

Camillo Agrippa's Hydraulic Inventions on the Pincian Hill (1574-1578)
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Introduction

The Pincian is one of the hills that characterize the Roman panorama. It rises just to the east of the Campus Martius, the low alluvial plain where most of Rome's residents lived during the early modern period. During the sixteenth century, as in antiquity, prosperous and influential families built villas, gardens and orchards on the Pincian hill, in spite of the fact that no aqueduct water was directly available there. The Aqua Virgo (also known as Acqua Vergine), an aqueduct constructed by Marcus Agrippa in 19 BC, ran beneath the Pincian and originally arrived in the city at less than twenty meters above sea level. The Vergine took this subterranean route because its low-level springs, which are located about twenty kilometers outside the city, are only 26 meters above sea level. **(Figure 1)**



Figure 1. *An interior view of the Acqua Vergine as it flows beneath the Pincian hill. Leonardo Lombardi*

The Acqua Vergine was the only one of Rome's eleven ancient aqueducts that still flowed in the sixteenth century, but because of its very low elevation its waters could not reach the top of the Pincian hill, which stands at an elevation of between forty-five and fifty-five meters above sea level. Indeed, it directly served only the Campus Martius. Yet although the Pincian lay outside the densely populated city core, and although it was not immediately served by aqueduct water, it provided the setting for an innovative development in hydraulic technology. It was here in the 1570s, in the gardens of what is now the Villa Medici, that Camillo Agrippa designed and constructed a sophisticated water lifting mechanism (the first of its kind to be built in Italy) to bring water to the top of the hill.

Early water delivery solutions

Before the Aqua Anio Vetus (Rome's first high-level aqueduct), was constructed in 273 BC, people who lived atop the city's hills made do with natural springs, which were generally restricted to the lower slopes of the hills.¹ In the absence of springs and aqueducts, the only readily available technological strategies to provide water to Rome's higher zones were to construct cisterns within buildings (to collect rainwater), or to build a subterranean well to collect water from underground aquifers. In the case of the Pincian hill, at least during the early sixteenth century, a new strategy was employed to take advantage of the water that flowed in the Acqua Vergine's subterranean channel.² As originally constructed, the aqueduct was provided along the length of its channel with *pozzi* (manholes) constructed at regular intervals. These were built in order to clean and service the aqueduct, but they could also be used as access points for lowering buckets into the channel to raise water, as was done by Cardinal Marcello Crescenzi who purchased the property in 1543 and lived there until his death in 1552. **(Figure 2)** He had a rainwater cistern constructed on the property, but it must have been insufficient for his needs. So, in order to deal with this deficiency, he also had one of the shafts into the aqueduct that ran under his property, opened to allow access to its water.

In 1564, the Crescenzi family ceded the property to Cardinal Giovanni Ricci da Montepulciano (1498-1574), a wealthy Tuscan, who soon modified and enlarged the house and embellished the garden. It is worth noting that in 1567, Cardinal Ricci was appointed papal superintendent for aqueducts and fountains, as well as roads and bridges. In this capacity he oversaw administration of a complete restoration of the Acqua Vergine between 1567 and 1570, and then he administered the allotment of water rights to the newly expanded water supply.

¹ A. Corazza and L.Lombardi, "Idrogeologia dell'area del centro storico di Roma" in *Memorie descrittive della Carta Geologica d'Italia*, (Rome: Servizio Geologico Nazionale), 50: 187-211.

² A high level line did not serve the Pincian until 1592 when a branch of the Acqua Felice arrived at the villa after having been authorized by Pope Sixtus V in 1587.

