ballista," *Sumer* 33 no. 1 (1977): 141–51; idem, "Das Torsionsgeschütz von Hatra," *Antike Welt* 9 no. 4 (1978): 50–57; idem, "Recent Finds of Ancient Artillery," *Britannia* 9 (1978): 1–17, Pls. 1–5; idem, "Teile Hellenistischer Geschütze aus Griechenland," *Archäologischer Anzeiger* (1979): 68–75; idem, "Ein Katapult der *Legio IV Macedonica* aus Cremona," *Römische Mitteilungen* 87 (1980): 283–99; idem, "Hellenistische Katapulte aus Ephyra (Epirus)," *Athenische Mitteilungen* 97 (1982): 211–33; idem, "Katapultteile aus dem Schiffswrack von Mahdia (Tunesien)," *Archäologischer Anzeiger* (1985): 677–91; idem, "Eine Katapult-Spannbuchse aus Pityus, Georgien (UDSSR)," *Saalburg Jahrbuch* 44 (1988): 63–64; idem, "Die Römische Jagdarmbrust," *Archäologisches Korrespondenzblatt* 21 (1991): 283–90; idem, *Bauten und Katapulte des römischen Heeres* (Stuttgart, 1994); Dietwulf Baatz and Michel Feugère, "Éléments d'une catapulte romaine trouvée à Lyon," *Gallia* 39 (1981): 201–9; A. G. Drachmann, *The Mechanical Technology of Greek and Roman Antiquity* (Copenhagen, 1963), 186–91; idem, "Biton and the Development of the Catapult," *Prismata, Naturwissenschaftsgeschichtliche Studien, Festschrift für Willy Hartner,* ed. Y. Maeyama and W. G. Saltzer (Wiesbaden, 1977), 119–31; Barton C. Hacker, "Greek Catapults and Catapult Technology: Science, Technology and War in the Ancient World," *Technology and Culture* 9 (1968): 34–50; Yvon Garlan, *Recherches de poliorcétique grecque* (Paris, 1974), 212–25; John G. Landels, *Engineering in the Ancient World* (Berkeley, 1978), 99–132; Arnold W. Lawrence, *Greek Aims in Fortification* (Oxford, 1979), 43–49; Werner Soedel and Vernard Foley, "Ancient Catapults," *Scientific American* 240 (March 1979): 150–60; Philippe Fleury, "Vitruve et la nomenclature des machines de jet romaines," *Revue des Études Latines* 59 (1981): 216–34; idem, *La mécanique de Vitruve* (Caen, France, 1993); Paul E. Chevedden, "Artillery in Late Antiquity: Prelude to the Middle Ages," in *The Medieval City under Siege,* ed. Ivy Corfis and Michael Wolfe (Woodbridge, Suffolk, 1995), 131–73; and Alan Wilkins, "Reconstructing the *cheiroballistra,*" *Journal of Roman*

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Bolt-projecting trebuchets played an important role in the Mamluk army, particularly in the campaigns of conquest that brought an end to the Crusader states in Syria. This new class of artillery was designated by the term *manjanīq qarābughrā* (the "Black Camel" trebuchet).[12] The most important technical treatise devoted to the trebuchet, Yūsuf ibn Urunbughā al-Zaradkāsh's *An Elegant Book on Trebuchets (Kitāb Anīq fī al-Manājanīq),*[13] written in 867/1462–63, offers a detailed description of the "Black Camel" trebuchet.

Ibn Urunbughā's Bolt-Projecting Trebuchet

The steps that are required to convert a stone-projecting, trestle-framed, counterweight trebuchet into a bolt-projecting machine are explained by Ibn Urunbughā, the foremost authority on medieval artillery:

> If you want to shoot bolts *(nushshāb)*—some of which are filled with inflammable material *(al-nār)* and sticky gums (*or* resins) *(lizāqāt)* and others are not—from a trebuchet *(manjanīq)* [do as follows]. If you want that [i.e., to shoot bolts], put a hook *(kullāb)*[14] at the center of gravity *(*'*idl)* of the bolt (*al-nushshāb*). The hook should be made

Military Equipment Studies 6 (1995): 5–59.

[12]The word *bughrā* is the Arabic form of the Turkish term for a camel stallion, *buğra*. The prefix *qarā-* is the Arabic form of the Turkish word for black *(kara),* which carries figurative meanings, often pejorative, but it can also mean "strong" or "powerful." On these Turkish terms, see Gerard Clauson, *An Etymological Dictionary of Pre-Thirteenth-Century Turkish* (Oxford, 1972), 317–18 *(buğra);* 643–44 *(kara);* J. H. Kramers, "Ḳarā," *The Encyclopaedia of Islam,* 2nd ed., 4:572.

[13]Yūsuf ibn Urunbughā al-Zaradkāsh, "Kitāb Anīq fī al-Manājanīq," Topkapı Sarayı Muzesi Kutuphanesi MS Ahmet III 3469/1. This treatise is the longest and most profusely illustrated work in any language dealing with the trebuchet. Two editions of this text have appeared. The first was edited by Nabīl Muḥammad 'Abd al-'Azīz under the title *Al-Anīq fī al-Manājīq* (Cairo, 1981), and the second was edited by Iḥsān Hindī under the title *Al-Anīq fī al-Manājanīq,* Maṣādir wa-Dirāsāt fī Tārīkh al-Taknūlūjiyā al-'Arabīyah, no. 4 [Aleppo and Kuwait, 1985]). This treatise is hereafter cited as "Anīq," and its two published editions as *Anīq,* ed. 'Abd al-'Azīz, and *Anīq,* ed. Hindī.

[14]The "hook" holds the loose end of the cord that is tied to the end of the throwing arm of the trebuchet. The "hook" is presumably attached to the loose end of the cord by a ring. The bolt is released when the ring at the end of cord frees itself from the "hook" during the launch cycle. This "hook" serves the same purpose as the device identified by Francesco di Giorgio Martini as a "nock" and probably resembled this component (see discussion below, "The Bolt-Projecting Trebuchets of Taccola and Francesco di Giorgio," and Fig. 12). In Arabic, the term "hook" can be applied to a variety of devices. Al-Ṭarsūsī uses the term "hook" *(khuṭṭāf)* to denote the prong, or style, that is fixed to the tip of the throwing arm to hold the loose end of the sling. This device may be bent or straight and looks nothing like a normal hook ("Tabṣirah fī al-Ḥurūb," Bodl., fols. 134v, 136v; "Tabṣirah fī al-Ḥurūb," Süleymaniye, fols. 97r, 100v; *Tabṣirah fī al-Ḥurūb,* ed. Ṣādir, 167, 169; Cahen, "Traité," 119, 120, 141, 142).

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of iron. The hook will facilitate the lift-off (*yaḥmil*)[15] of the bolt (*al-sahm*) and effect the discharge (*ḍarb*) [16] [of the projectile]. The front part of the hook should face the head of the bolt (*nasl al-nushshāb*), and its back should face the fletching of the bolt (*rīsh al-sahm*). Then, after [doing] that, remove the pouch (*kaffah*) of the trebuchet and take out its first cord (*sā'id*)[17] [i.e., the cord attached to the loose

[15]The verb *ḥamala,* meaning ″to carry,″ ″to pick up″ (something in order to carry it), ″to lift,″ or ″to convey″ (something), is used to describe the launching operation of the bolt-projecting trebuchet. Al-Ṭarsūsī also uses the verb *ḥamala* to describe the launching of projectiles from trebuchets (″Tabṣirah fī al-Ḥurūb,″ Bodl., fol. 130r; ″Tabṣirah fī al-Ḥurūb,″ Süleymaniye, fol. 95r; *Tabṣirah fī al-Ḥurūb,* ed. Ṣādir, 163). The action associated with this verb perfectly describes the first two stages of the launch cycle of a trebuchet. A missile that is launched from a sling is first *carried* by the sling of the trebuchet as the loaded sling slides along the trough of the machine prior to lift off. When the sling leaves the ground at lift-off, the missile is *lifted* from the trough but continues to be *carried* by the sling as it rotates in a circular orbit around the extremity of the long arm of the beam before being released. In the case of the bolt-projecting trebuchet, the ″hook″ holds the loose end of the cord that is fastened to the end of the throwing arm of the trebuchet. Just like the sling, the ″hook″ can be viewed as *carrying* the bolt as it first *carries* the bolt along the trough during the first stage of the launch cycle and then facilitates the *lift-off* of the bolt during the second stage of the launch cycle. The bolt enters the third stage of the launch cycle, the ballistic phase, when the loose end of the cord frees itself from the ″hook.″ In the context of hurling a missile from a trebuchet, the verb *ḥamala* means ″to carry″ (a projectile along the running-path of the trough), ″to facilitate lift-off″ (of a projectile), or simply ″to shoot″ or ″to discharge″ (a projectile), in the sense that a trebuchet can be said *to carry* a projectile a specified distance or in a specified way. The subsequent use of the verb *ramá,* meaning ″to throw″ or ″to hurl,″ to describe the launching of a bolt from the *qarābughrā* seems to indicate that the author seeks to establish a difference between the two initial stages of the launch cycle and the ballistic stage.

[16]According to Hindī, *ḍarb* (″discharge,″ ″shooting″) designates the projectile *(maqdhūf)* of the machine (*Anīq,* ed. Hindī, 45 n. 10). He cites Reinhart Dozy, *Supplément aux dictionnaires arabes* (Leiden, 1881; repr., Leiden, 1967), 2:6, as the source of this information, but Dozy provides no such translation for *ḍarb*.

[17]Hindī believes that the term *sā'id* (pl. *sawā'id*) refers to the rotating beam of the trebuchet (*Anīq,* ed. Hindī, 41 n. 9, 42 n. 2, 43 n. 9, 44 nn. 1 and 5, 45 n. 6). This term, which means ″forearm,″ refers specifically to the two sling cords of a trebuchet. This is made abundantly clear in Ibn Shaddād′s account of the Mongol siege of al-Bīrah (Birecik) in 674/1275. The Mongol battery of trebuchets bombarding the city was commanded by a Muslim artillerist who presumably had been impressed into Mongol service against his will. At the height of the siege, he seized an opportunity to betray his new masters. As the city defenders were attempting to bring counter-battery to bear upon the Mongol artillery, they persistently overshot their mark. Realizing that a simple adjustment to the sling cord would correct for overshooting, the Muslim artillerist shouted in Arabic to the operator of a trebuchet inside al-Bīrah and directed him to shorten the sling cord *(sā'id)* of his trebuchet by a cubit. When he had made this adjustment, the range of his shot was reduced, and he was able to make a direct hit on a Mongol trebuchet. This episode illustrates that medieval artillerists knew full well that slings of different lengths provided variations in trajectory

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> end of the sling]. Then, attach the hook to the second cord [i.e., the cord fixed to the end of the throwing arm] and launch it (*tarmī bi-hi*), and it will hit the target you want, if God wills. This account of ours is a compete [description of the] operation of the trebuchet which is known as the "Black Camel" (*qarābughrā*).[18]

Although the text clearly states that the "Black Camel" trebuchet is a bolt-projecting machine, Iḥsān Hindī, who edited *Elegant Book,* asserts that "it is a type of trebuchet specifically designed for hurling stone-shot."[19] *Elegant Book* describes and illustrates three trebuchet incendiary bolts, providing detailed information on the type of projectiles that were discharged from a *qarābughrā*.[20] Three illustrations of the *qarābughrā* appear in *Elegant Book,* but they are difficult to interpret. The machine depicted is not designated a *qarābughrā,* but a *ziyār,* a machine identified in *Elegant Book* as a base-mounted, two-armed torsion catapult.[21] All three

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and range (ʿIzz al-Dīn Muḥammad Ibn Shaddād, *Tārīkh al-Malik al-Ẓāhir,* ed. Aḥmad Huṭayṭ [Wiesbaden, 1983], 125). The trebuchet was apparently viewed as a metonymic extension of the human arm, since the trebuchet both closely resembles the human arm and operates in much the same way as the human arm. The long bone of the arm, the humerus, closely resembles the throwing arm of the trebuchet. The two thinner bones of the forearm, the radius and ulna, resemble the two sling cords of a trebuchet. The terminal part of the arm, the hand, bears a likeness to the pouch of the sling, since it both holds and releases the projectile. In addition, the mechanical properties of the human arm and the trebuchet have a marked resemblance to one another, because both the trebuchet and the human arm operate as a lever system. The pivoting motion of the trebuchet mimics the human arm in the act of throwing. The beam, resembling the humerus, pivots on its axle and sets in motion the sling, which is swung on its pivot around the extremity of the throwing arm, imitating the action of the elbow and the forearm. The energy flow process of the trebuchet and the human thrower is also similar. Potential energy given to the counterweight is converted into kinetic energy as it passes from the throwing arm to the sling and finally to the projectile. Similarly, energy supplied by muscle in the human thrower comes down the upper arm and acts to bend the arm at the elbow enabling the hand to move upward and downward in the act of throwing. For other parallels that contemporaries drew between human anatomy and the trebuchet, see Chevedden, "Artillery of King James I," 73–74, Pls. 14–15; Chevedden et al., "Traction Trebuchet," 446; and note 10 above and text.

[18] "Anīq," fol. 3v; *Anīq,* ed. ʿAbd al-ʿAzīz, 26; *Anīq,* ed. Hindī, 45.

[19] *Anīq,* ed. Hindī, 46 n. 1. In his discussion of the bolt-projecting trebuchet, Hindī again insists that the *qarābughrā* launches stone-shot, while the *ziyār* launches bolts (*Anīq,* ed. Hindī, 94). Hindī also identifies the *qarābughrā* with the trestle-framed, stone-projecting trebuchet referred to as a "Turkish" trebuchet *(manjanīq turkī)* in *Elegant Book* (*Anīq,* ed. Hindī, 110).

[20] "Anīq," fols. 53v–54r; *Anīq,* ed. ʿAbd al-ʿAzīz, 117–19; *Anīq,* ed. Hindī, 185–87.

[21] "Anīq," fol. 33r; *Anīq,* ed. ʿAbd al-ʿAzīz, 73; *Anīq,* ed. Hindī, 109–10: a crude drawing of a *ziyār,* depicted as a bolt-projecting, two-armed torsion catapult mounted on a cruciform base, is shown together with a pole-framed traction trebuchet and a trestle-framed counterweight trebuchet atop a fortress tower. The projectile of the machine is a large bolt or shaft, identified by the term,

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illustrations reveal an engine that is a true Frankenstein monster of medieval artillery. Two disparate species of artillery are combined in a single drawing. A torsion catapult and a bolt-projecting, trestle-framed trebuchet are united into one machine. The numerous drawings of trebuchets and other siege engines in *Elegant Book* indicate a high degree of technical competence, so the composite creations representing a bolt-projector do not appear to be the result of a casual or accidental act. Still less do they appear to be the result of inexperience or ineptitude on the part of the illustrator. Rather, it seems, the illustrator set out to deliberately produce in a single drawing two different types of bolt-projecting artillery used by the Mamluk army: the *ziyār* and the *qarābughrā*. Drawings of machines dating from the classical and medieval periods often incorporated multiple perspectives in the same figure. The draftsman could include, all in one diagram, the plan of a machine, its two side elevations, as well as its front and rear-elevations, making it very difficult for the modern researcher to interpret. Our illustrator has gone a step further and created a bastard machine by fusing two machines into one. This experiment, like Dr. Frankenstein′s, does not appear to have been very successful, although anyone with a sound knowledge of artillery construction would likely have been able to make out the meaning of the drawing.

Two of the illustrations of the bastard bolt-projector show a single, vertically-mounted torsion spring set in the center of one of the trusses of the trestle frame of a trebuchet (Figs. 7–8), while a third illustration shows a single, horizontally-mounted torsion spring positioned halfway up one of the trusses of a trestle-frame (Fig. 9). Although the illustrations are a fusion of incongruous elements, the features that are most characteristic of a *qarābughrā* predominate: a trestle framework, a beam with a counterweight fixed rigidly to its butt-end, a windlass for hauling down the beam, and a trough loaded with a bolt. The famous Sienese engineers Mariano di Iacopo, known as Taccola (1381–ca. 1458), and Francesco di Giorgio Martini (1439–1502) have fortunately provided a number of fairly accurate illustrations of the ″Black Camel″ trebuchet.[22]

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kazz. This word may be derived from ξυσ–τον *(xus-ton),* the Greek term for ″shaft,″ ″spear-shaft,″ or ″spear.″ On *kazz,* mistranscribed as *karr,* see Abū al-Faraj ʻAbd al-Raḥmān ibn ʻAlī Ibn al-Jawzī, *Al-Muntaẓam fī Tārīkh al-Mulūk wa-al-Umam* (Hyderabad, 1360/1940), 10:169. The machine known as the *Kashk-anjīr* (″Battlement-Piercer″), a bolt-projecting, two-armed torsion catapult mounted on a cruciform base, is related structurally to the *ziyār* (″Anīq,″ fol. 23r, 33v, 35r; *Anīq,* ed. ʻAbd al-ʻAzīz, 53, 74, 77; *Anīq,* ed. Hindī, 103–8). Al-Ṭarsūsī identifies the *ziyār* as a base-mounted bolt-projecting tension catapult. He describes and illustrates a single-bolt *ziyār,* a multiple-bolt *ziyār,* and a compound pulley for spanning a *ziyār* (*Tabṣirah fī al-Ḥurūb,* ed. Ṣādir, 118–23, 245–47, Figs. 1–3; Cahen, ″Traité,″ 108–10, 129–32, 151–52, Pl. 1, Figs. 1–3).