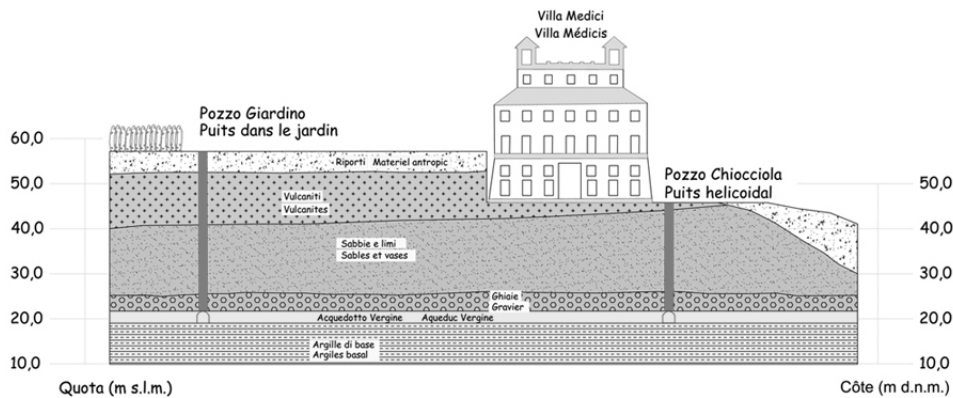


Figure 2. A section through the Pincian hill (looking to the east) taken at the Villa Medici showing the location of two pozzos (manhole shafts) that were utilized to raise water from the Acqua Vergine channel. Image courtesy of Daria dell'Acqua.

At the villa Cardinal Ricci also made use of the Crescenzi cistern, but its limited capacity curbed his ambitions for the garden. He commissioned a ramp to be built that cut through the hill from the level of the garden down to the level of the aqueduct.³ Mules were employed to carry water up the ramp from the aqueduct and into the garden. But both lowered buckets and plodding mules were inefficient and unsightly solutions. Therefore, in order to increase the water supply to his property, Ricci hired the well-known Milanese fountain designer Camillo Agrippa in 1574 to build a water-lifting device that would bypass both buckets and mules.⁴

Water-lifting devices

Water-lifting devices, known since the Hellenistic period, included the manual pump of Ctesibius, the Archimedes Screw and the waterwheel, which could be operated either by manual or hydraulic means. Each device had limitations that made it unsuited to raise water thirty meters from the Acqua Vergine to the garden. Ctesibius' pump yielded paltry amounts of water, while the Archimedes Screw had a higher capacity but modest ability to raise water. Manual

waterwheels, which used chains and buckets to raise water through human or animal labor, trapped fish that then had to be dealt with. In spite of this, waterwheels were relatively efficient, although relying on men and animals made them unrealistic on this scale. Hydraulic waterwheels offered another alternative. If built directly over a watercourse, like a stream, river, or even an aqueduct, waterwheels offered an efficient and widely used way to harness energy directly from flowing water.⁵

Toward the end of the twelfth century, the Arabic scientist Ibn al-Jazari (1136-1206) applied (or perhaps designed) a surge system that utilized a hydraulic wheel to supply energy to a pump, which in turn raised water. (Figures 3a and 3b) Later, in 1559, another Arabic scientist, Taqi al-Din' (1526-1585), invented a new system to connect a hydraulic wheel to a pump for lifting water.⁶ There were also important investigations occurring in Europe in the fifteenth and early sixteenth centuries. The Siense engineers Mariano di Iacopo, known as il Taccola (1382-1458?), and Francesco di Giorgio (1459-1501) both designed waterwheels that connected to pumps, but it is unclear whether their proposals were ever implemented. Georg Bauer, known as Georgius Agricola (1494-1555), in his posthumous publication *De re Metallica* of 1556, illustrated a hydraulic wheel connected to piston pumps that could raise water from underground mines. But it was only with the publication of *Le diverse et artificiose machine* of 1588 by Augustino Ramelli (1561-1600) that this technique was clearly illustrated in a widely

³ For a general history of the property under the Crescenzi, Cardinal Ricci and later Cardinal Ferdinando de' Medici, see M. L. Andres, *The Villa Medicis in Rome*, two volumes, London and New York, 1976, especially pages 227-256 and 342-349, and S. B. Butters, *Le cardinal Ferdinando de Medicis*, in *La Villa Medicis*, vol. II, especially pages 170-196 and 350-410.

⁴ Camillo Agrippa was a highly regarded mathematician, engineer and most particularly, a fencing theorist. His best known works are *Trattato di Scientia d'Arme, con un Dialogo di Filosofia* (Rome: 1553) and *Dialogo sopra la generatione de venti, baleni, tuoni, fulgori, fiumi, laghi, valli et montagne* (Rome: 1584).

⁵ For example, the grain mills that were built from at least the sixth century AD using power from the Tiber River.

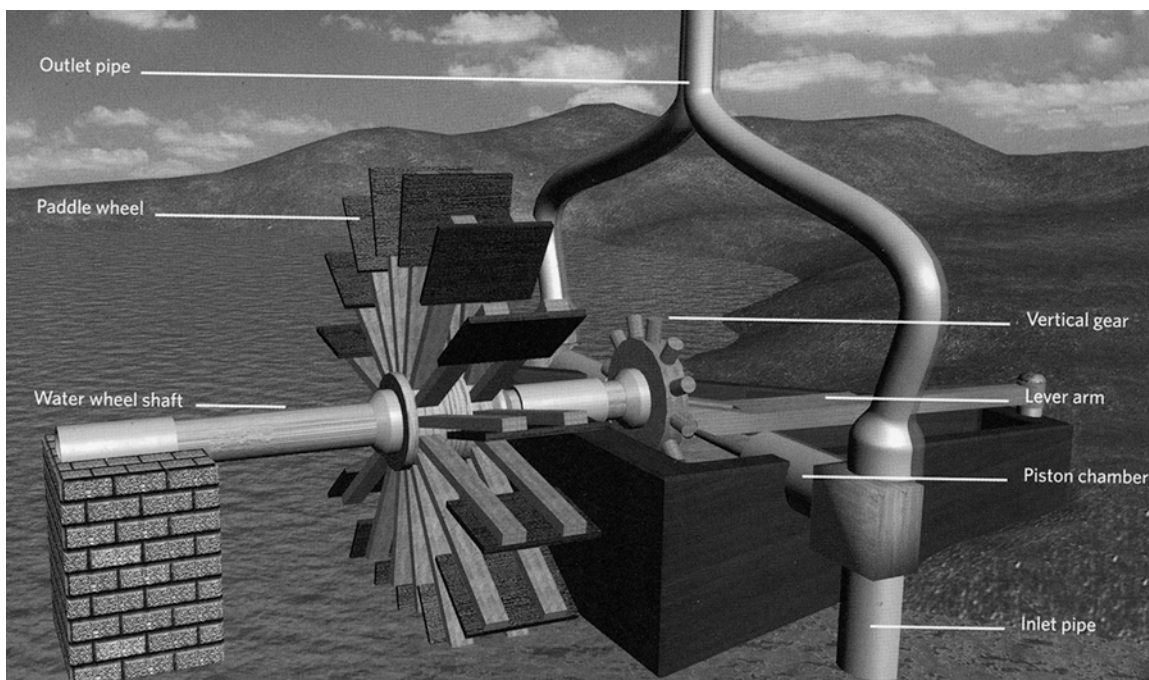
⁶ D. R. Hill, "Engineering", in Roshdi Rashed, ed., *Encyclopedia of the History of Arabic Science*, Vol. 2, p. 776-779. Routledge, London and New York.

circulated book with over one hundred examples of pumps connected to hydraulic wheels.

Figure 3a (right). *An example of a water-lifting device proposed by Ibn-al-Jazari in “The Book of Knowledge of Ingenious Mechanical Devices”, 1206. Image source: Bodleian Library, MS Greaves 27, folio 101r.*



Figure 3b (below). *A computer reconstruction drawing of a double pump designed by Ibn al-Jazari. Image source T. S. Al-Hassani Salim, editor, Muslim Heritage in Our World, 1001 Inventions, (2006: 119).*



Perhaps taking his ideas from Arabic sources and earlier Italian experiments, an Italian, Juanelo Turriano (Giovanni Torriani, 1500-1585), upon the request of King Philip II of Spain, raised water from the Tagus River to supply the Alcázar of Toledo in 1569. The mechanism that Turriano designed could raise a cubic meter of water 96 meters every hour. A hydraulic wheel, driven by the river’s current, supplied the energy, which operated either an alternative pump or a bucket to perform the first action of raising water. Once raised, the water was gradually transferred through another hydraulic wheel that moved two chains of rods with an alternative movement. The “tilted channels” raised

the water up to the feeder channel of the aqueduct of the Alcazar.⁷ (**Figures 4a and 4b**)

⁷ See, for example *The Twenty-One Books of Engineering and Machines of Juanelo Turriano* [c. 1590-1600], translated and edited by Alexander Keller (Madrid: Fundacio Juanelo Turriano, 1999).

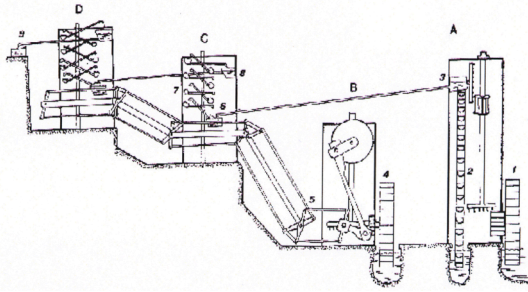


Figure 4a. Water-lifting devices developed by Juanelo Turriano.