[22]Mariano Taccola, ″De ingeneis″ (ca. 1419–50), Munich, Bayerische Staatsbibliothek Codex CLM 197 II, fol. 68v: trebuchet with hinged counterweight launching a single bolt (reproduced in

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THE BOLT-PROJECTING TREBUCHETS OF TACCOLA AND FRANCESCO DI GIORGIO

Taccola′s bolt-projector is a trestle-framed trebuchet with a hinged-counterweight (Fig. 10). The throwing arm terminates in a special four-pronged appendage that holds four ″sling″ ropes for the simultaneous discharge of four bolts. For simplicity′s sake, the illustrator has only drawn one of the bolts. Above the four-pronged appendage of the beam is an insert showing details of a two-tined fork for the throwing arm. A caption underneath the insert reads, ″It [the component shown above] shall be placed on the end of the beam *(mictatur in stilo istius pertice).*″ Taccola′s illustration of the bolt-projecting trebuchet is the earliest depiction of the machine and the most accurate. The four-tined throwing arm shown in the illustration may have been a less than optimal design for the bolt-release mechanism, due to the close proximity of the ″sling″ ropes, but the two-tined fork that is depicted appears to be able to actuate the discharge of two bolts with adequate success.

Francesco di Giorgio′s illustration of a bolt-projecting trebuchet carries more than a caption title; it is accompanied by a full-length description of the machine,

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Mariano Taccola, *De ingeneis: Liber primus leonis, Liber secundus draconis, addenda*: *Books I and II, On Engines and Addenda [The Notebook],* ed. Gustina Scaglia, Frank D. Prager, Ulrich Montagsda [Wiesbaden, 1984], 1:86; 2:fol. 68v); Francesco di Giorgio Martini, ″Opusculum de architectura″ (ca. 1470–75), British Museum Department of Prints and Drawings 1947–1–17–2 (= London, British Museum Cod. Lat. 197 b 21), fol. 40r: trebuchet with hinged counterweight launching two bolts; Francesco di Giorgio, ″Codicetto″ (ca. 1470–90s), Biblioteca apostolica vaticana MS Vat. Urb. lat. 1757, fol. 99v: trebuchet with hinged counterweight and forked attachment at tip of beam launching two bolts (reproduced in Francesco di Giorgio Martini, *Das Skizzenbuch des Francesco di Giorgio Martini: Vat. Urb. lat. 1757*, Belser faksimile Editionen aus der Biblioteca apostolica vaticana Codices e Vaticanis selecti quam simillime expressi iussu Ioannis Pauli PP II consilio et opera curatorum Bibliothecae Vaticanae, vol. 80 [Zurich, 1989], 2:99v); Francesco di Giorgio, ″Trattato I,″ copy (ca. 1480–1500), Biblioteca Reale di Torino Codex 148 Saluzzo, fol. 61v: trebuchet with fixed counterweight and forked attachment at tip of beam launching two bolts (reproduced in Francesco di Giorgio Martini, *Trattati di architettura, ingegneria e arte militare,* ed. Corrado Maltese, Trattati di architettura, vol. 3 [Milan, 1967], 1:227 and Pl. 114); Anon. Sienese Engineer, Copybook Drawings, ca. 1470–90s, British Library Add. MS 34,113, fol. 133r: trebuchet with hinged counterweight launching two bolts with no forked appendage at tip of beam; Anon. Sienese Engineer, Copybook Drawings, ca. 1470–90s, British Library Add. MS 34,113, fol. 219v: trebuchet with hinged counterweight and forked appendage at tip of beam; and Anon. Raccolta Artist Engineer, ″Raccolta di città e macchine″ (ca. 1490s), Florence, Biblioteca Nazionale Centrale, Codex Magliabechiana II I 141 part 3, fol. 195v: trebuchet with fixed counterweight and forked attachment at tip of beam launching two bolts (reproduced in Chevedden, ″The Artillery of King James,″ Fig. 10). For information on the manuscripts and drawings of Francesco di Giorgio Martini, see Gustina Scaglia, *Francesco di Giorgio: Checklist and History of Manuscripts and Drawings in Autographs and Copies from ca. 1470 to 1687 and Renewed Copies (1764–1839)* (Bethlehem, Penn., and London, 1992).

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which reads as follows:

> If we want to shoot bolts in another way, we first have to make a base frame composed of large and firmly-fastened beams of wood, above which two other beams of wood are nailed in an upright position and set a foot apart from each other. Between them [the uprights] is put a squared beam [counter]balanced like [the beam of] a trebuchet. The beam is twenty-five feet or more in length and has a [counterweight] box on top of its [butt-]end secured by iron straps. At the tip of the beam is a fork with three rings. The two lateral rings [of the fork] have a cord attached to them that is connected to the nock of the bolts, and the middle ring is connected to the serpentine lever [of the catch-and-trigger device], which is pulled up [to free the beam] after the beam has been elevated by a capstan. So, by elevating the [counterweight] box to the height at which gravitational energy [can be effectively employed], and by lifting the curved release, the bolts are discharged with great force because of the recoil of the [counterweight] box as it falls on the cords [stretched between the two uprights] below.[23]

Francesco´s illustration accompanying his description of the bolt-projecting trebuchet (Fig. 11) shows heavy cords wound around the lower portion of the uprights of the machine that act as a buffer for the descending beam. The buffer provides a safeguard against a movement of the beam that would damage the mechanical pull-back system of the throwing arm. This pull-back system is made up of two ropes that run from the top of the counterweight box to a capstan positioned behind the base frame of the machine. Incorporated in the system is a horizontal bar placed above the axle of the beam that redirects the ropes downward to the base frame where a set of rollers sends the ropes in the direction of the

[23]Francesco di Giorgio, *Trattati di architettura,* 1:227: ˝Se in altro modo i dardi trar vorremo, faccisi in prima un pavimento di grosse e ben commesse travi, sopra delle quali due altri diritti legni fermarai d´altezza piè vinti quattro, in distanzia uno piè dall´una e l´altra. Infra le quali una quadrata trave bilicata a guisa di trabocco, in longhezza piei vinticinque o più, in nella testa da piè una cassa con corregge di ferro collegata, e nella sua sommità uno forcone con tre anelli, e ai due che di fuore sono sia accomandato un pezzo di canape a ciascuno ch´el groppo loro a la bolgionella de´ dardi si riferischi, e all´anello di mezzo al lasso sia accomandato, ch´è dopo l´azar della tirata trave che all´argano tirare bisogna. Elevandosi la cassa dell´altezza della gravedine el lasso lassando i dardi potentemente trae per la repercussione della cadente cassa che ne´ canapi dappiè ribatte.˝ I thank Silvia Orvietani Busch of the University of California at Los Angeles for her generous help in the translation of this passage. I alone am responsible for any errors.

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capstan. This pull-back system fails to utilize the mechanical advantage that would be gained by the use of a lever. Worse, it requires the insertion of a cross-member that is placed in the direct path of the beam. A buffer must therefore halt the beam before it crashes into this component. This resolves one problem but creates another. With each discharge the beam would forcibly strike the buffer. Repeated blows would shake the machine apart. Design flaws—even catastrophic ones, such as this—are not altogether uncommon in the works of the great Italian Renaissance engineers, such as Taccola, Francesco di Giorgio, and Leonardo da Vinci. However, such flaws are not likely to have been repeated in workshops where heavy artillery was built. Here experienced craftsmen with a sound knowledge of artillery construction exercised control over production, not ″engineer-artists/authors″ whose kaleidoscopic interests occasionally overshot their technical skills.

Another problem with Francesco′s bolt-projecting trebuchet is the short span of the axle, a mere foot, which would have been quite detrimental to the lateral stability of the machine. Counterweight trebuchets were commonly constructed with wide axles to provide better lateral stability for the axle of the machine.[24] An axle measuring only a foot would have made it quite impossible for the counterweight box to pass between the uprights of the machine, despite the fact that Francesco′s illustration indicates that this was feasible. In addition, a gap of only a foot between the uprights does not provide adequate space for the two bolts positioned for launch at the base of the machine (Fig. 11). Another illustration of a bolt-projecting trebuchet, one by an anonymous artist-engineer that is based upon Francesco′s drawing, depicts a wider axle for the machine (Fig. 12). This axle is supported upon a trestle framework that is far more robust than the vertical posts depicted in Francesco′s drawing.

The anonymous artist-engineer has improved some features of Francesco′s machine and drawn others more distinctly. The release mechanism for the bolts in Francesco′s drawing is deficient in its details, making it impossible to determine how the bolts were discharged (Fig. 11). This feature is clearly represented by the anonymous artist-engineer. The device, identified by Francesco as a ″nock,″ is shown to consist of a tube, or sleeve, that is fitted over each of the bolts at the balance point (center of gravity). A notch on the upper side of the ″nock″ holds the loose end of the cords. The fixed end of the cords is attached to the outer prongs of the forked appendage at the end of the throwing arm of the trebuchet (Fig. 12). The bolts are projected during the launch cycle when the loose ends of the cords are freed from the ″nock.″ This device performs the same function as the ″hook″ on the bolts of Ibn Urunbughā′s machine (see above).

[24]Chevedden et al., ″Traction Trebuchet,″ 447, 453–54.

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The anonymous artist-engineer has provided Francesco′s machine with a more efficient mechanical pull-back system for the throwing arm, one that utilizes leverage. A single rope, threaded through a roller at the base of the machine, runs from the end of the beam to the capstan. The catch-and-trigger device for both machines consists of an S-shaped (serpentine) lever that is pivoted backward. This device is so crudely depicted in Francesco′s original drawing that the lever cannot be pivoted backward (Fig. 11), but the anonymous artist-engineer has delineated it accurately so that it can be turned (Fig. 12).

One component that remains unchanged is the buffer. Since the version of the machine drawn by the anonymous artist-engineer has no cross-member obstructing the path of the beam, the sole purpose of the buffer is to stop the throwing arm before it reaches a fully upright position. Francesco apparently believed that the recoil of the counterweight box against this buffer served in some way to discharge the bolts. In fact, such recoil would shake the machine to pieces. Furthermore, it is not the breaking action of the buffer and the recoil of the beam that effects the discharge of the bolts, but gravitational energy as it flows from the counterweight box to the beam, to the cords, and finally to the bolts. The presence of the buffer seems to indicate that Francesco held the view that the pivoting beam of the trebuchet must be halted before it reached a fully vertical position in order for the bolts to fly free from the two cords attached to the throwing arm. The buffer prevents the full range of the beam′s rotation from being utilized to hurl the bolts, since the buffer halts the beam before it can reach a fully upright position. Taccola′s drawing of the bolt-projecting trebuchet shows no such buffer for the beam (Fig. 10), and Ibn Urunbughā makes no mention of one in his description of the *qarābughrā* (see above).[25] It is unlikely, therefore, that the bolt-projecting trebuchet was furnished with a buffer for the beam, a device that would have hampered the operation of the machine.

Nomenclature of the ″Black Camel″ Trebuchet

The nomenclature of the ″Black Camel″ trebuchet presents a problem. Ibn Urunbughā is almost alone in identifying the bolt-projecting trebuchet by the term ″Black Camel″ *(qarābughrā)*. The only other Arabic work that adopts this designation for the bolt-projecting machine is *Sīrat al-Sulṭān Jalāl al-Dīn Mankubirtī* by Muḥammad ibn Aḥmad al-Nasawī, which was produced in a Persian cultural milieu.[26] All other Arabic historical sources refer to this engine as the ″Black Bull″

[25]On the question of whether Francesco′s bolt projecting trebuchet, as well as many of his other ″ingenious devices,″ were ever meant to be actually operated, see Scaglia, *Francesco di Giorgio,* 9–10. For Taccola′s drawing of the bolt-projecting trebuchet, see note 22 above.

[26]Muḥammad ibn Aḥmad al-Nasawī, *Sīrat al-Sulṭān Jalāl al-Dīn Mankubirtī,* ed. Ḥāfiẓ Aḥmad

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(qarābughā) trebuchet, a corruption of the original term.[27] *Qarābughrā* is clearly the parent term, since *Elegant Book,* a technical treatise, employs this word, as does the first historical source to refer to the bolt-projecting trebuchet, al-Nasawī's *Sīrat Jalāl al-Dīn*. The romance cognate *caraboha* and its kindred terms *carabouha, carabaga, carabaccani,* and *carabachani* are all derived from *qarābughā* ("Black Bull"),[28] not from *qarābughrā* ("Black Camel").

The Turkish name for the bolt-projecting trebuchet may be linked to an association of the trebuchet with the camel that is also found in Arabic. One of the Arabic synonyms for a trestle-framed trebuchet *(manjanīq)* was *khaṭṭārah,* a word applied originally to a stallion-camel engaged in the action termed *khaṭarān,* the raising of its tail time after time which happens during bouts with rival camels. A connection was made in Arabic between the camel's tail being raised repeatedly and the motion of the throwing arm of a trebuchet as it goes through its launch cycle.[29] Although it seems sensible to establish a link between the camel-trebuchet connection in Arabic and that in Turkish, there is no absolute necessity to postulate such a relationship. The Turkish language appears to have associated the camel with the trebuchet in a semantic context related to the power of the machine, not to its operation. The camel stallion was one of the totem animals of the Turks, and this fact alone may explain why it was coupled with the most powerful form of artillery. The Turkish dynasty of the Ilek-Khans or Qarakhanids, which ruled over the regions of Eastern and Western Turkestan from 992 to 1212, commonly used

Ḥamdī (Cairo, 1953), 303.

[27]David Ayalon, "Ḥiṣār," *EI*², 3:473.

[28]The word *bughā* is the Arabic form of the Turkish term for bull, *buğa* or *buka* (Clauson, *Pre-Thirteenth-Century Turkish,* 312).

[29]Edward W. Lane, *An Arabic-English Lexicon*, (London, 1863–93), s.v. *khaṭara;* Hill, "Trebuchets," 100; and Kennedy, *Armies of the Caliphs,* 110. When the Umayyad Caliph Yazīd I besieged Mecca in 64/683, he employed a trestle-framed, traction trebuchet called *Umm Farwah* (Mother of Hair) that was described by the poet al-Zubayr ibn Khuzaymah al-Khath'amī as a *khaṭṭārah:* "raising its tail [i.e., beam] like a raging stallion camel *(khaṭṭārah mithla al-fanīq al-muzbid)*" (Abū Ja'far Muḥammad ibn Jarīr al-Ṭabarī, *Tārīkh al-Rusul wa-al-Mulūk [Annales]*, ed. Michael Jan de Goeje et al., 3 series, 15 vols. [Leiden, 1879–1901], 2:426 [the reference is to series and page number, not to volume and page number]; idem, *Tārīkh,* trans. I. K. A. Howard, *The History of al-Ṭabarī [Tārīkh al-rusul wa'l-mulūk],* vol. 19, *The Caliphate of Yazīd b. Mu'āwiyah,* SUNY Series in Near Eastern Studies, Bibliotheca Persica [Albany, 1990], 224). The poet Abū Ya'qūb al-Khuraymī also refers to the trebuchet as a *khaṭṭārah* in his description of defensive artillery at Baghdad during al-Ma'mūn's siege of the city in 197–98/812–13. "In every gated street and on every side," the poet relates, was a *khaṭṭārah* that launched stone-shot the size of a man's head, and the barrage was so intense that the projectiles resembled "flocks of dusky sand grouse taking flight in commotion" (al-Ṭabarī, *Tārīkh,* 3:877; idem, *Tārīkh,* trans. Michael Fishbein, *The History of al-Ṭabarī (Tārīkh al-rusul wa'l-mulūk),* vol. 31, *The War Between Brothers*, SUNY Series in Near Eastern Studies, Bibliotheca Persica [Albany, 1992], 145–46).

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a totemistic title formed from the term for a camel stallion, Bughra Khān.[30] The Turkish prefix *qarā-* (literally "black") carries the figurative meaning of "strong" or "powerful" and serves to intensify the meaning of *bughrā,* a term which on its own communicates the idea of power actively and efficiently displayed. Since the trebuchet was an instrument of enormous power, it was given a name in Turkish that symbolized great physical strength and energy.

The Turkish origin of the term *qarābughrā* suggests a Turco-Islamic origin for the bolt-projecting trebuchet. It may have emerged in the sultanate of the Great Saljuqs or in one of the Atabeg or Turkish principalities of western Asia. Alternatively, the Qarakhanids, who made the camel part of their regnal titles, may have invented the machine. As the western realms of the Qarakhanids passed into Saljuq and Khwarazm Shah spheres of influence, these two states may have acquired the bolt-projecting trebuchet and effected its diffusion westward.

THE "BLACK CAMEL" TREBUCHET IN MIDDLE EASTERN HISTORICAL SOURCES

Arabic historical chronicles identify the *qarābughrā,* usually under its corrupt form *qarābughā,* as being used in six sieges. In 626/1229, the last Khwarazm-Shah, Jalāl al-Dīn Mengübirti, became the first recorded military leader to employ a *qarābughrā* in his six-month siege of Akhlāṭ.[31] When the Ayyubid Sultan al-Malik al-Ṣāliḥ Najm al-Dīn Ayyūb laid siege to Homs in the winter of 646/1248–49, he employed a battery of artillery consisting of two trestle-framed, counterweight trebuchets—a bolt-projecting *qarābughrā* and a stone-projecting *manjanīq maghribī* (Western Islamic trebuchet)—and twelve "Devilish" traction machines *(majānīq al-shayṭānīyah).*[32] In 684/1285, the Mamluk Sultan Qalāwūn besieged the Hospitaller fortress of al-Marqab (Margat) with three *qarābughrā*s, three *bricola*s, identified as "Frankish" or "European" trebuchets *(majānīq firanjīyah),* and four traction trebuchets *(majānīq shayṭānīyah).*[33] In 688/1289, he attacked the

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[30]Clifford Edmund Bosworth, *The New Islamic Dynasties: A Chronological and Genealogical Manual* (New York, 1996), 181–84; idem, "Ilek-Khāns," *EI*^{2}, 3:1113–17; *History of Civilizations of Central Asia*, ed. Aḥmad H. Dani and Vadim M. Masson, vol. 4, *The Age of Achievement, A.D. 750 to the End of the Fifteenth Century*, pt. 1, *The Historical, Social and Economic Setting*, ed. M. S. Asimov and C. E. Bosworth (Paris, 1998), 121.

[31]Al-Nasawī, *Sīrat Jalāl al-Dīn,* 303.

[32]Jamāl al-Dīn Muḥammad ibn Sālim Ibn Wāṣil, "Mufarrij al-Kurūb fī Akhbār Banī Ayyūb," Paris, Bibliothèque Nationale MS fonds arabe 1703, fol. 61r. Al-Ṣāliḥ Ayyūb's *manjanīq maghribī* threw stone-shot against Homs weighing 140 Syrian *raṭl*s (259 kg or 571 lb). On the "Devilish" trebuchet *(manjanīq shayṭānī),* see Chevedden, "Artillery of King James I," 61, and note 58 below and text.

[33]Muḥyī al-Dīn Ibn ʿAbd al-Ẓāhir, *Tashrīf al-Ayyām wa-al-ʿUṣūr fī Sīrat al-Malik al-Manṣūr,* ed. Murād Kāmil and Muḥammad ʿAlī al-Najjār (Cairo, 1961), 78.

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Crusader port city of Tripoli with a battery of nineteen counterweight trebuchets composed of thirteen *qarābughrā*s and six *bricola*s *(ifranjīyah)*.[34] After Qalāwūn's death, his son and successor, Sultan al-Ashraf Khalīl, took up the siege of Acre, which his father had already set in motion. In 690/1291, he unleashed a deadly artillery attack against this heavily defended Crusader stronghold using a battery of seventy-two trebuchets, which included a complement of *qarābughrā*s alongside fifteen *bricola*s and fifty-two traction machines.[35] During the following year, in 691/1292, al-Ashraf Khalīl conquered the mighty fortress of Qalʿat al-Rūm with a battery of artillery comprised of five *qarābughrā*s, five *bricola*s *(majānīq firanjīyah),* and fifteen traction trebuchets *(majānīq shayṭānīyah)*.[36] Rarely do the historical

[34]Abū Bakr ibn ʿAbd Allāh ibn Aybak al-Dawādārī, known as Ibn al-Dawādārī, *Kanz al-Durar wa-Jāmiʿ al-Ghurar,* vol. 8, *Al-Durrah al-Zakīyah fī Akhbār al-Dawlah al-Turkīyah,* ed. Ulrich Haarmann (Cairo and Wiesbaden, 1971), 283; Shihāb al-Dīn Aḥmad ibn ʿAbd al-Wahhāb al-Nuwayrī, *Nihāyat al-Arab fī Funūn al-Adab,* vol. 31, ed. al-Bāz al-ʿArīnī (Cairo, 1992), 47; and Nāṣir al-Dīn Muḥammad ibn ʿAbd al-Raḥīm Ibn al-Furāt, *Tārīkh Ibn al-Furāt,* ed. Costi K. Zurayk and Nejla Izzedin, vols. 7–9, Publications of the Faculty of Arts and Sciences of the American University of Beirut, Oriental Series, nos. 9–10, 14, 17 (Beirut, 1936–42), 8:80.

[35]Shams al-Dīn Abū ʿAbd Allāh Muḥammad ibn Ibrāhīm ibn Abū Bakr al-Jazarī, *Ḥawādith al-Zamān wa-Anbāʾihi wa-Wafayāt al-Akābir wa-al-Aʿyān min Abnāʾih: al-Maʿrūf bi-Tārīkh Ibn al-Jazarī (min Wafayāt Sanat 689 ḥattá Ḥawādith Sanat 699 H),* ed. ʿUmar ʿAbd al-Salām Tadmurī (Sidon, 1998), 1:45; Quṭb al-Dīn Mūsá ibn Muḥammad al-Yūnīnī, *Dhayl Mirʾāt al-Zamān,* ed. Antranig Melkonian, *Die Jahre 1287–1291 in der Chronik al-Yūnīnīs* (Freiburg im Breisgau, 1975), 86 (Arabic text), 163 (trans.); Muḥammad Ibn Shākir al-Kutubī, *ʿUyūn al-Tawārīkh: Sanawāt 688–699 H,* ed. Nabīlah ʿAbd al-Munʿim Dāwūd (Baghdad, 1991), 71; and Ibn al-Furāt, *Tārīkh,* 8:112. See the excellent article by Donald P. Little, which analyzes the Arabic accounts of the siege of Acre in great detail, "The Fall of ʿAkkā in 690/1291: The Muslim Version," in *Studies in Islamic History and Civilization in Honour of Professor David Ayalon,* ed. Moshe Sharon (Jerusalem and Leiden, 1986), 159–81. Little's student Andreas D'Sousa has also produced an important study of the siege of Acre comparing Christian and Muslim sources, "The Conquest of ʿAkkā (690/1291): A Comparative Analysis of Christian and Muslim Sources," *Muslim World* 80 (July–October 1990): 234–50.

[36]Al-Jazarī, *Ḥawādith al-Zamān,* 1:109; *Beiträge zur Geschichte der Mamlukensultane in den Jahren 690–741 der Higra, nach arabischen Handschriften,* ed. Karl V. Zetterstéen (Leiden, 1919), 16; Ibn al-Dawādārī, *Kanz,* 8:333; Mufaḍḍal Ibn Abī al-Faḍāʾil, *Al-Nahj al-Sadīd wa-al-Durr al-Farīd fīmā baʿda Tārīkh Ibn al-ʿAmīd,* ed. and trans. Edgar Blochet, "Histoire des Sultans Mamlouks," *Patrologia Orientalis* 14, no. 3 (1920): 553; al-Nuwayrī, *Nihāyat al-Arab,* 226; and Ibn al-Furāt, *Tārīkh,* 8:136. All of the accounts of the siege of Qalʿat al-Rūm that provide an enumeration of the several types of trebuchets used against this castle suffer from textual corruption. The most authoritative account appears to be that of al-Jazarī, who relates information received from two eyewitnesses to the siege, Amir Shams al-Dīn Abū al-Bayyān, known as Ibn al-Miḥaffadār, Amīr Jandār (armor bearer or guard officer), and his son Amir Sayf al-Dīn. The version of the siege in the anonymous chronicle edited by Zetterstéen is based on al-Jazarī's account, and the later accounts of the siege by Ibn al-Dawādārī and the Christian historian al-Mufaḍḍal Ibn Abī

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sources give an enumeration of the different types of artillery used in a siege, so the actual use of *qarābughrā*s was probably far more numerous than the extant sources suggest.

al-Faḍā'il, appear to be unsuccessful attempts to resolve the textual problems of al-Jazarī's original (debased) narrative. Al-Jazarī's enumeration of the different trebuchets at Qal'at al-Rūm omits the number "five" before the second substantive in the list of three types of machines: "nuṣiba 'alayhā min al-majānīq khams majānīq ifranjīyah wa-qarābughā wa-shayṭānīyah khamsata 'ashr manjanīqan." Since the anonymous author, Ibn al-Dawādārī, and al-Mufaḍḍal Ibn Abī al-Faḍā'il all state that five *qarābughrā*s were positioned on the western side of the castle, it is evident that there were five *qarābughrā*s at the siege, and that al-Jazarī's enumeration of artillery should be interpreted as entailing five "Frankish" trebuchets *(khams majānīq ifranjīyah),* or *bricola*s, five bolt-projecting trebuchets *(qarābughā),* and fifteen traction trebuchets *(shayṭānīyah khamsata ashr manjanīqan).* The ungrammatical phrase, *min al-gharbīyah jihat qarābughā,* that appears in al-Jazarī's description of the artillery at Qal'at al-Rūm should be amended to read, *min al-jihah al-gharbīyah khamsat qarābughā* ("on the western side [of the castle] were five *qarābughrā*s"), which follows, exactly or approximately, the phraseology found in the accounts of the anonymous author, Ibn al-Dawādārī, and al-Mufaḍḍal Ibn Abī al-Faḍā'il. The attempts by authors after al-Jazarī to provide an accurate tally of the number of trebuchets used against Qal'at al-Rūm were unsuccessful. Ibn al-Dawādārī and al-Mufaḍḍal Ibn Abī al-Faḍā'il, either confused by al-Jazarī's phraseology or the corrupt nature of his text, set the number at nineteen (Ibn al-Dawādārī, *Kanz,* 8:333; Ibn Abī al-Faḍā'il, *Al-Nahj,* 553). Al-Nuwayrī and Ibn al-Furāt did better and came to a total of twenty trebuchets (al-Nuwayrī, *Nihāyat al-Arab,* 226; Ibn al-Furāt, *Tārīkh,* 8:136), while al-'Aynī came closest to the mark with a tally of twenty-three trebuchets (Badr al-Dīn Maḥmūd ibn Aḥmad al-'Aynī, *'Iqd al-Jumān fī Tārīkh Ahl al-Zamān: 'Aṣr Salāṭīn al-Mamālīk,* vol. 3, *Ḥawādith wa-Tarājim, 689–698 H/1290–1298 M,* ed. Muḥammad Muḥammad Amīn [Cairo, 1989], 113).

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The "Black Camel" *(Qarābughrā)* Trebuchet Used Together with Other Pieces of Military Ordnance in Thirteenth-Century Sieges

Date	*Siege of*	*Besieged by*	*Artillery*
626/1229	Akhlāṭ	Jalāl al-Dīn Mengübirti	1 *qarābughrā*
646/1248–49	Homs	al-Ṣāliḥ Ayyūb	1 *qarābughrā* 1 Western Islamic trebuchet *(manjanīq maghribī)* that hurled stone-shot weighing 140 Syrian *raṭl*s (259 kg or 571 lb) 12 "Devilish" traction trebuchets *(majānīq al-shayṭānīyah)*
684/1285	al-Marqab	Qalāwūn	3 *qarābughrā*s 3 *bricola*s (*majānīq firanjīyah*) 4 ""Devilish" traction trebuchets *(majānīq al-shayṭānīyah)*
688/1289	Tripoli	Qalāwūn	13 *qarābughrā*s 6 *bricola*s *(ifranjīyah)*
690/1291	Acre	al-Ashraf Khalīl	5 *qarābughrā*s 15 *bricola*s (*majānīq al-kibār al-ifranjīyah*) that hurled stone-shot weighing one Damascene *qinṭār* or more (185 kg or 408 lb +) 52 "Devilish" traction trebuchets *(majānīq al-shayṭānīyah)* an unspecified number of traction-powered pole-framed "Playthings" *(luʿab)*
691/1292	Qalʿat al-Rūm	al-Ashraf Khalīl	5 *qarābughrā*s 5 *bricola*s *(majānīq firanjīyah)* 15 "Devilish" traction trebuchets *(majānīq al-shayṭānīyah)*

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THE TACTICAL ROLE OF THE "BLACK CAMEL" TREBUCHET

Judging from its employment in the six important sieges mentioned above and its likely use in other sieges, it seems reasonable to assume that the *qarābughrā* played a useful role in most of the major sieges undertaken by the Mamluks in the thirteenth century. Unfortunately, the historical sources provide no hints about the tactical use of this piece of artillery. What purpose did the "Black Camel" trebuchet serve? As a piece of artillery for shooting flaming bolts, it was perfectly suited for destroying the protective screens that shielded fortifications from stone-shot discharged from trebuchets. To protect defensive circuits in the Middle Ages, load-bearing curtains, or screens, were hung down over the walls on beams of wood projecting about a meter from the battlements. These screens were commonly composed of netting overlaid with cushioning material that served to deaden the impact of stones cast by artillery.[37] Since stone-shot of heavy artillery could only take effect on exposed masonry, it was essential for besiegers to destroy the protective screens in order to knock down walls with artillery safely from a distance. With the introduction of the counterweight trebuchet, the breaching capacity of artillery was greatly enhanced. Besiegers found that they could not only use the new ordnance to batter walls safely from a distance, but they could also—with a few minor adjustments, as indicated by Ibn Urunbughā—use this

[37]On the use of protective screens in premodern warfare, see Paul E. Chevedden, "The Citadel of Damascus," Ph.D. diss., University of California, Los Angeles, 1986, 1:194–97; idem, "Artillery of King James I," 79 and Pl. 12; Robert I. Burns and Paul E. Chevedden, *Negotiating Cultures: Bilingual Surrender Treaties in Muslim-Crusader Spain under James the Conqueror*, The Medieval Mediterranean, vol. 22 (Leiden, 1999), 176–77; Needham and Yates, *Science and Civilization in China*, 5:6:398–413; and Lawrence*, Greek Aims in Fortification,* 59, 64, 103–5. Several types of protective screens were employed in China during the Warring States Period (403–222 B.C.E.). These are described in the book *Mozi* (Book of Master Mo), dating from the fourth century B.C.E., and are analyzed in Yates, "Siege Engines and Late Zhou Military Technology," 420–23. Philo of Byzantium, writing around 200 B.C.E., discusses the use of screens on fortifications (Lawrence, *Greek Aims in Fortifications,* 105), as does Vegetius and an anonymous sixth-century Byzantine author (Flavius Vegetius Renatus, *Epitoma rei militaris,* ed. and trans. Leo F. Stelten [New York, 1990], 4.23; *Three Byzantine Military Treatise,* George T. Dennis, ed. and trans. [Washington, D.C., 1985], 43). In the Islamic world, a discussion of protective screens *(satā'ir,* sing. *sitārah)* can be found in Rashīd al-Dīn Faḍl Allāh Ṭabīb, *Histoire des Mongols de la Perse*, trans. Étienne Quatremère, Collection orientale, manuscrits inédits de la Bibliothèque royale (Paris, 1836; repr., Amsterdam, 1968), 286–87; Abū al-Sa'īd al-Harthamī, *Mukhtaṣar fī Siyāsat al-Ḥurūb,* ed. 'Ārif Aḥmad 'Abd al-Ghanī, Silsilat Kutub al-Turāth, vol. 5 (Damascus, 1995), 61 *(sutar);* 'Alī ibn Bakr al-Harawī, *Al-Tadhkirah al-Harawīyah fī al-Ḥiyal al-Ḥarbīyah,* ed. and trans. Janine Sourdel-Thomine, "Les conseils du šayḫ al-Harawi à un prince ayyūbide," *Bulletin d'Études Orientales* 17 (1961–62): 239 (trans.), 243; and al-Ḥasan ibn 'Abd Allāh al-'Abbāsī, *Āthār al-Uwal fī Tartīb al-Duwal,* ed. 'Abd al-Raḥmān 'Umayrah (Beirut, 1989), 368 (on fixed fortifications), 372 (on ships).

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artillery to destroy protective screens safely from a distance.[38] The trestle-framed counterweight trebuchet appears to have been adapted for this task. Although crossbows could also be used to shoot flaming bolts, their smaller projectiles were less likely to cause a conflagration that would consume the protective screen due to incendiary-proofing measures taken by defenders. These measures included soaking the protective screens in fire-retardant liquid and pouring water down from the battlements. An immense incendiary bolt launched by a *qarābughrā* facilitated rapid combustion by the release of the stored energy in its pyrotechnic mixture. If trebuchets could lodge a sufficient number of flaming bolts in a protective screen, a serious outbreak of fire would result that was capable of setting a protective screen ablaze. Aside from being well adapted for the task of destroying protective screens, the *qarābughrā* was equally suited for raining fire from heaven upon besieged towns and fortresses, but this does not appear to have been its primary function. Rounded fire-pots released from the sling of a trebuchet were quite capable of setting ablaze the interior parts of cities and castles, but only flaming bolts were capable of cleaving to a protective screen, thereby allowing combustion to spread and fire to consume the defensive shield of a masonry wall.[39] As a destroyer of protective screens, the *qarābughrā* appears to have filled a special niche in the medieval siege arsenal.

This is one possible route by which the idea of the bolt-projecting trebuchet may have been arrived at. On the other hand, this piece of artillery could have been invented to serve a defensive function and been subsequently adapted to perform in an offensive capacity. The defensive value of bolt-projecting artillery, particularly against approach-works, such as filling-mantlets, digging-mantlets, ram-mantlets, and mobile siege-towers, as well as against hostile artillery and densely packed groups of soldiers, is quite obvious. The fiery-bolt launched by a *qarābughrā* had the great advantage of being able to stick to wooden equipment and set it ablaze. Whatever in fact prompted the development of the bolt-projecting

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[38]On the introduction of the counterweight trebuchet, see Chevedden, "Invention of the Counterweight Trebuchet."

[39]Ibn Urunbughā offers the following instructions for launching fire-pots *(qudūr al-nafṭ)* and other rounded incendiary missiles from a trebuchet: "If you want to shoot a pot *(qidrah)* filled with naphtha *(nafṭ)* and *lizāqāt* [sticky gums or resins], a pot of quicklime *(kils)* and smoke pots *(dakhkhānāt),* or a stone of a trebuchet packed with naphtha *(nafṭ),* first of all, take the oil of the radish *(mā' al-fujl)* or mica *(talq)* dissolved in strong vinegar *(khall al-'atīq)* and wet [some] felt in [this]. [Then], stitch this felt in the pouch *(kaffah)* of the trebuchet and [on] the cords *(sawā'id)* [of the sling] up to their middle. Put the [fire-]pot *(qidrah)* in it [the pouch] and launch it, and it will burn what you want." ("Anīq," fol. 18r; *Anīq,* ed. 'Abd al-'Azīz, 24–25; *Anīq,* ed. Hindī, 44–45).