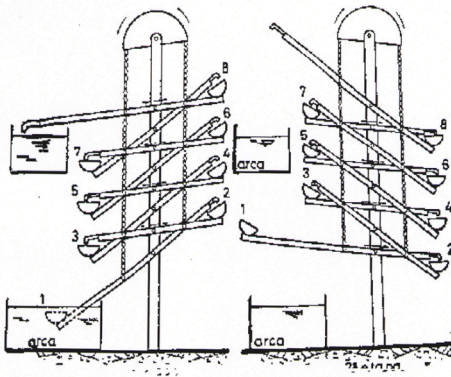


Figure 4b. Detail of the bascule counterweight used in Turriano's water lifting device. Images source J. A. Garcia-Diego (1986: 45).



Figure 5. The remains of the small dam (T) built inside the channel of the Acqua Vergine. Leonardo Lombardi.

Camillo Agrippa and his clients on the Pincian hill

It is possible that Camillo Agrippa was aware of the hydraulic innovations that were circulating in Europe at the time. In any case, in 1574 he designed a system for Cardinal Ricci that was able to raise water a full thirty meters up to the level of his gardens at the villa. The delivery conduit was inserted into the *pozzo*

(shaft) that already existed in the garden, which led directly into the subterranean conduit of the Acqua Vergine. The water fed a fountain that also acted as a small holding tank to irrigate the garden. Recent archaeological and hydraulic surveys, carried out under the auspices of the French Academy, have made it possible to reconstruct Agrippa's hydraulic pump. In order to operate the hydraulic wheel Agrippa constructed a dam inside the aqueduct channel that raised the level of the water by approximately two meters. Next, he constructed a second channel that ran parallel to the original aqueduct for a short distance. The wall diverted water from the main channel into the one that paralleled it. It was here in the second channel that Agrippa inserted the waterwheel that supplied energy to the pump. (Figures 5, 6, 7 and 8)

Two years later, in 1576, Cardinal Ferdinando de' Medici (1549-1609) bought the villa and its gardens from Cardinal Ricci's heirs. Medici took possession of all the hydraulic machinery installed for Ricci and hired Camillo Agrippa to install another fountain. The new fountain was intended to stand on top of an artificial hill that Medici wanted to build in the garden. The hill, known as the Parnassus, would rise to a height of seventy-three meters above sea level. Unfortunately, Agrippa's original waterworks for Cardinal Ricci were inadequate for the new fountain, which would stand about twenty meters higher than the garden and more than fifty meters above the Vergine channel. It was therefore necessary for Agrippa to construct a second water-lifting device, realized in 1577-1578, which was hidden inside the artificial Parnassus.



Figure 6. Remains of the second channel constructed parallel to the Acqua Vergine. Leonardo Lombardi.

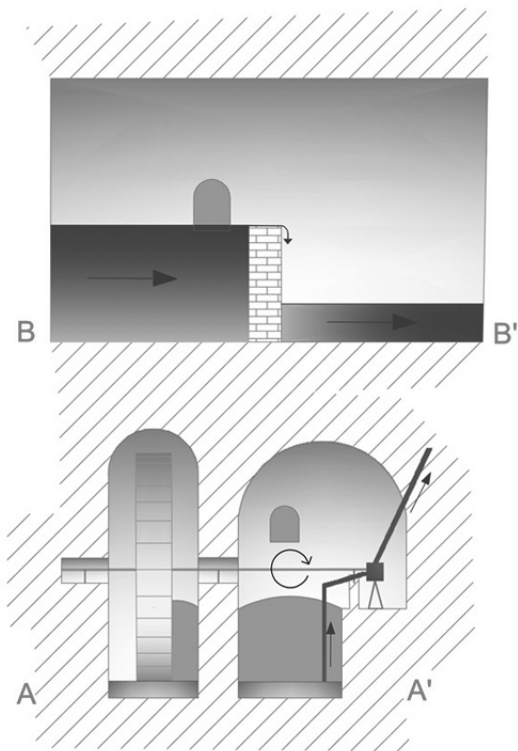
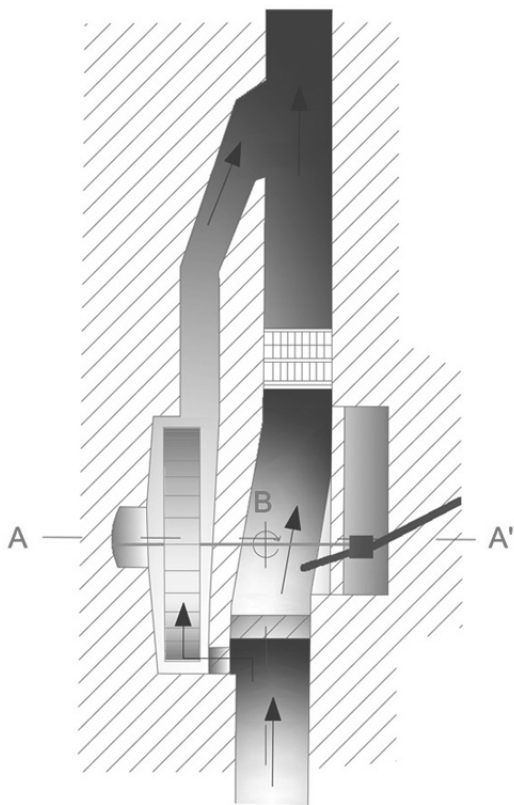