For additional descriptions, as well as illustrations, of trebuchets hurling fire-pots, see al-Rammāḥ, *Furūsīyah,* 114–18, Figs. 66, 67, 68, 71.

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trebuchet, it seems certain that defending, as well as attacking, forces could readily make use of this piece of artillery.

Baybars al-Manṣūrī describes, with great rhetorical flourish, the incendiary projectiles that the Mamluks launched against Acre in 690/1291. The "Islamic trebuchets" *(majānīq al-islāmīyah),* he says, shot stones "resembling stunning thunderbolts" *(ka-al-ṣawāʻiq al-ṣāʻiqah)* and hurled bolts "bearing the likeness of gleaming flashes of lightning" *(ka-al-bawāriq al-bāriqah).*[40] His description of the stone-shot conveys the image of a flash of lightning viewed as an intensely hot solid body moving rapidly through the air before striking something. Ibn Urunbughā describes stone-shot perforated with holes to contain naphtha *(nafṭ)* that easily fits this image.[41] Baybars may be referring to this type of projectile or to any incendiary device having the shape of rounded stone-shot. His depiction of the bolts as "gleaming flashes of lightning" conveys the image of an electrical storm that rains down destruction by means of bolts or darts. There can be little doubt that Baybars is referring here to incendiary missiles hurled by bolt-projecting trebuchets.[42] Although there is no direct evidence that the Mamluk *qarābughrā*s were used to destroy the protective screens at Acre, we can be fairly certain that the defenses of the city were equipped with these devices. The inhabitants of Acre had a full seven months to prepare for the Mamluk siege, and Arabic sources note that they prepared the city extremely well for an assault. Al-ʻAynī affirms that when Sultan al-Ashraf Khalīl reached Acre during the first ten day of Rabīʻ II/4–13 April, "he found it fortified with all kinds of equipment and siege machines."[43] Since the outfitting of defenses with protective screens was a normal measure taken by besieged forces in the Middle Ages, we can assume that the defenders furnished the walls and towers of Acre with these screens. Their absence would certainly have merited a comment in the Arabic sources. Baybars al-Manṣūrī, an eyewitness to the siege, states that the inhabitants of Acre were so convinced of their ability to withstand a siege, due to the defensive measures that they had taken to fortify the towers and walls, that "they did not even close the gates of the city, nor even

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[40] Baybars al-Manṣūrī, *Zubdat al-Fikrah fī Tārīkh al-Hijrah,* ed. Donald S. Richards, Nasharāt al-Islāmīyah, vol. 42 (Beirut, 1998), 279; Little, "Fall of ʻAkkā," 172.

[41] See note 39 above, and "Anīq," fol. 54r–54v; *Anīq,* ed. ʻAbd al-ʻAzīz, 119–21; *Anīq,* ed. Hindī, 188–91, where Ibn Urunbughā describes three types of "flaming" stones, i.e., rounded stone-shot drilled with holes to contain naphtha and other inflammable substances.

[42] For an alternate view, see Little, "Fall of ʻAkkā," 172, where Baybars al-Manṣūrī's description of the missiles hurled by trebuchets is credited to rhetorical exaggeration.

[43] Al-ʻAynī, *ʻIqd al-Jumān,* 57: "fa-wajadahā qad taḥaṣṣanat bi-sā'ir al-ʻudad wa-al-ālāt." Here, "equipment" *(ʻudad,* sing. *ʻuddah)* would include protective screens, and "siege machines" *(ālāt,* sing. *ālah)* would imply artillery as well as other siege engines.

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hang down a protective screen *(ḥijāb)* in front of the gates."[44] Baybars's observation is quite revealing. It indicates that the defenders properly prepared their city for a siege, which would certainly have entailed the use of protective screens. It shows the supreme confidence of the inhabitants in the defensive measures that they had taken to protect the city from siege, but, more importantly, it discloses that the confidence, or "indifference" *(ʿadam al-mubālāh bi-al-muḥāṣarah),* that they exhibited had its limits. It only extended to leaving the gates of the city open and not hanging protective screens in front of the gates. Had this confidence been more robust and involved leaving the city walls and towers bereft of protective screens, Baybars would doubtless have commented on this fact.

The specialized function to which the *qarābughrā* was put hardly precludes other uses for the machine. Ibn Urunbughā describes the *qarābughrā* as a modified stone-projecting, trestle-framed counterweight trebuchet. As such, it could easily be restored to its original condition as a stone-projecting piece of artillery. Once it had completed its primary task of reducing the protective screens to ashes, the *qarābughrā* could be refitted with a sling without any difficulty and put into action as a stone-projector. This may explain why Western European accounts of the *qarābughrā* mention it as being employed solely as a stone-projector (see below).

The "Black Camel" Trebuchet in Western European Historical Sources

Western European sources that refer to the *qarābughrā* cite it as being used by the Mamluks in only two sieges: the siege of Tripoli in 688/1289[45] and the siege of Acre in 690/1291.[46] The Mamluk conquest of these two great port cities effectively brought an end to Latin rule in Syria. The machine is designated by its romance

[44]Baybars al-Manṣūrī, *Zubdah,* 279; Little, "Fall of ʿAkkā," 171–72. The use of the term *ḥijāb,* rather than *sitārah* (sing.) or *satāʾir* (pl.), for a protective screen draped in front a gate seems to indicate that protective screens were differentiated in Arabic on the basis of size. A small screen hung in front of a gate was denoted by the term *ḥijāb,* while a large screen hung in front of a curtain wall or tower was generally referred to by the plural word for screen, *satāʾir*.

[45]"Les Gestes des Chiprois," in *Recueil des historiens des croisades, Documents arméniens* (Paris, 1869–1906), 2:no. 476 (*carabohas*).

[46]"Ibid., no. 491 (*carabouhas*); *Chroniques d'Amadi et de Strambaldi,* vol. 1, *Chronique d'Amadi,* ed. René de Mas Latrie (Paris, 1891), 220; Marino Sanudo, "Liber secretorum fidelium crucis super Terrae Sanctae recuperatione et conservaione," in *Gesta Dei per Francos,* ed. Jacques Bongars (Hanau, 1611), 2:230 (*carabagas*); John of Ypres, *Chronicon Sythiense Sancti Bertini,* in *Thesaurus novus anecdotorum,* ed. Edmond Martène and Ursin Durand (Paris, 1717), 3:770E (*carabagas*); and Florio Bustron, *Chronique de l'île de Chypre,* ed. René de Mas Latrie, in Comité des travaux historiques et scientifiques (France), *Mélanges historiques: Choix de documents*, Collection des documents inédits sur l'histoire de la France, Mélanges historiques (Paris, 1873–86), 5:120 *(carabaccani).*

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cognate *caraboha* or kindred terms (derived from *qarābughrā* through its corrupt form *qarābughā*), but no reference is made to it being used to hurl bolts, flaming or otherwise. According to the accounts of the siege of Acre by Marino Sanudo, John of Ypres, and Florio Bustron, the *caraboha* hurled large stones. The so-called ″Templar of Tyre,″ who authored *Les Gestes des Chiprois*, contends that ″*carabohas* are small traction-powered Turkish trebuchets that have a rapid rate of discharge.″[47] The anonymous *Chronique d′Amadi,* which is dependent on *Les Gestes,* depicts *carabachani* as light artillery with a rapid sequence of discharge used for clearing the battlements of defenders.[48] The first three authors may have applied the term to an actual bolt-projecting trebuchet *(qarābughrā)* that had been refitted to launch stone-shot. Alternately, the authors may have confused the trestle-framed, bolt-projecting trebuchet *(qarābughrā)* with the gravity-powered, pole-framed trebuchet known as the *bricola.* According to al-Yūnīnī, the Mamluks employed fifteen ″big″ (i.e., counterweighted) *bricolas (majānīq al-kibār al-ifranjīyah)* against Acre, which hurled stone-shot weighing one Damascene *qinṭār* or more (185 kg or 408 lb +).[49] The ″Templar of Tyre,″ on the other hand, has probably mistaken the *qarābughrā* trebuchets for the numerous traction trebuchets used by the Muslims at Acre (see below), which had an extremely rapid sequence of discharge.[50] This misidentification of the *qarābughrā* has led Christopher Marshall to conclude that this machine is a hand-held sling used for hurling stones.[51] Other scholars, such as Charles Dufresne Du Cange, Henry Yule, and Eugène Martin-Chabot, have associated the *qarābughrā* with the hybrid trebuchet called a *calabre* in French.[52]

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[47]″Gestes des Chiprois,″ 2:no. 491: ″Qarabouhas, que sont engins petis turqueis quy se tirent as mains.″

[48]*Chroniques d′Amadi,* 220: ″. . . et il quarto dì da poi venuto fece drizar ripari in molti lochi et fece metter grandi ingegni et machine et caravachani, che gittavano spesso li muri della terra.″ Andreas D′Souza identifies both the *carabachani* in the *Chroniques d′Amadi* and the *caraboha* in *Les Gestes* as ″catapults″ and considers them to be different machines (D′Sousa, ″Conquest of ʿAkkā,″ 242 and n. 62).

[49]Al-Yūnīnī, *Dhayl,* 86 (Arabic text), 162 (trans.). The editor of *Dhayl Mirʾāt al-Zamān,* Antranig Melkonian, incorrectly gives the weight of stone-shot launched by the Mamluk *bricolas* as 44.93 kilograms (99.05 lb.), by assuming that one Damascene *qinṭār* (185 kg or 408 lb) is equivalent to 100 Egyptian *raṭls* (al-Yūnīnī, *Dhayl,* 162 n. 7 [trans.]). Little accepts Melkonian′s calculation and drastically underestimates the weight of stone-shot hurled by the *bricolas* (Little, ″Fall of ʿAkkā,″ 171). On the Damascene *qinṭār,* a weight of 100 Syrian *raṭls* of 1.85 kilograms, see Walther Hinz, *Islamische Masse und Gewichte umgerechnet ins metrische System* (Leiden, 1970), 26, 30.

[50]Al-Yūnīnī, *Dhayl,* 86 (Arabic text), 162–63 (trans.): ″majānīq al-shayṭānīyah wa-al-laʿab″; al-ʿAynī, *ʿIqd al-Jumān,* 58: ″majānīq ithnān wa-khamsūn manjanīqan shayṭānīyan.″

[51]Christopher Marshall, *Warfare in the Latin East, 1192–1291* (Cambridge, 1992), 214, 234.

[52]Charles Dufresne Du Cange, *Glossarium mediae et infimae latinitatis* (Niort, 1883–87), s.v.

MAMLUK LIGHT ARTILLERY AT THE SIEGE OF ACRE

The account of the Mamluk artillery at Acre found in *Les Gestes* appears to be contradictory. We are told that the light artillery, identified by the "Templar of Tyre" as *carabohas*, "did more harm to our men than the heavy artillery."[53] This statement does not mean to imply that the small caliber machines caused more damage than the large caliber machines. Light artillery would certainly not have inflicted more damage than heavy artillery, but large numbers of small trebuchets deployed in batteries could put down a tremendous barrage against defending forces. By producing a concentrated hail of missiles, light artillery served to neutralize the defenders on the battlements so that heavy artillery could engage in its work of destruction while siege-works and machinery were advanced against fortified positions. Given the slow sequence of discharge of the counterweight trebuchet, its effective use in siege operations required the deployment of sufficient numbers of light traction-powered trebuchets capable of delivering sustained volleys of small shot that would send defenders diving for cover. By putting down a heavy barrage against defending forces, the light artillery enabled heavy artillery to bombard strongpoints with virtual impunity. The anti-personnel use of light artillery also facilitated the approach of siege-engines and assault-works. Since the light artillery was employed specifically to kill or injure human beings, it would have taken from Acre a heavy toll of its defenders, thereby eliciting the seemingly paradoxical remark by the "Templar of Tyre." Both the Latinate and Arabic descriptions of the siege of Acre indicate that Muslim light artillery provided neutralizing shooting that gave support to heavy artillery and mining operations by keeping the defenders at bay.[54]

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calabra; Marco Polo, *Book of Ser Marco Polo,* 2:168; William of Tudela and anonymous, *La Chanson de la croisade Albigeoise,* ed. Eugène Martin-Chabot, Les classiques de l'histoire de France au moyen âge, vols. 13, 24–25 (Paris, 1931–61), 3:59. On the *calabre* as a hybrid trebuchet, see Chevedden, "Hybrid Trebuchet," 210–11.

[53]"Gestes des Chiprois," 2:no. 491: "Qarabouhas . . . faizoient plus de maus a la gent que les grans engins."

[54]Amadi's chronicle claims that bombardment from the Mamluk *carabachani* neutralized the defenders on the battlements of the Tower of the King, or the Accursed Tower, thereby allowing the besiegers to undermine it (*Chroniques d'Amadi,* 221). *Les Gestes* provides additional details on the Mamluk mining operations ("Gestes des Chiprois," 2:nos. 491, 493). Al-Yūnīnī indicates that the artillery destroyed the tops of the towers and the walls (al-Yūnīnī, *Dhayl,* 87 [Arabic text], 163 [trans.]), and al-ʻAynī describes how the trebuchets tore away the battlements and shook the denuded curtain walls in order to bring about their collapse (al-ʻAynī, *ʻIqd al-Jumān,* 60). With the battlements sheared off, the defenders along the rampart walk of the curtain walls and the towers were completely exposed to the hail of missiles being directed at them by the besieging Mamluk army. The Mamluks were able to easily undermine the walls of the city

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Fifty-two of the Mamluk trebuchets at Acre, according to al-ʿAynī, were traction-powered machines called ″Devilish″ trebuchets *(manjanīq shayṭānī).*[55] Al-Yūnīnī states that three varieties of trebuchets were used in great numbers: ″Devilish″ machines, ″Playthings,″ and *qarābughrā*s.[56] The first two machines are traction powered. The ″Plaything″ (*luʿbah*, pl. *luʿab*), called an *ʿarrādah* in most Arabic sources, was a pole-framed traction machine with a throwing arm mounted upon a pivot-yoke.[57] The name ″Plaything″ comes from the play, or rapid movement, of its throwing arm as it is sent skyward in quick succession during continuous operation. Al-ʿAynī may have included the pole-framed ″Playthings″ in his figure for ″Devilish″ trebuchets, or the ″playful″ artillery could be additional to the number of ″Devilish″ machines. Whatever interpretation is accepted regarding the number of traction trebuchets at Acre, it is clear that they were employed in great numbers and were used to neutralize the defenders on the ramparts.[58]

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because the barrage of missiles prevented the defenders from mounting any effective resistance. Even sallies in force failed to stop the mining operations. Al-Jazarī, al-Yūnīnī, and al-Nuwayrī comment briefly on the mining operations undertaken by the Mamluk army, but neither Little nor D′Souza make mention of the Arabic accounts of these activities, which were critical to the conquest of Acre (al-Jazarī, *Ḥawādith al-Zamān,* 1:45; al-Yūnīnī, *Dhayl,* 87 [Arabic text], 163 [trans.]; al-Nuwayrī, *Nihāyat al-Arab,* 198; Little, ″Fall of ʿAkkā″; and D′Sousa, ″Conquest of ʿAkkā″). Little credits the successful Mamluk assault on Acre to artillery bombardment that weakened the defenses of the city. He ignores the fact that mining operations created the breaches in the walls that made the assault possible (Little, ″Fall of ʿAkkā,″ 174). The references to mining operations in the Arabic sources confirm and corroborate the Christian accounts of these siege-works.

55 Al-ʿAynī, *ʿIqd al-Jumān,* 58.

56 Al-Yūnīnī, *Dhayl,* 86 (Arabic text), 162–63 (trans.): ″ammā al-majānīq shayṭānīyah wa-al-laʿab wa-qarābughā shay' kathīr.″

57 On the pole-framed traction trebuchet, referred to in Arabic sources as the *luʿbah* and the *ʿarrādah,* see Chevedden, ″ Artillery of King James I,″ 58–59, 61, 68, Figs. 1–4; idem, ″Hybrid Trebuchet,″ 184, 199, 206, 211, Figs. 1, 3, 7, 9; Chevedden et al., ″Traction Trebuchet,″ 460–61, 464 (Fig. 3), 466 (Fig. 5), 470 (Fig. 10), 474 (Fig. 14), 484 (Fig. 24). *Elegant Book* includes a number of illustrations of the pole-framed trebuchet (″Anīq,″ fols. 33r, 43v, 44r; *Anīq,* ed. ʿAbd al-ʿAzīz, 73, 94, 95; *Anīq,* ed. Hindī, 109, 117, 118).

58 The design of the ″Devilish″ trebuchet is open to debate. *Elegant Book* is the only source that provides illustrations of it, depicting it as a traction version of the pole-framed *bricola* (″Anīq,″ fols. 21v, 31r; *Anīq,* ed. ʿAbd al-ʿAzīz, 50, 69; *Anīq,* ed. Hindī, 100–102). The two editors of *Elegant Book* both identify the machine incorrectly as a ″Sultanic″ or ″Royal″ trebuchet *(manjanīq sulṭānī),* due to the fact it is erroneously identified as such on fol. 21v of the text. The caption title for this machine is accurately inscribed on fol. 31r as *manjanīq shayṭānī,* so there is no question regarding the precise name of this trebuchet, which is the name by which it is known in all of the Arabic historical sources. Since Ibn Urunbughā′s pole-framed traction machine known by the names *ʿarrādah* and ″Plaything″ *(luʿbah)* is quite different from the ″Devilish″ trebuchet, it is clear that he, like al-Yūnīnī, considers it to be a different machine (″Anīq,″ fols. 33r, 44r; *Anīq,* ed. ʿAbd al-ʿAzīz, 73, 95; *Anīq,* ed. Hindī, 109, 118; Chevedden, ″Artillery of James I,″ 61, Fig. 1;

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MAMLUK HEAVY ARTILLERY AT THE SIEGE OF ACRE ACCORDING TO *LES GESTES DES CHIPROIS*

Despite his misidentification of the *qarābughrā,* the ″Templar of Tyre″ does provide important and reliable information on the Mamluk artillery at Acre that demonstrates both his competency in Arabic and his ability to acquire accurate information on the Muslim assault. According to him, the heavy artillery launched stone-shot weighing a *qinṭār* (185 kg or 408 lb), which is in agreement with the weight given by al-Yūnīnī for stone-shot discharged by the Muslim *bricola*s. The ″Templar of Tyre″ describes four separate pieces of heavy artillery employed by the Mamluks. The first he calls by its Arabic name ″Haveben,″ giving a rough transliteration of

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idem, ″Hybrid Trebuchet,″ 184, Fig. 9; and Chevedden et al., ″Traction Trebuchet,″ 461, 484, Fig. 24). It may well have been configured as a traction version of a *bricola,* as illustrated in *Elegant Book*, but it is hard to imagine that the trestle-framed traction trebuchet passed out of use. The ″Templar of Tyre″ speaks of his so-called *carabohas* as small traction-powered ″Turkish″ trebuchets. While these small-caliber machines may be identified with the pole-framed *ʻarrādah* or *luʻbah,* which had an extremely rapid rate of discharge, it is equally plausible that the stone-projectors dubbed ″Turkish″ trebuchets by the ″Templar of Tyre″ were the same machines that are called ″Turkish″ by al-Ṭarsūsī. His ″Turkish″ trebuchet *(manjanīq turkī)* is a trestle-framed traction machine that has a framework consisting of two paired trusses in the shape of the Greek letter *lambda* (*Tabṣirah fī al-Ḥurūb,* ed. Ṣādir, 167, 254, Fig. 10; Cahen, ″Traité,″ 119, 141–42, Pl. 2, Fig. 11; and Chevedden et al., ″Traction Trebuchet,″ 460–61, 481, Fig. 21). Al-Ṭarsūsī recommends the ″Turkish″ trebuchet as the cheapest of all the trebuchets he describes and the one composed of the least amount of parts. This machine was used widely across Eurasia and North Africa and was known as the ″Crouching Tiger″ trebuchet *(hu dun pao)* in Chinese sources and as the *labdarea* (the *lambda*-shaped machine) in Byzantine sources. The Chinese machine had a beam of 7.50 meters in length mounted on a framework that stood approximately 5.19 meters in height. Attached to the butt-end of the beam were forty pulling-ropes that were hauled down by a crew of forty men, while a single loader directed the shot. The machine was capable of throwing a stone projectile weighing 7.56 kilograms a distance of more than 75.0 meters (Chevedden,″ Artillery of King James I,″ 61, 66, 86, Fig. 5; idem, ″Hybrid Trebuchet,″ 199–200; and Chevedden et al., ″Traction Trebuchet,″ 452, 475, Fig. 15). Although the evidence is somewhat tenuous, the ″Devilish″ trebuchet *(manjanīq shayṭānī)* and the ″Plaything″ *(ʻarrādah* or *luʻbah)* do appear to be different types of traction machines. The ″Plaything″ probably never deviated significantly from the Chinese machine of the same design, known as the ″Whirlwind″ trebuchet *(xuan feng pao)* (see Fig. 1, and Chevedden et al., ″Traction Trebuchet,″ 452, 474, Fig. 14), while the ″Devilish″ trebuchet was doubtless a larger machine. The design of the ″Devilish″ machine may have resembled Ibn Urunbughā′s drawing of it as a traction-powered *bricola*, or it may have had a trestle framework. Both the ″Devilish″ trebuchet and the ″Plaything″ worked their devilish ways by playing the enemy with rapid volleys of stone-shot. A discharge of slightly better than four shots per minute could be maintained by traction-powered trebuchets, so a battery of these machines was quite capable of neutralizing defenders on the battlements (Chevedden, ″Artillery of King James I,″ 55; idem, ″Hybrid Trebuchet,″ 209; and Chevedden et al., ″Traction Trebuchet,″ 441, 457).

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the Arabic *al-ghaḍbān* (The Furious One). This term was originally applied to a hybrid trebuchet used in the defense of Baghdad in 251/865.[59] The term went on to become a generic name for the hybrid trebuchet and passed into Armenian and Turkish as *baban,* designating this class of artillery.[60] At the siege of Acre in 690/1291 the term was applied once again to an individual trebuchet, in this case, most probably a counterweight trebuchet from among the battery of gravity-powered machines used by the Mamluks. The "Templar of Tyre" correctly translates the name of this trebuchet as "furious" and indicates that this machine directed its shot against the guard of the Templars. His description of the second trebuchet provides the same data as his description of the first: "Another trebuchet that was shooting at the guard of the Pisans had the name *Mensour,* which means the Victorious." The Arabic title *al-Manṣūr* does indeed mean "The Victorious One," but the name of the trestle-framed counterweight trebuchet *(manjanīq ʻaẓīm)* identified by the "Templar of Tyre" takes the form of a *nisbah, al-Manṣūrī,* and refers to a trebuchet of Sultan al-Manṣūr Qalāwūn, or a "Royal" trebuchet.[61] The "Templar of Tyre" admits that he does not know the name of the third trebuchet, but he does specify that it was a "big" machine that directed its shot at the guard of the Hospitallers. For the fourth trebuchet he provides only its location, not its name: "The fourth trebuchet *(le cart* [sic] *engin)* was shooting at a great tower called the ʹAccursed Tower,ʹ which is along the second [i.e., outer] wall [of the city] and is under the

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[59]*Fragmenta historicorum arabicorum,* vol. 1, Anon., *Kitāb al-ʻUyūn wa-al-Ḥadāʼiq fī Akhbār al-Ḥaqāʼiq,* ed. Michael Jan de Goeje (Leiden, 1869), 580; al-Ṭabarī, *Tārīkh,* 3:1551; idem, *Tārīkh,* trans. George Saliba, *The History of al-Ṭabarī* (*Tārīkh al-rusul waʼl-mulūk,*), vol. 35, *The Crisis of the ʻAbbāsid Caliphate,* SUNY Series in Near Eastern Studies, Bibliotheca Persica (Albany, 1985), 40.

[60]For references to *baban* in Armenian historical sources, see Matthew of Edessa, *Patmutʻiwn* (Jerusalem, 1869), 142–45, 177, 231, 235, 303, 306, 448, 452, 454, 465; idem, *Armenia and the Crusades, Tenth to Twelfth Centuries: The Chronicle of Matthew of Edessa,* trans. Ara Edmond Dostourian (Belmont, Mass., and Lanham, 1993), 87–88, 103, 128, 131, 162, 163, 232, 233, 235, 241; Aristakēs Lastivertts'i, *Patmutʻiwn Aristakisi Lastivertts'woy* (Erevan, 1963), 92–93; and idem, *Aristakēs Lastivertcʻiʹs History,* trans. Robert Bedrosian (New York, 1985), 103–4. Aristakēs notes that the Saljuqs also employed this term (Aristakēs, *Patmutʻiwn,* 92; idem, *Aristakēs Lastivertcʻiʹs History,* 103). On the Arabic term *al-ghaḍbān,* see Chevedden, "Hybrid Trebuchet," 189–90, 202, 203.

[61]On this royal Mamluk trebuchet that required a hundred carts to transport it from Ḥiṣn al-Akrād (Krac des Chevaliers) to Acre, see Ismāʻil ibn ʻAlī Abū al-Fidāʼ, *Al-Mukhtaṣar fī Tārīkh al-Bashar,* (Cairo, 1907–8), 4:24; idem, *Al-Mukhtaṣar fī Tārīkh al-Bashar,* trans. Peter M. Holt, *The Memoirs of a Syrian Prince: Abūʼl-Fidāʼ, Sultan of Ḥamāh (672–732/1273–1331),* Freiburger Islamstudien, vol. 9 (Wiesbaden, 1983), 16. On the use of the term "great" trebuchet *(manjanīq ʻaẓīm)* to denote a trestle-framed counterweight trebuchet, see Chevedden, "Invention of the Counterweight Trebuchet," 77, 90, 92, 93, 96, 106, 113.

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guard of the king."[62]

MAMLUK HEAVY ARTILLERY AT THE SIEGE OF ACRE ACCORDING TO ARABIC HISTORICAL SOURCES

The "Templar of Tyre" does not give a full accounting of the heavy artillery arrayed against Acre. For that we must turn to the Arabic sources. According to Abū al-Fidā', the number of "big" and "small" trebuchets (*majānīq al-kibār wa-al-ṣighār,* i.e., counterweight and traction machines) deployed against Acre "was the greatest concentration of artillery ever assembled against any locality."[63] The very detailed and authoritative accounts of the siege by Shams al-Dīn al-Jazarī and Badr al-Dīn al-'Aynī put the total number of Muslim trebuchets at seventy-two.[64] Ibn al-Furāt, al-Maqrīzī, and al-Nuwayrī put the number even higher, at ninety-two, but this figure is most probably a scribal error for seventy-two, since the unpointed *sab'* and *tis'* are often confused.[65] Of the seventy-two machines, most were traction-powered,[66] but a significant number were gravity-driven. Two types of gravity-powered engines were used: *bricola*s and *qarābughrā*s. According to al-Yūnīnī, fifteen *bricola*s *(majānīq al-kibār al-ifranjīyah)* were employed, but no specific figures are given in any source for the number of *qarābughrā*s used. If from a total number of seventy-two trebuchets (the figure given by al-Jazarī and al-'Aynī), al-Yūnīnī's fifteen *bricola*s and al-'Aynī's fifty-two "Devilish" traction engines

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[62] "Gestes des Chiprois," 2:no. 490: "Et a terme de ses .viii. jours; adreserent et aseïrent au point lor engins, que la piere qu'y getoi[en]t pezoit un quintar. L'un de ses engins, quy avoit nom Haveben, quy vient a dire Yrious, si estoit devers la garde dou Temple, et l'autre engin, quy getet contre la garde des Pizans, avoit nom le Mensour, ce est a dire le Victorious; et l'autre grant, que je ne vos le say nomer, getoit contre la garde de l'Ospitau; et le cart engin getoit contre une grant tour quy a nom la tour Maudite, qui est a[s] segons murs et est de la garde dou roy." Andreas D'Souza translates "le cart [sic] engin" ("the fourth trebuchet") as "the cart engine" (D'Sousa, "Conquest of 'Akkā," 242).

[63] Abū al-Fidā', *Mukhtaṣar,* 4:24; idem, *Memoirs,* 16.

[64] Al-Jazarī, *Ḥawādith al-Zamān,* 1:45; al-'Aynī, *'Iqd al-Jumān,* 58. Although al-Jazarī was not present at the siege of Acre, his account of it is based on the report of the Mamluk Amir Sayf al-Dīn ibn al-Miḥaffadār, who witnessed the entire operation. Al-Yūnīnī also drew upon this important source for his account of the siege (Little, "Fall of 'Akkā," 163, 171, 172). Ibn Shākir al-Kutubī follows al-Jazarī and al-'Aynī and sets the total number of trebuchets used against Acre at seventy-two (*'Uyūn al-Tawārīkh,* 71).

[65] Ibn al-Furāt, *Tārīkh,* 8:112; Aḥmad ibn 'Alī al-Maqrīzī, *Kitāb al-Sulūk li-Ma'rifat Duwal al-Mulūk,* (Cairo, 1934–73), 1:3:764; al-Nuwayrī, *Nihāyat al-Arab,* 226.

[66] If the total number of "Devilish" traction trebuchets given by al-'Aynī (fifty-two) does not include the numerous pole-framed traction trebuchets *(lu'ab)* cited by al-Yūnīnī, there would have been far more than seventy-two pieces of artillery deployed by the Mamluks at Acre and a far greater percentage of these machines would have been traction powered.

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are subtracted, the remainder will be five. We can assume therefore that the Mamluks employed at least five *qarābughrā*s at Acre.

Mamluk Artillery and Siege Tactics at Acre

Artillery played an important role in the conquest of Acre. Batteries of artillery were erected to effect both destruction and neutralization. Bolt-projecting trebuchets were probably used to launch incendiary missiles to consume the protective screens shielding the walls and towers from bombardment. Other pieces of artillery rained down incendiary projectiles on the interior of the city to cause a serious outbreak of fire. Once the walls were laid bare, heavy artillery began stripping away the battlements and pounding the ramparts, as light artillery and other missile weapons kept the defenders at bay. The neutralizing shooting allowed sapping operations to be conducted with virtual impunity. Sallies in force mounted by the defenders were unable to disperse the attackers or to seriously hamper the progress of the siege. Once the saps had effected substantial breaches in the urban defenses, the city was successfully stormed. Acre, one of the best defended cities of its day, was unable to withstand the powerful and well-organized Mamluk assault, which made use of the most advanced techniques of mechanized siegecraft then known. Key to the Mamluk victory was the extensive use of siege-works and artillery. Of no less importance was the sustained and determined spirit that motivated the besieging forces.[67]

The "Black Camel" Trebuchet and the East-West Artillery Axis

Although the trebuchet can be traced back to ancient China, many civilizations contributed to its development. The story of the trebuchet is not a simple one of linear diffusion in a five-part sequential process: from China to the Sasanian and Byzantine Empires, thence to Arabia, and finally to the Latin West. Divergent paths of innovation and dissemination permeated the Sino-Sasanian-Byzantine-Islamic-Latin axis as advancements in one cultural zone spread to others in a process of continuous interchange across Eurasia and North Africa. Knowledge of the trebuchet took some time to reach other parts of the world, but once Western Asia and the Mediterranean discovered the machine its dissemination and advancement proceeded at an accelerated pace. By the eighth century the civilization of Islam had greatly improved China's human-powered artillery. Muslim conquerors introduced a much larger traction-powered machine that utilized the action of gravity to assist in the discharge of a projectile (the hybrid trebuchet). Byzantium

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[67]See Little, "Fall of ʿAkkā," and D'Souza, "Conquest of ʿAkkā," for details on the powerful siege-train brought against Acre by the Mamluks, especially well equipped with ordnance, as well as for information on the spirit motivating the campaign.

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and the Latin West quickly adopted this new machine and took the technology even further. From the eleventh century on, the pace of development quickened. Byzantine advances culminated in the invention of the first gravity-powered piece of artillery, the trestle-framed counterweight trebuchet. Progress in projectile technology did not stop there. A process of diversification of gravity-powered artillery soon began. The Latin West introduced a counterweight trebuchet with a pole framework that was capable of discharging missiles in any direction (the *bricola*). The Islamic world readily adopted this machine, as did the Mongols, who used it to subdue the Southern Song and consolidate their hold on all of China. As the *bricola* made its way eastward from Western Europe, the *qarābughrā* proceeded westward from the eastern realms of Islam. The Mamluks made the ″Black Camel″ trebuchet a standard piece of artillery, and their employment of this machine at Acre in 1291 is likely to have inspired Europeans to incorporate it into their siege arsenal. Although precise information is lacking regarding the dissemination of the bolt-projecting trebuchet to Europe, we may presume that it reached the West and found a place in European siege warfare.[68] The attention

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[68]Roland Bechmann has reconstructed the trestle-framed, counterweight trebuchet *(trebucet)* of Villard de Honnecourt as a bolt-projecting machine (Roland Bechmann, *Villard de Honnecourt: La pensée technique au XIIIe siècle et sa communication* [Paris, 1991], 255–72). If this interpretation stands, the presumption that the bolt-projecting trebuchet was diffused from a common source will be undermined, and the likelihood that it was invented independently and nearly simultaneously in the Latin West and in the eastern realms of Islam will emerge as a distinct possibility. The description and plan of the base frame of Villard′s trebuchet, which survives in his portfolio of architectural drawings dating from ca. 1230–35, has elicited a number of interpretations since the first facsimile edition of Villard′s drawings was published in 1858. The description of the machine ends with a passage pertaining to the release of the ″shaft,″ or ″beam″ *(fleke),* of the trebuchet: ″Et al descocier de le fleke penses. Et si vus en dones gard. Car il le doit estre atenue a cel estancon la devant″ [As for the discharging of the beam, remember and take heed, because it must be connected to the upright post in front]. The term *fleke* proved problematic because another word, *verge,* had been used by Villard to refer to the beam of the machine. Could *fleke* and *verge* signify the same component—the beam—or was *fleke* a different component, and if so, which one? The original editors of Villard′s portfolio, J. B. A. Lassus and Alfred Darcel, assumed that *fleke* referred to the projectile of the machine, which they believed was an arrow. (*Album de Villard de Honnecourt: Architecte du XIIIe siècle, manuscrit publié en facsimile,* ed. Jean-Baptiste-Antoine Lassus and Alfred Darcel [Paris, 1858; repr., Paris 1976]). In an important review of the Lassus-Darcel edition, Prosper Mérimée observed that the trebuchet was a stone-projecting machine and that the term *fleke* could only be understood as the pivoting beam of a trebuchet (Prosper Mérimée, review of *Album de Villard de Honnecourt: Architecte du XIIIe siècle,* ed. Jean-Baptiste-Antoine Lassus and Alfred Darcel, *Le Moniteur Universal* [20 December 1858]). Mérimée′s sensible interpretation is adopted here. In the first English edition of Villard′s portfolio, Robert Willis suggested that *fleke* should be understood as a detaining bolt of a catch-and-trigger device that held the beam in place prior to discharge and effected the release of the beam when it was dislodged by a mallet (*Facsimile of the Sketch Book of Wilars de Honecort with Commentaries and Descriptions by M.*

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given to it by the great architect-engineers of the Renaissance attests to its assimilation by Western Europe.