Figure 7. Reconstruction drawings made from the archaeological remains of Camillo Agrippa's water-lifting device for the Parnassus. Image courtesy of Daria dell'Acqua.

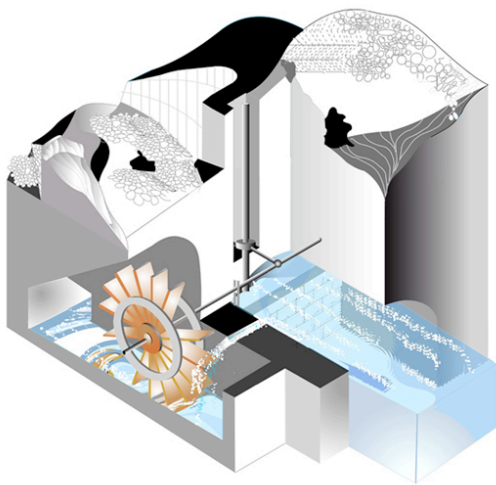


Figure 8. A 3-D reconstruction of Camillo Agrippa's water-lifting device. Image courtesy of Giacinto Laparola.

Agrippa's success was recorded in an inscription that Cardinal Medici installed at the Parnassus that emphasized the importance of Agrippa's technical innovation. In the inscription Camillo Agrippa is praised above Marcus Agrippa who constructed the Aqua Virgo in 19 BC. The dedication, which was read and transcribed in the

seventeenth century, has been lost. (Figure 9) Fortunately, in addition to the transcription, there is also a reference to Agrippa's hydraulic invention that supports the claim that the water was raised approximately fifty meters.⁸ This accords with actual conditions, since the level of the aqueduct water at this point was about twenty-two to twenty-three meters, while the height of the Parnassus is about seventy-three meters above sea level.

Camillo Agrippa's invention must have provoked great interest. In 1588, only ten years after the device was installed in Medici's garden, Andrea Bacci, a noted physician, wrote in his treatise, *De Thermis* that the technology that Agrippa employed was unknown to the great Roman architects. He praised Agrippa and proposed that he would be remembered for all future centuries for his new hydraulic device that allowed water to gush thirty *passi* (which is about equal to fifty meters) from the depths of the underground channel to the height of the leafy

⁸ For the transcription, see *BAV, Barb. lat. 2016, c537*, published in C. D'Onofrio, (1977: 246, ft. 6).

summit.⁹ Bacci described the device as being fashioned with a metal tube and he clearly indicated that the aqueduct water provided the motive power for the waterwheel.

“Marco Agrippa (genero di Augusto) condusse l’acqua Vergine in Campo Marzio, Agrippa e l’opera sua sono egregi, Camillo Agrippa condusse l’acqua al vertice del Pincio, il suo ingegno è esimio.”

“Marco Agrippa (gendre de Auguste) porta l’eau de l’aqueduc Vierge au « Campo Marzio », Agrippa et son ouvrage sont excellents, Camillo Agrippa emmène l’eau au sommet du Pincio, son génie est exceptionnel.”