The history of the trebuchet represents a complex process of diffusion and cross-fertilization of new ideas and techniques produced by cultural interaction on a vast scale. Just as the trebuchet is a fusion of different elements, which when working in proper relation produce a successful machine, the history of this weaponry exhibits a fusion of contributions of many cultures and peoples. Although the trebuchet may be characterized as a collective work, it was not the multitude that produced the dramatic breakthroughs in the development of the machine, but individual engineers who were the source of every important innovation.

J. B. A. Lassus and by M. J. Quicherat: Translated and Edited with Many Additional Articles and Notes by the Rev. R. Willis [London, 1859]). Bechmann has reverted back to the idea proposed originally by Lassus and Darcel and has reconstructed Villard´s trebuchet as a Rube Goldberg device for launching arrows. His design rivals any of Rube Goldberg´s machines and is just as preposterous. A mammoth scaffolding towers above the trestle frame of the machine upon which rests a single arrow that is discharged by the impact of the throwing arm as it pivots skyward following release. Bechmann´s machine is made out of whole cloth. He invents key design elements (e.g., the scaffolding) and radically reinterprets other components. The catch-and-trigger device of the machine, for example, which consists of a stanchion *(estancon),* or upright post, to hold a detaining bolt is refashioned as a break lever to restrain the rotation of a drum. Bechmann uses textual and pictorial evidence as a mirror to reflect his own *a priori* assumptions.

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GUIDE TO ILLUSTRATIONS

Fig. 1. Two traction-powered trebuchets depicted in the Song dynasty′s military encyclopedia entitled *Wu jing zong yao* (The Essentials of the military classics), chap. 12, p. 50a, edited in 1044 by Zeng Gongliang (in *Ying yin Wen yuan ge Si ku quan shu,* vol. 726 [Taipei, 1983], 420). *Center,* the Chinese pole-framed trebuchet called a ″Whirlwind″ trebuchet″ *(xuan feng pao)* because it could be turned to face any direction. This machine had a beam of 5.40 meters in length mounted on top of a pole-frame that stood approximately 4.30 meters in height. Attached to the butt-end of the beam were forty pulling-ropes that were hauled down by a crew of forty men. The machine was capable of throwing a stone-shot weighing 1.89 kilograms a distance of more than 75.0 meters. In Arabic sources this machine was designated an *ʿarrādah* or a ″Plaything″ *(luʿbah,* pl. *luʿab),* due to the play, or rapid movement, of its throwing arm as it was sent skyward in quick succession during continuous operation. In the Latin West the most commonly used term for this machine was *manganellus* (mangonel). *Left,* the Chinese ″Hand-Trebuchet″ *(shou pao),* operated by a single man. A pole, fixed in the ground, carried a pin at its topmost extremity, which acted as a fulcrum for the arm of the machine. In Byzantine sources this machine was designated a χειρομάγγανα *(cheiromangana).*

Fig. 2. The most powerful trebuchet depicted in the *Wu jing zong yao,* chap. 12, p. 48a (in *Ying yin Wen yuan ge Si ku quan shu,* vol. 726 [Taipei, 1983], 419): a traction-powered, trestle-framed trebuchet, identified as ″The Septuple-Beam″ trebuchet *(qi shao pao).* It had a composite beam made up of seven wooden spars lashed together with rope or bound with metal bands that measured 8.40 meters in length. The beam was mounted on a framework 5.55 meters in height and 6.78 meters wide with trusses that were tilted inward 23 degrees off the vertical. The butt-end of the beam had 125 pulling ropes attached to it that were hauled down by a crew of 250 men. This machine was capable of throwing a stone-shot weighing between 56.70 and 63.0 kilograms a distance of more than 75.0 meters. In Arabic sources the trestle-framed trebuchet was called a *manjanīq,* and in the Latin West it was usually identified by the term *petraria* (″rock-thrower″).

Fig. 3. A pole-framed hybrid trebuchet identified as a *manjanīq ʿarrādah* in Ibn Urunbughā al-Zaradkāsh′s *An Elegant Book on Trebuchets (Kitāb Anīq fī al-Manājanīq),* 867/1462–63. This machine is identified in Chinese sources as the ″Whirlwind″ trebuchet (Fig. 1). A small counterweight is fixed to the butt-end of the main beam of the machine to keep it in balance when the sling is loaded with a projectile. Caption titles *(clockwise):* ″a pole-framed trebuchet″ *(manjanīq*

'arrādah); ″beam″ *(al-sahm);* ″pivot yoke [literally, ′housing′] of the trebuchet″ *(bayt al-manjanīq);* ″pulling-rope″ *(al-watar);* ″pole-frame″ *('amūd);* ″small counterbalance″ *(al-aṣghar tathqīlah);* ″axle″ *(khinzīrah);* ″framing-piece [literally, ′bow′] of the trebuchet″ *(qaws al-manjanīq);* ″sling″ *(al-filqān).* After ″Kitāb Anīq fī al-Manājanīq,″ Topkapı Sarayı Muzesi Kutuphanesi MS Ahmet III 3469/1, fol. 44r.

Fig. 4. Detail of a stone fragment with a relief carving on its outer face depicting a siege. This fragment, mounted on a wall in the Church of Saint-Nazaire in Carcassonne, France, dates from the early thirteenth century. Some scholars believe it represents the siege of Toulouse in 1218 in which Simon de Montfort was killed by a stone-shot hurled from a trestle-framed trebuchet operated by women. If so, the stone-carver has saved Simon de Montfort embarrassment by depicting an all-male artillery crew. The relief carving shows a trestle-framed hybrid machine being prepared for discharge. Pulling-ropes are attached to six rings affixed to a weighted-base at the butt-end of the beam. A six-member pulling-crew is set to launch a rounded stone-shot which is being placed in the pouch of the sling by the operator of the machine (positioned, for purely artistic considerations, above the pulling-crew). Five of the crew are placed behind the trestle framework of the machine. Four of the five are ready to pull horizontally with both hands on two lines of rope, while the fifth, in a kneeling position, is about to pull downwards on a single line of rope. The sixth member of the crew is located directly under the butt-end of the beam and is set to pull vertically downwards on two lines of rope. This trebuchet has a curved axle, a feature which it shares with the pole-framed hybrid trebuchet pictured in Ibn Urunbughā al-Zaradkāsh′s *An Elegant Book on Trebuchets* (Fig. 3).

Fig. 5. Reconstruction of a trestle-framed counterweight trebuchet (*trebucet*) of Villard de Honnecourt, France, ca. 1230–35. This reconstruction by the Reverend Robert Willis (1800–75), the first professor of the University of Cambridge to win an international reputation as a mechanical engineer, is based upon Villard′s own account of the machine (description and plan of the base frame), which survives in his portfolio in the Bibliothèque nationale in Paris (MS Fr 19093, fol. 30r; Villard de Honnecourt, *Facsimile of the Sketch-Book of Wilars de Honecourt,* trans. and ed. R. Willis [London, 1859], 197). Lateral and longitudinal bracing is omitted and the capstan in the foreground is left unfinished since the construction of both capstans would be the same. The volume of the counterweight box has been estimated to have been about eighteen cubic meters and was able to carry a mass weighing up to thirty tons. With such a gravitating mass, it has been conjectured that this trebuchet could launch a 100-kilogram projectile more than 400 meters

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and a 250-kilogram projectile more than 160 meters. This reconstruction of the machine is to be preferred to that of Eugène Emmanuel Viollet-le-Duc (1814–79), which appears in his *Dictionnaire raisonné de l'architecture du XI^{e} au XVI^{e} siècles* ([Paris, 1854–68], 5:227–28), and to that of Roland Bechmann, which appears in his study *Villard de Honnecourt: La pensée technique au XIII^{e} siécle et sa communication* (Paris, 1991), 255–72. This machine was identified in Arabic historical sources as the "Western Islamic" trebuchet *(manjanīq maghribī* or *manjanīq gharbī).*

Fig. 6. Mariano Taccola, "Liber Tertius de ingeneis ac edifitiis non usitatis" (1433), Biblioteca Nazionale Centrale (Florence) Cod. palat. 766, fol. 41r. The "brichola" *(bricola),* or the "Two-Testicle" machine, from the combination of the prefix *bi-,* "having two," and the Latin *coleus,* meaning testicle. This pole-framed trebuchet with two hinged counterweights was invented in the Latin West by the beginning of the thirteenth century. The Mamluks acquired it post 1250 and called it the "Frankish" or "European" trebuchet *(manjanīq ifranjī* or *manjanīq firanjī).* Muslim engineers employed by the Mongols brought the *bricola* to China, where it was designated the "Muslim" trebuchet *(hui-hui pao)*. At the siege of Acre in 690/1291, the Mamluk *bricola*s hurled stone-shot weighing one Damascene *qinṭār* or more (185 kg or 408 lb +).

Fig. 7. Yūsuf ibn Urunbughā al-Zaradkāsh, "Kitāb Anīq fī al-Manājanīq," Topkapı Sarayı Muzesi Kutuphanesi MS Ahmet III 3469/1, fol. 34r. A bastard bolt-projector: a cross between a torsion catapult and a bolt-projecting, trestle-framed trebuchet. Figure title: "Depiction of its fabrication that you make just as you make the first [trebuchet]." Figure subtitle: "A *ziyār* different from the first." Caption titles in figure identifying parts of a torsion catapult: *jisr fawqānī:* the upper transom [of a catapult connecting the two tension-frames of a two-armed torsion catapult]; *jusūr taḥtānīyah:* the lower transoms [of a catapult fixed to the stock of the machine]; *sha'r rafī':* "fine hair" [making up the vertically-mounted torsion-spring]. Caption titles in figure identifying parts of a trestle-framed trebuchet: *qā'imah:* vertical support post [of the trestle frame] x 6; *jisr al-awwal:* first horizontal crosspiece [of the trestle frame]; *jisr thānī:* second horizontal crosspiece [of the trestle frame]; *jisr thālith:* third horizontal crosspiece [of the trestle frame]; *jisr rābi':* fourth horizontal crosspiece [of the trestle frame]; *dūlāb:* windlass [one handspike-drum of the windlass is depicted next to the tip of the throwing arm]; *mizrīb al-sahm:* the trough of the bolt; *qā'idah:* base frame [of the trebuchet]; *tathqīl al-sahm:* counterweight of the beam.

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Fig. 8. Yūsuf ibn Urunbughā al-Zaradkāsh, ″Kitāb Anīq fī al-Manājanīq,″ Topkapı Sarayı Muzesi Kutuphanesi MS Ahmet III 3469/1, fol. 11r. A bastard bolt-projector: a cross between a torsion catapult and a bolt-projecting, trestle-framed trebuchet. Figure title: ″Depiction of the fabrication of this [trebuchet] that you make just as you made the first [trebuchet].″ Caption titles in figure identifying parts of a torsion catapult: *jisr fawqānī:* the upper transom [of a catapult connecting the two tension-frames of a two-armed torsion catapult]; *jisr taḥtānī:* the lower transom [of a catapult fixed to the stock of the machine] x 5; *sha'r rafī':* ″fine hair″ [making up the vertically-mounted torsion-spring]. Caption titles in figure identifying parts of a trestle-framed trebuchet: *qā'imah:* vertical support post [of the trestle frame] x 6; *jisr al-awwal:* first horizontal crosspiece [of the trestle frame]; *jisr thānī:* second horizontal crosspiece [of the trestle frame]; *jisr thālith:* third horizontal crosspiece [of the trestle frame]; *jisr rābi':* fourth horizontal crosspiece [of the trestle frame]; *dūlāb:* windlass [one handspike-drum of the windlass is depicted next to the tip of the throwing arm]; *mizrīb:* trough; *tathqīl al-sahm:* counterweight of the beam.

Fig. 9. Yūsuf ibn Urunbughā al-Zaradkāsh, ″Kitāb Anīq fi al-Manājanīq,″ Topkapı Sarayı Muzesi Kutuphanesi MS Ahmet III 3469/1, fol. 32r. A bastard bolt-projector: a cross between a torsion catapult and a bolt-projecting, trestle-framed trebuchet. Figure title: ″Another *ziyār* different from the first on which infantry *(al-rijāl al-ḥarīkah)* are stationed atop the *ḥiṣār* [lit., ′fortress,′ i.e., the crenellated superstructure atop the framework of the trebuchet].″ Caption titles in figure identifying parts of a torsion catapult: *sha'r:* ″hair″ [making up the horizontally-mounted torsion-spring]; *bayt al-sha'r:* tension frame of the torsion-spring. Caption titles in figure identifying parts of a trestle-framed trebuchet: *qā'imah:* vertical support post [of the trestle frame] x 4; *wasaṭ:* middle [support post of the trestle frame]; *dūlāb:* windlass x 2 [the two handspike-drums of the windlass are shown in front of the framework of the machine (defined here as the downrange side of the trebuchet)]; *jisr al-dūlāb:* windlass-roller; *mizrīb al-sahm:* the trough of the bolt; *mizrīb:* trough; *qā'idah:* base frame [of the trebuchet]; *al-sahm:* the beam; *tathqīl al-sahm:* counterweight of the beam; *mafrūkah:* handspike [of windlass] x 2 [One windlass handspike has five bars or levers by which the windlass is worked, another has four].

Fig. 10. Mariano Taccola, ″De ingeneis,″ ca. 1419–50, Munich, Bayerische Staatsbibliothek Codex CLM 197 II, fol. 68v. Trebuchet with hinged counterweight launching a bolt. A four-tined throwing arm allows for the simultaneous release of four bolts. For simplicity′s sake, the illustrator has only drawn one of the bolts. Above the beam is an insert showing details of a two-tined fork for the throwing

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arm with a caption underneath reading, ″It [the component shown above] shall be placed on the end of the beam *(mictatur in stilo istius pertice)*.″

Fig. 11. Francesco di Giorgio Martini, ″Trattato I,″ copy, ca. 1480–1500, Turin, Biblioteca Reale di Torino Codex 148 Saluzzo, fol. 61v. Trebuchet with fixed counterweight launching two bolts. Distinctive features include: a buffer that prevents the beam from attaining a full upright position; a mechanical pull-back system that requires a cross-member positioned in the path of the beam above the axle; a three-pronged forked appendage at the tip of the beam designed to release two bolts simultaneously; and a catch-and-trigger device consisting of an S-shaped (serpentine) lever that is designed to be pivoted backward but would be unable to perform its function as illustrated.

Fig. 12. Anon. Raccolta Artist Engineer, ″Raccolta di città e macchine,″ ca. 1490s, Florence, Biblioteca Nazionale Centrale, Codex Magliabechiana II I 141 part 3, fol. 195v. Trestle-framed trebuchet with fixed counterweight launching two bolts. Distinctive features include: a buffer that prevents the beam from attaining a full upright position; a mechanical pull-back system that utilizes the leverage of the beam; a two-pronged forked appendage at the tip of the beam designed to release two bolts simultaneously; and a catch-and-trigger device consisting of an S-shaped (serpentine) lever that is pivoted backward.

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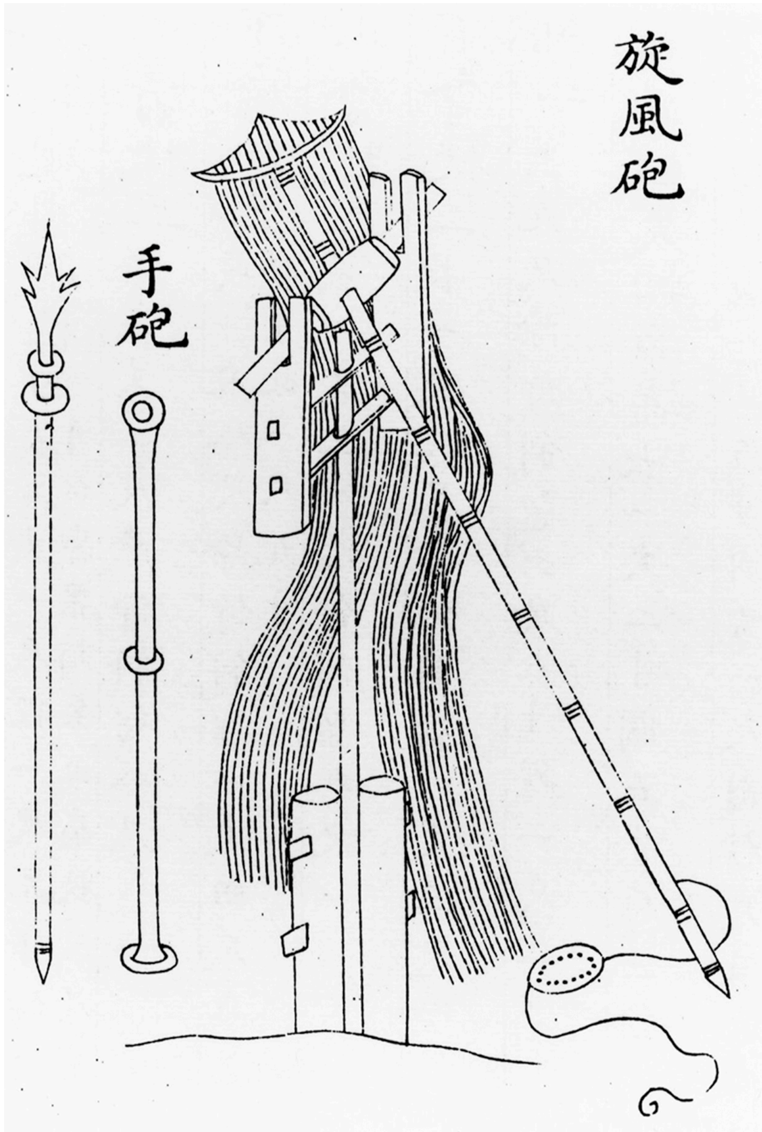

Fig. 1. Two traction-powered trebuchets depicted in the Song dynasty´s military encyclopedia entitled *Wu jing zong yao* (The Essentials of the military classics).