Figure 9: Transcriptions of the original Latin inscription that commemorated Camillo Agrippa’s engineering triumph at the Parnassus. Leonardo Lombardi

From direct observations made by the present author, it is clear that Camillo Agrippa did not exploit the same shaft that he had utilized for Cardinal Ricci, but that he designed something entirely new. This time he took advantage of a second shaft, which might also have been an ancient *pozzo*, located further to the south of the original waterworks. This shaft, known as the “chiocciola del Pincio”, or “the snail of the Pincian”, is located immediately south of the palace at Villa Medici, on Via Trinità dei Monti. (Figure 10) It leads directly down into the channel of the Vergine, by way of a circular stair, which gives it its name.

While the well may have been ancient, it is likely that the circular stair was intentional and realized expressly for Cardinal Medici’s garden, but unfortunately no mention has yet been uncovered in archival research to support this hypothesis. In 2001, the present author visited the stair, and observed a conduit, five centimeters in diameter, that was embedded in plaster. (Figure 11) The tube was seen to run along the handrail of the stair, following it in a spiral. There can be no doubt that the ascending tube is related to Camillo Agrippa’s water lifting device.¹⁰



Figure 10. “La chiocciola del Pincio”. Leonardo Lombardi.



Figure 11. Remains of a tube embedded in the wall. Leonardo Lombardi



Figure 12. The remains of the stone slab found in the vault of the staircase chamber. Leonardo Lombardi.

⁹ Andrea Bacci, *De Thermis* (Rome: 1588), 431.

¹⁰ L. Lombardi, 2003, 264

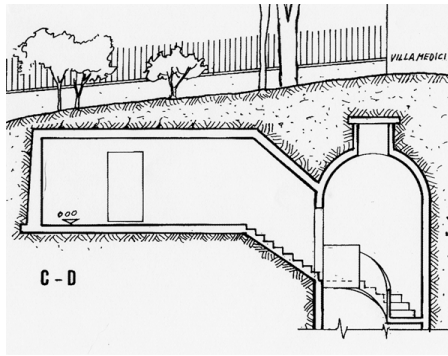


Figure 13a. Access to the Pincian staircase.

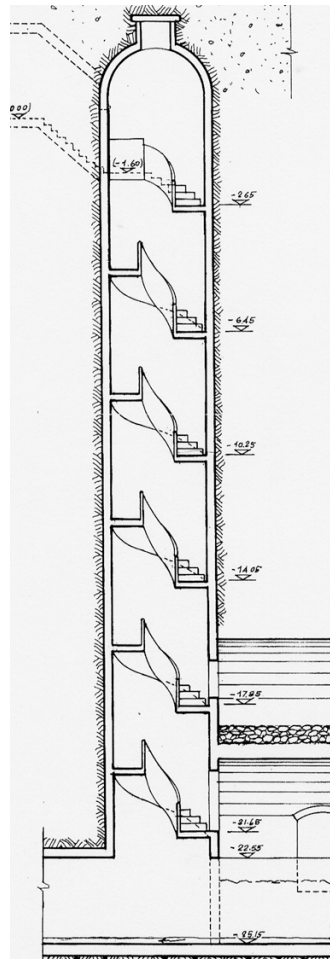


Figure 13b. A section through the staircase down to the water in the aqueduct channel. Image source V. Nicolazzo, (2000: fig XXIII).

Both the staircase and the water tube (which was embedded in the wall in order to resist pressure) clearly date to the sixteenth century. The discoveries made in the staircase, in the area at its apex and in the channel of the Acqua Vergine, provide further opportunities for appraisal and reflection on the

water-lifting device. At the head of the stair, on the underside of the vault's northern side (towards the villa), there is a stone slab with a hole and the imprint of a large conduit. (Figure 12) This pipeline is evidently connected to the one seen rising inside the stair along the handrail.

The staircase terminates just above the level of the water in the channel of the Acqua Vergine. (Figures 13a and b) There, in the wall, is a trace of a conduit ten centimeters in diameter and a fragment of a small diameter lead pipe that might indicate where the terracotta tube that ascended within the masonry wall along the stair was initially connected. Moreover, in the bottom of the Vergine channel, approximately ten meters upstream of the staircase, there is the trace of a wall (broken, but clearly legible) that runs crosswise to the direction of flow. This wall served as a dam that raised the level of the aqueduct water at least two meters. Thanks to the dam, the water was transferred into another channel, parallel to the main Vergine channel, to provide the energy for a hydraulic wheel – no trace of which, however, remains. The hydraulic wheel would have been connected to one or more alternative pumps that pushed the water into and through the conduit discovered in the staircase wall. Unfortunately, we know nothing of the characteristics of the pump (or pumps).

The water-lifting device that Camillo Agrippa designed for Cardinal Medici was an important technical innovation, as nothing of this kind had been realized in Italy before its construction. Water wheels had been used in Italy to generate energy to operate grain and olive mills since the Hellenistic period, and the alternative pump was also known in Italy. But knowledge of using water wheels to activate a pump (as testified in Islamic literature from the twelfth to the sixteenth century) and in the project to raise the water of the Tagus River to the gardens of Phillip II of Spain was not. Might Camillo Agrippa have used the system proposed by Ibn al Jazari, in which the hydraulic wheel, through a lever, raises a weight fixed on the top of the piston of the pump. When the wheel releases the weight, it falls and provides energy to one or more pumps according to the Arabic typology. (Figure 14)

Once the water was raised inside the pipes buried in the wall of the staircase, it exited the “snail” (chiocciola) and ran in an arc, roughly southeast, for three hundred meters (cutting under the property of the Church of Santa Trinità di Monte). (Figure 15) Buried in a trench, the original conduit ran along the

edge of the woods toward the southeast corner of the villa, where the new artificial mountain – the Parnassus – was to be built. At the point in the garden where the Parnassus was planned, a barrel-vaulted tunnel about two meters tall and thirty-six meter long was built. A long channel was dug into the wall of the

tunnel in order to accommodate the pipes. **(Figure 16)** Rising gradually, the pipe led toward the center of the artificial hill where it entered in a twelve-meter high shaft. **(Figure 17)**

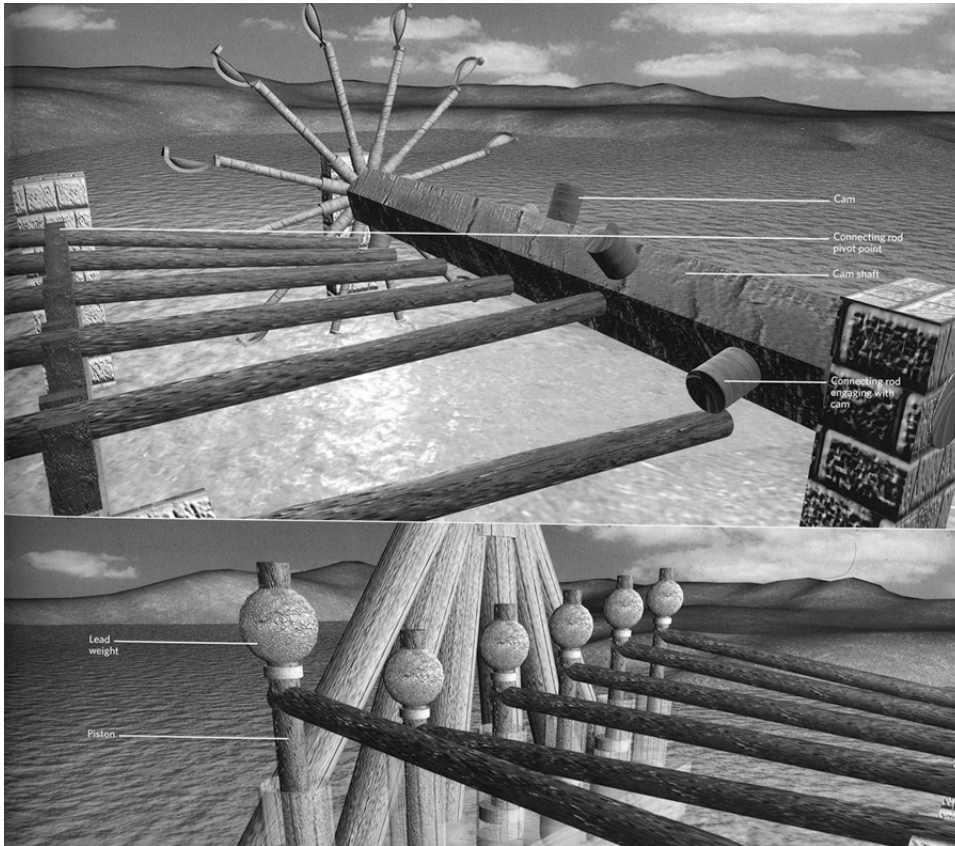


Figure 14. A computer reconstruction of an Arabic pump that will raise water from a river. Image source, T. S. Al-Hassani Salim, (2006: 116).