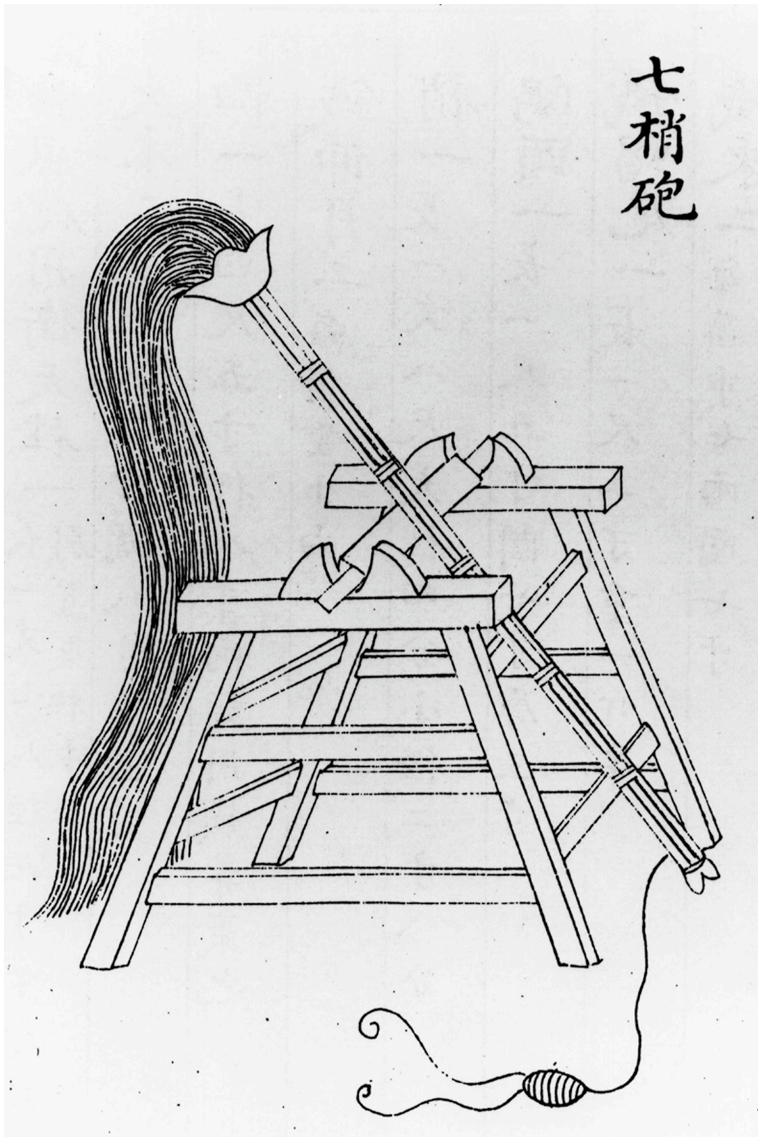

Fig. 2. The most powerful trebuchet depicted in the *Wu jing zong yao:* a traction-powered, trestle-framed trebuchet, identified as"The Septuple-Beam Trebuchet" *(qi shao pao).*

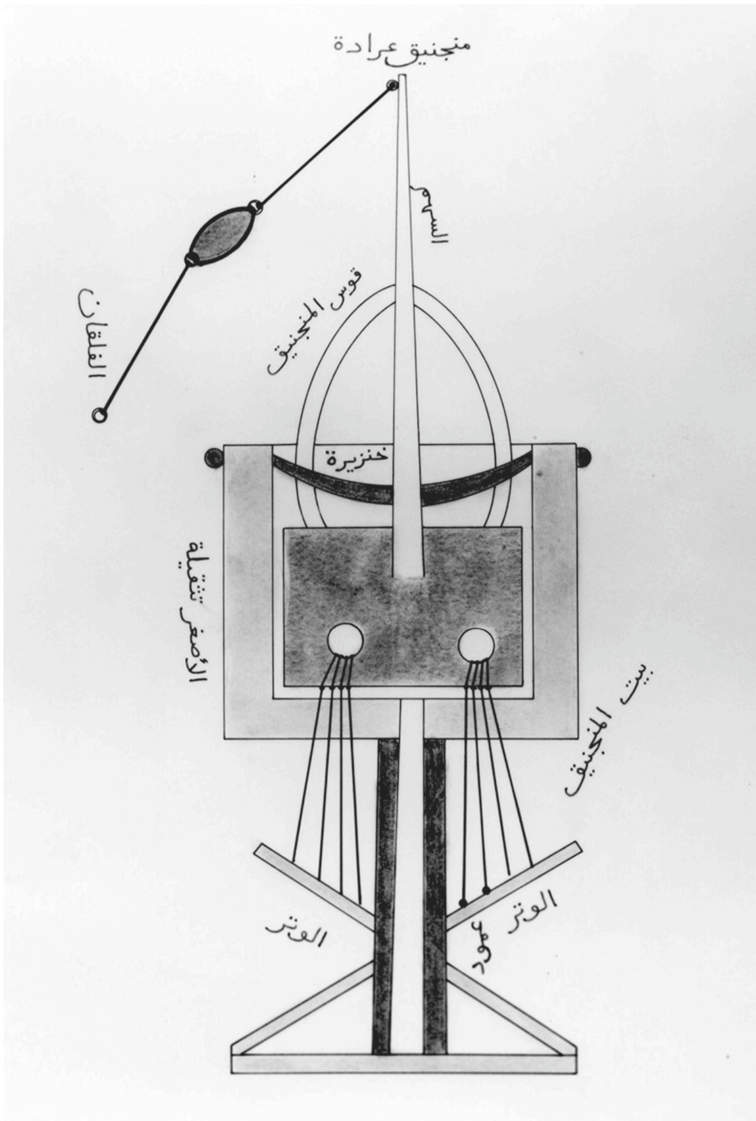

Fig. 3. A pole-framed hybrid trebuchet identified as a *manjanīq ʿarrādah* in Ibn Urunbughā al-Zaradkāsh's *An Elegant Book on Trebuchets (Kitāb Anīq fī al-Manājanīq),* 867/1462-63.

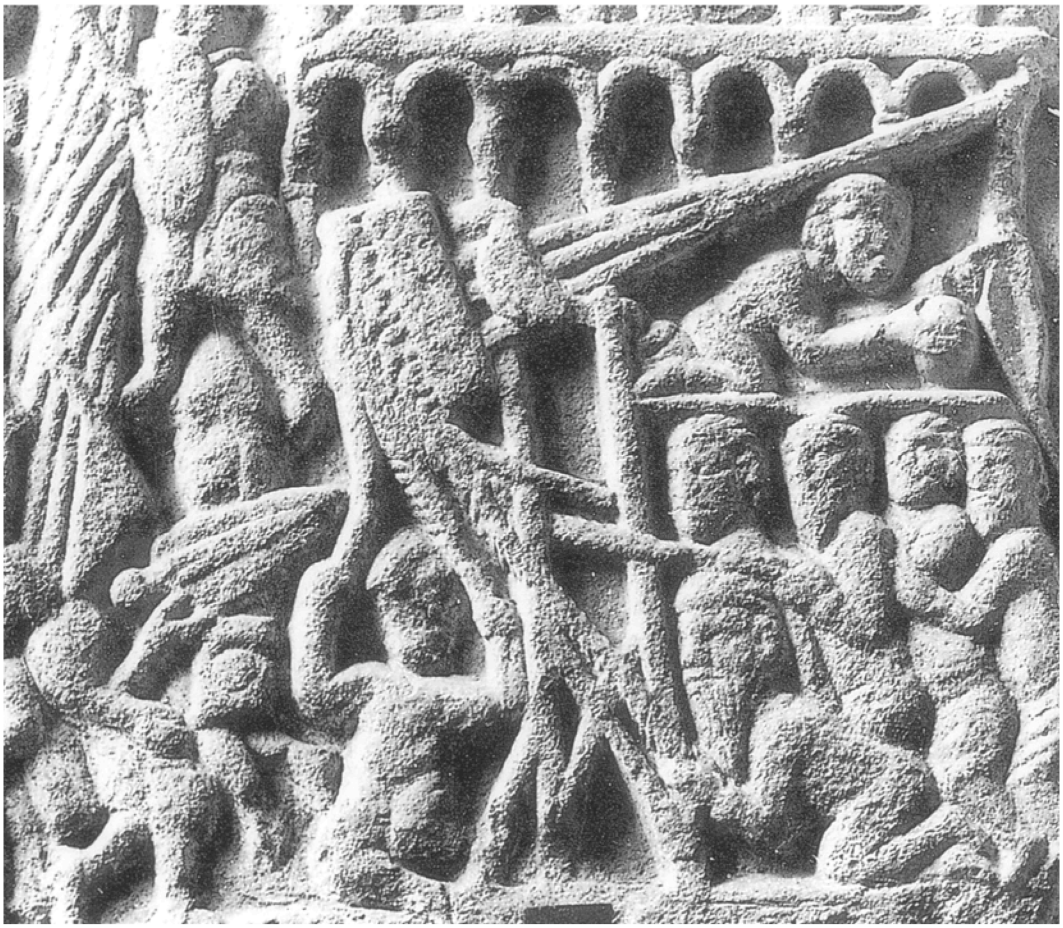

Fig. 4. Detail of a stone fragment in the Church of Saint-Nazaire in Carcassonne, France, with a relief carving on its outer face showing a trestle-framed, hybrid machine being prepared for discharge.

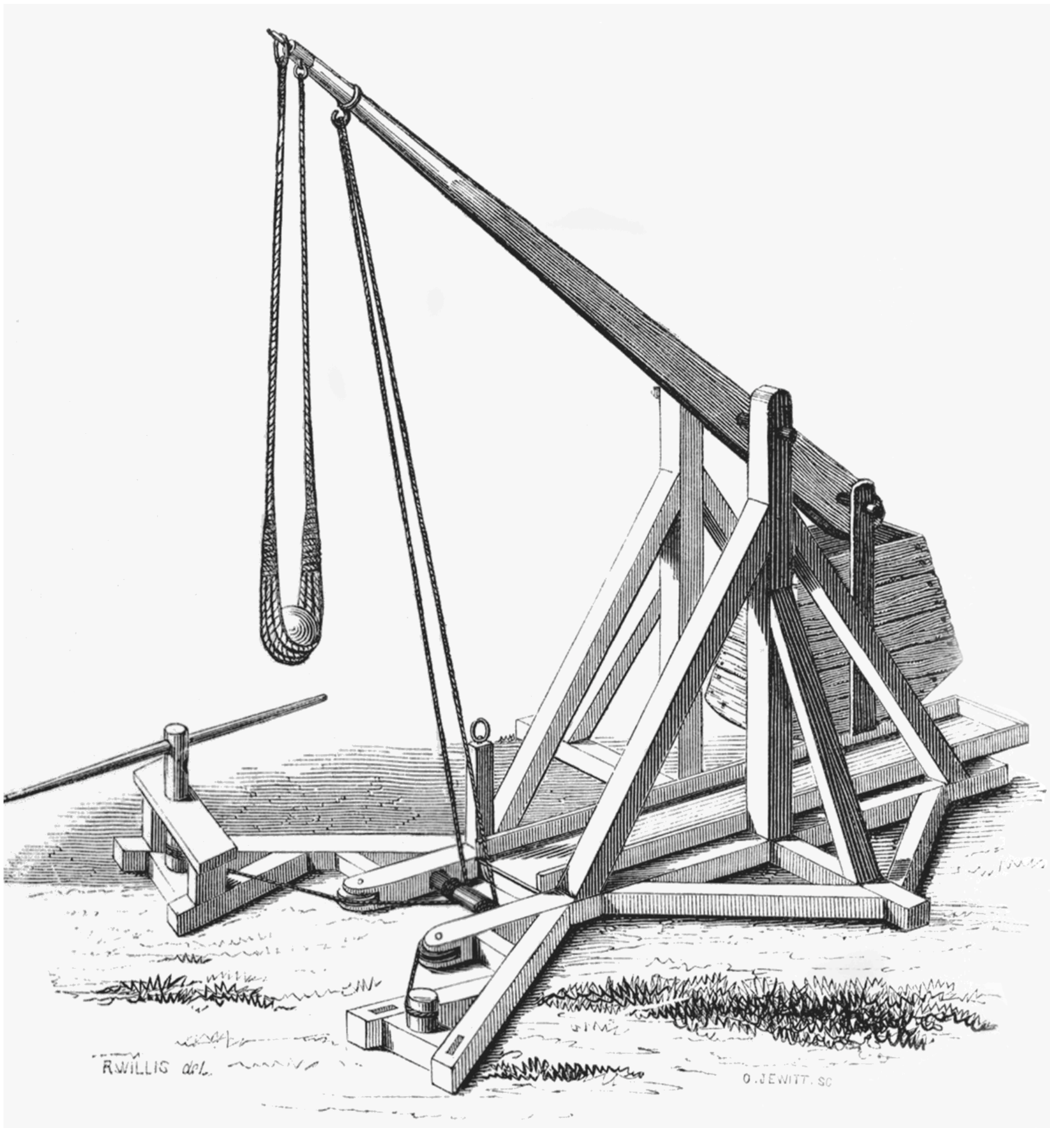

Fig. 5. Reconstruction of a trestle-framed, counterweight trebuchet *(trebucet)* of Villard de Honnecourt, France, ca. 1230–35, by the Rev. Robert Willis (1800–75).

Fig. 6. Mariano Taccola, ″Liber Tertius de ingeneis ac edifitiis non usitatis″ (1433), Biblioteca Nazionale Centrale (Florence) Cod. palat. 766, fol. 41r. The ″brichola″ *(bricola),* or the ″Two-Testicle″ machine, a pole-framed trebuchet with two hinged counterweights, identified in Arabic historical sources as the ″Frankish″ or ″European″ trebuchet *(manjanīq ifranjī* or *manjanīq firanjī)*.

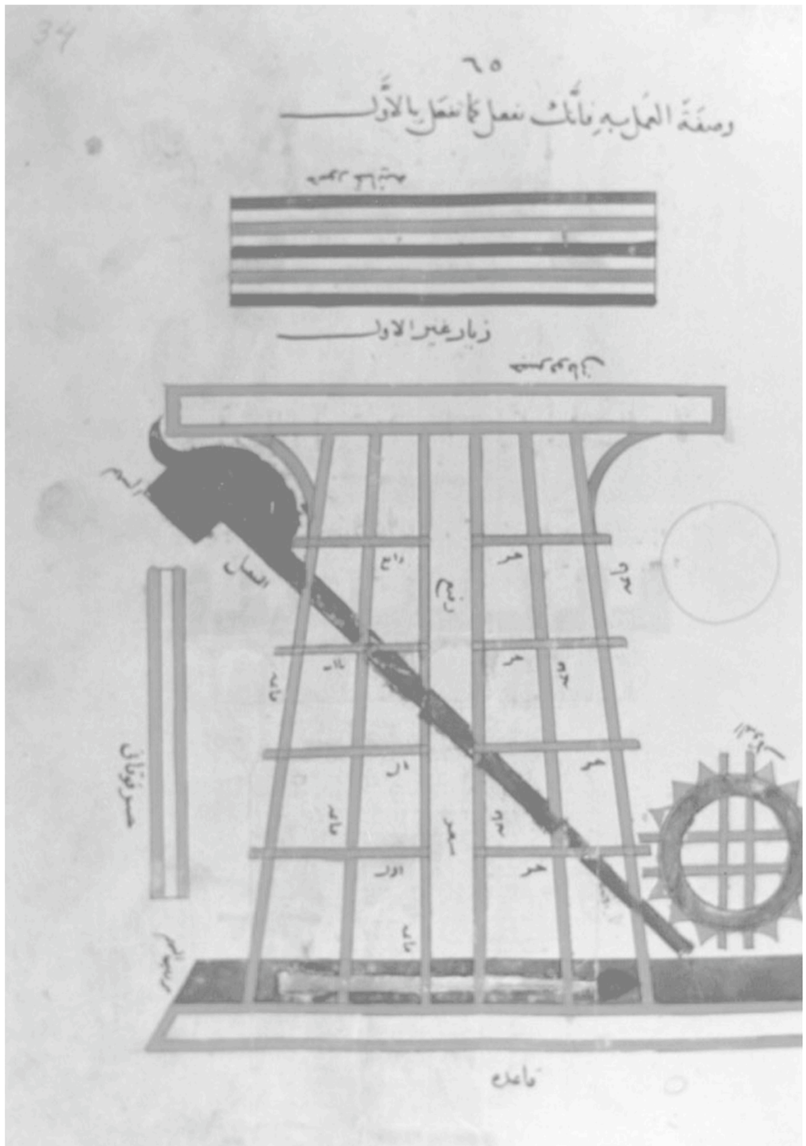

Fig. 7. Yūsuf ibn Urunbughā al-Zaradkāsh, ˝Kitāb Anīq fī al-Manājanīq,˝ Topkapı Sarayı Muzesi Kutuphanesi MS Ahmet III 3469/1, fol. 34r. A bastard bolt-projector: a cross between a torsion catapult and a bolt-projecting, trestle-framed trebuchet.