In essence, the Parnassus itself provided an elaborate container for the water-lifting mechanism. Inside the hill, the water rose in the tube and emerged in the small fountain placed atop the hill. Once it had flowed in the fountain, the water returned to a cistern that had been fitted with three inter-communicating rooms, also located within the Parnassus. The shaft, which was recently investigated by this author, is provided with footholds to allow easy access for maintenance.

We can hypothesize that the channel in the wall of the tunnel is the work of Camillo Agrippa and that it was intended to hold the pipe necessary to raise water to the high-level fountain. The presence of the tunnel and the shaft, built of poured concrete inside the hill, confirms that they were constructed at the same time as the Parnassus, and are therefore to be considered as a unified work. Furthermore, inside

the hill, there is a cistern (divided into three spaces), which communicates with the tunnel through a window where a pipe once entered. At the base of the cistern there is a hole that would have contained a pipe for the irrigation of the garden. The subdivided chamber would have operated as a holding tank to accumulate water once it had flowed through the fountain, so that it could be reused later. This is clearly indicated by the remains of a terracotta pipe that was found inserted at the top of the tank.¹¹ The room in question was probably adapted from the remains of an ancient structure, perhaps one of the two temples attributed by Jolivet to Spes and

¹¹ The room clearly shows evidence that it was maintained and altered sometime during the 1800s.

Fortuna.¹² The entire artificial hill of the Parnassus was built around these structures.

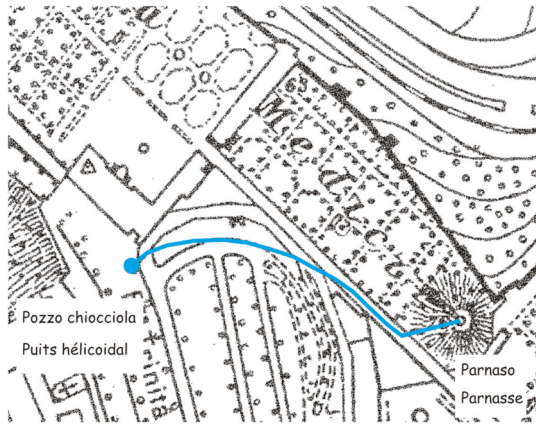


Figure 15. A plan of the route of Camillo Agrippa's conduit from the staircase to the Parnassus in indicated in blue.



Figure 16. The remains of the channel in the sidewalls of the connecting tunnel. Leonardo Lombardi.



Figure 17. The vertical shaft that ascends to the summit of the Parnassus. Leonardo Lombardi.

¹² V. Jolivet, "Pincio (Villa Medici), in *Mélanges de l'Ecole Française de Rome*, volume 118, number 1 (Rome: 2006), 327-331.

Conclusions

Unfortunately, Andrea Bacci's 1588 praise for Agrippa's marvelous water-lifting device may have been the last time it was mentioned. It is entirely possible that it became redundant once water from Rome's second early modern aqueduct, the *Acqua Felice*, reached the Villa Medici in 1592. But, it is more probable that it was abandoned in 1588 when Ferdinando's brother, Francesco de Medici, died and Ferdinando returned to Florence (renouncing his position as cardinal) in order to insure his succession to the throne as the Grand Duke of Tuscany.

In spite of its short history, Camillo Agrippa's project for Cardinal Medici was the most audacious water-lifting machine to be constructed in Italy between the time of the ancient Romans and the modern age. During the late sixteenth century there were many new and important water works, scenographic water displays, musical fountains and *giochi d'acqua* (water caprices) that were either in the planning stages or already constructed in Renaissance gardens, but none of them were fed by artificially raised water that defied the law of gravity.

It should be remembered that in this same period important hydraulic works were being carried out at Villa d'Este in Tivoli, at the gardens of the Quirinal and in the Pratolino gardens at Florence. Water organs, mechanical devices with singing birds and other musical instruments were becoming famous throughout Italy and Europe. But at the same time, the water-raising system constructed by Camillo Agrippa does not seem to have been imitated and used in any other villas or contexts. One needs to wait almost a century to see a similar system at Versailles and in other French villas.

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