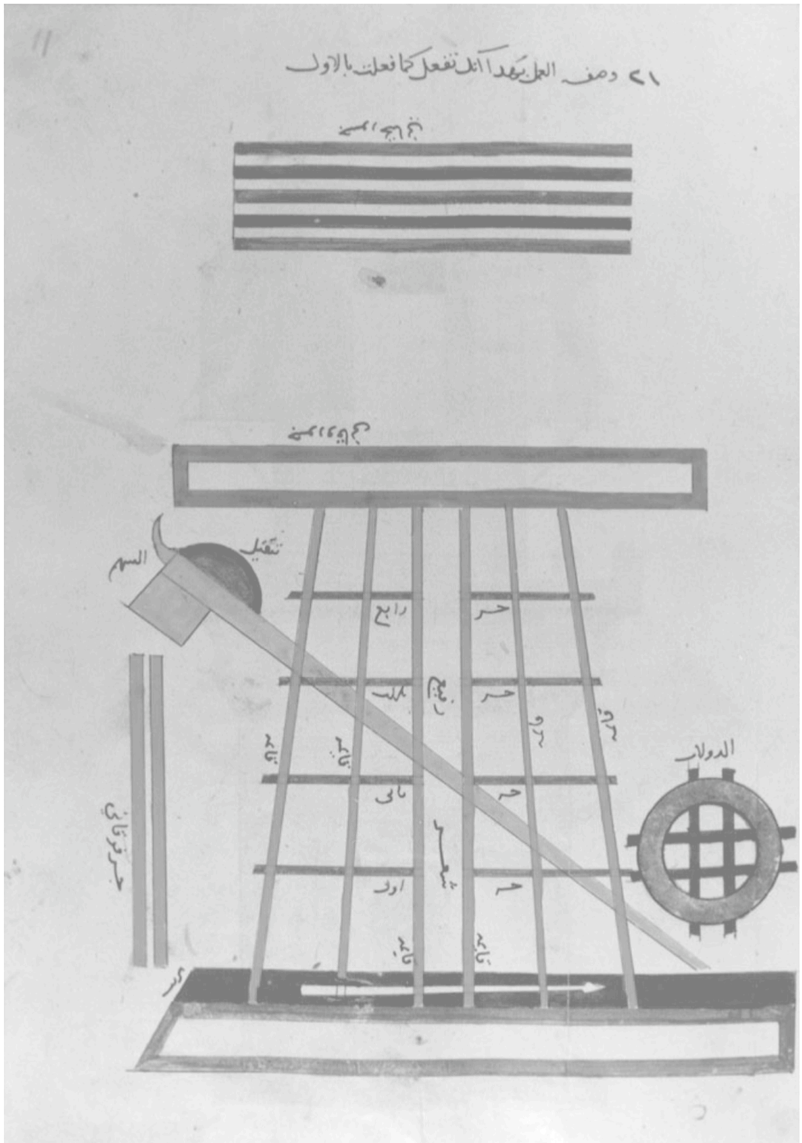

Fig. 8. Yūsuf ibn Urunbughā al-Zaradkāsh, ″Kitāb Anīq fī al-Manājanīq,″ Topkapı Sarayı Muzesi Kutuphanesi MS Ahmet III 3469/1, fol. 11r. A bastard bolt-projector: a cross between a torsion catapult and a bolt-projecting, trestle-framed trebuchet.

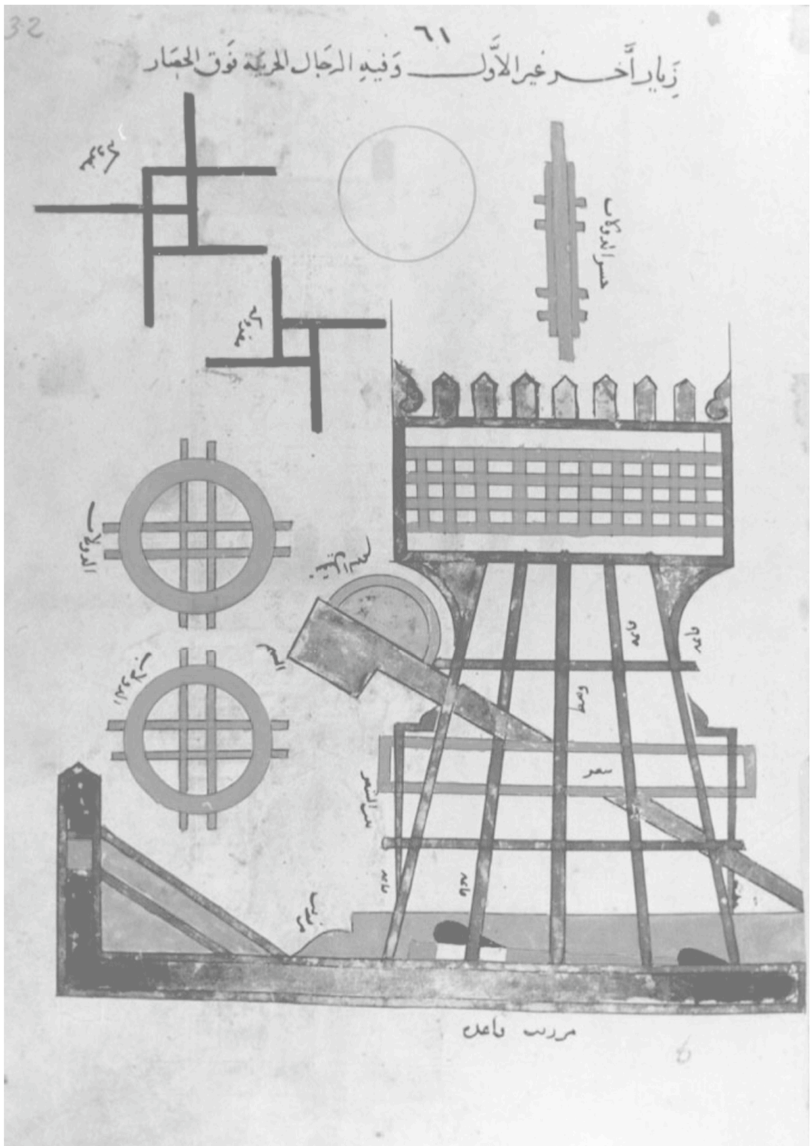

Fig. 9. Yūsuf ibn Urunbughā al-Zaradkāsh, ″Kitāb Anīq fi al-Manājanīq,″ Topkapı Sarayı Muzesi Kutuphanesi MS Ahmet III 3469/1, fol. 32r. A bastard bolt-projector: a cross between a torsion catapult and a bolt-projecting, trestle-framed trebuchet.

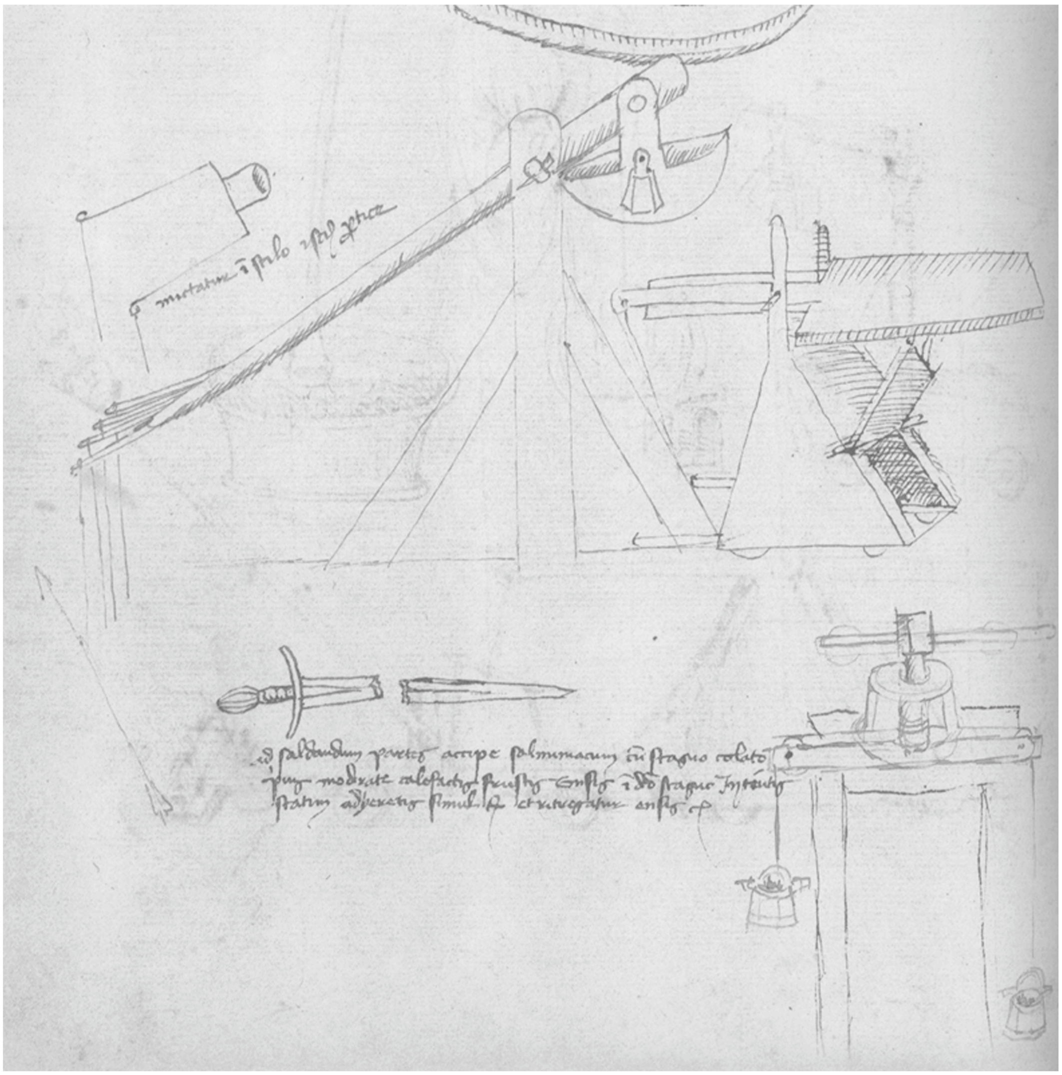

Fig. 10. Mariano Taccola, ″De ingeneis,″ ca. 1419–50, Munich, Bayerische Staatsbibliothek Codex CLM 197 II, fol. 68v. Trebuchet with a hinged counterweight and a four-tined throwing arm launching a bolt.

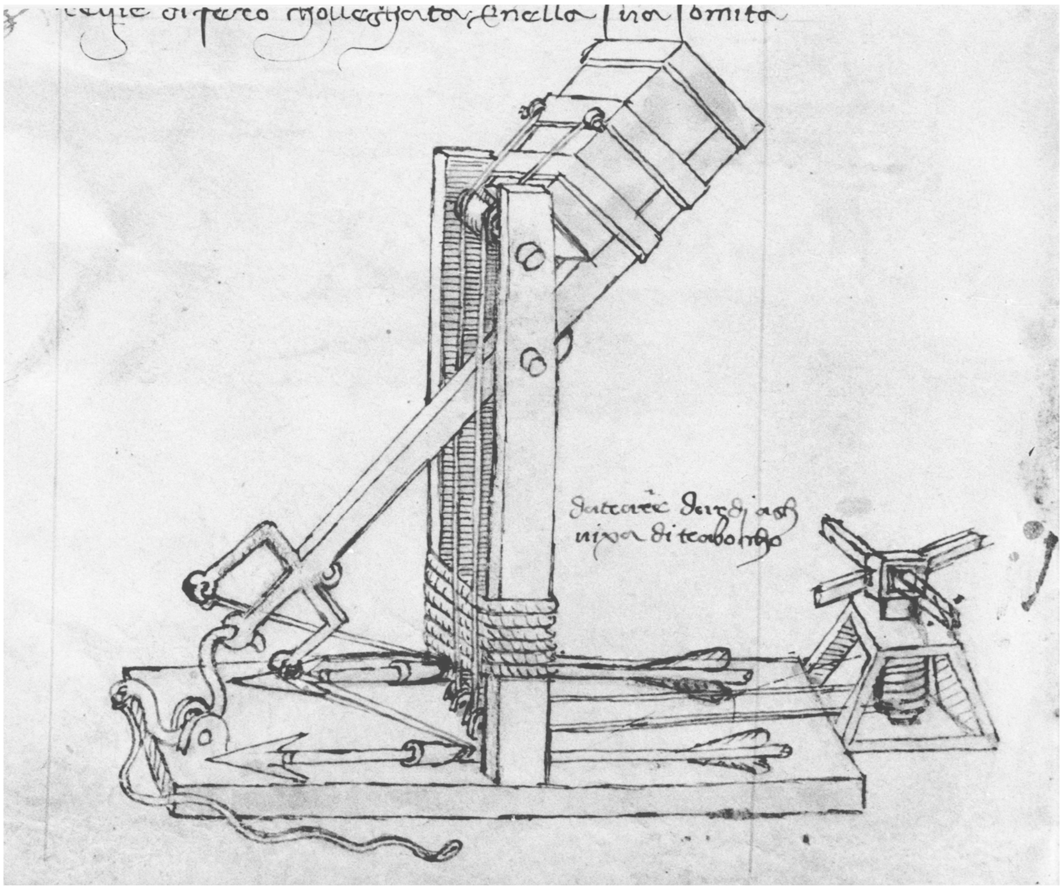

Fig. 11. Francesco di Giorgio Martini, "Trattato I," copy, ca. 1480–1500, Turin, Biblioteca Reale di Torino Codex 148 Saluzzo, fol. 61v. Trebuchet with fixed counterweight launching two bolts.

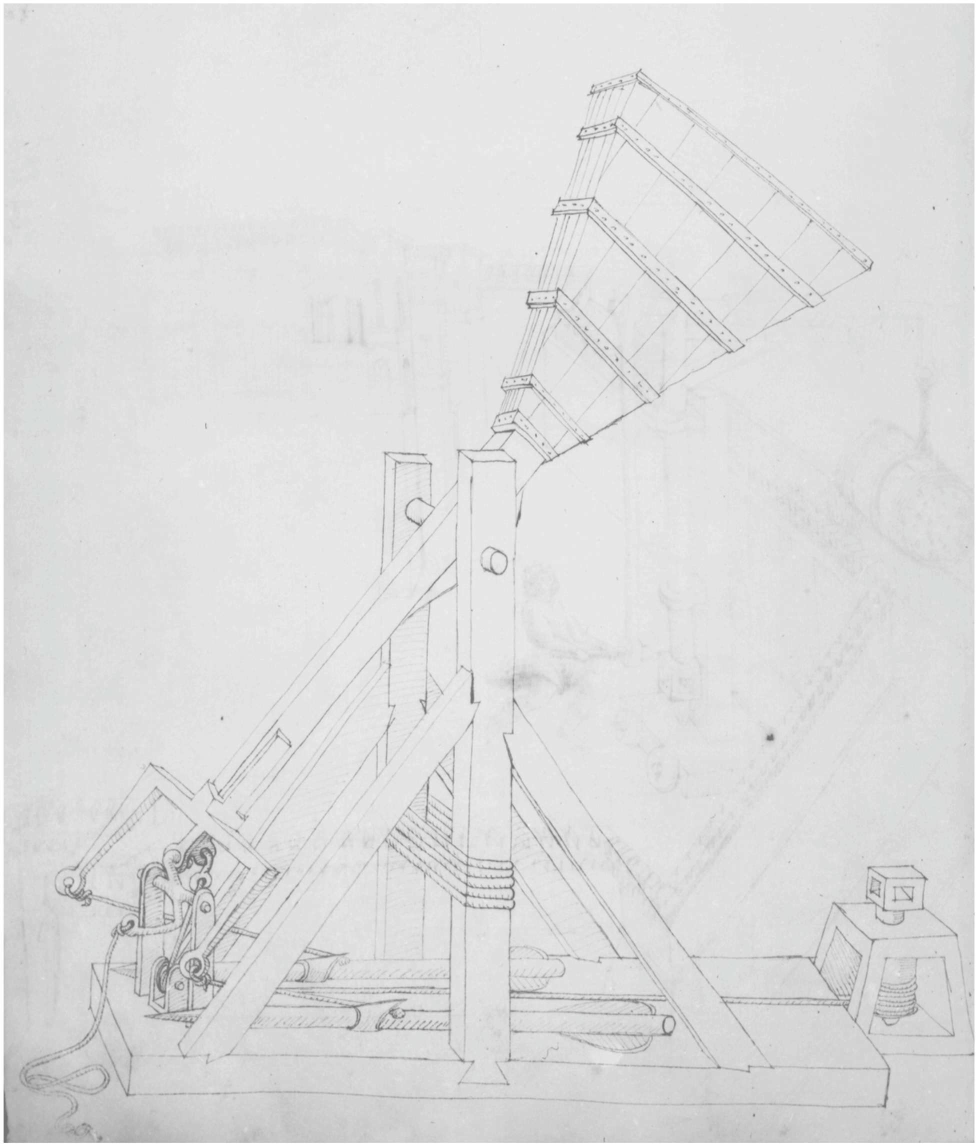

Fig. 12. Anon. Raccolta Artist Engineer, "Raccolta di città e macchine," ca. 1490s, Florence, Biblioteca Nazionale Centrale, Codex Magliabechiana II I 141 part 3, fol. 195v. Trebuchet with fixed counterweight launching two bolts.