Sophie Bouffier

10 Syracusan Water Networks in Antiquity

Abstract: During a long period, until the beginning of the 21st century, a lack of interest about the hydraulics in ancient Sicilian towns prevailed: archaeologists and historians felt more concerned by the traditional topics of Classical Archaeology. Nowadays, as environmental research has been booming, some specific cases have begun to be studied, like Syracusan aqueducts which were known almost exclusively from Francesco Saverio Cavallari and Adolf Holm's monograph in 1883. Using recent results, the paper will focus on the topics of the Galermi Aqueduct, investigated by a French team of Aix-Marseille University, and some parts of other channels, studied by local teams of Syracusan speleologists and engineers, inside the Epipolai shelf and the Achradine district. The people of Syracuse, maybe under the rule of the Deinomenids and then Hieron II, had been equipped with pipelines of drinking water as early as the 5th century BC and had increased them all through their history to cater for the needs of the fast-growing town, either for drinking water or craftsmanship.

Introduction

During the last few years, and in the context of current environmental debates, there has been a renewal of interest about ancient societies' behaviour concerning this vital substance, water. This revival has prompted the reopening of several dossiers, such as that of the water networks in the ancient city of Syracuse. For a long time, it was not a central theme of archaeological research, although Greek philosophers such as Platon[1] and Aristotle[2] pointed out the need to provide water to the community: according to them, the Greek city must have water in quantity – to avoid scarcity – and quality – to maintain the good health of its inhabitants. As early as the 5th century BC, Hippocrates and his school described people's health and environmental conditions and advised local physicians to consider this reality that changed depending on places. As Elisabeth Gruber argued in her paper about Danubian populations in the Middle Ages,[3] one could think that Greek governments faced the necessity of managing water resources and supplying the population, both with drinking water and staple foods. One might have thought that the Greeks had designed their cities taking into account the water resources of the chosen site and ensuring that the basic needs of the population were satisfied. Actually,[4] it is not a relevant factor as some Greek towns are settled on sites that lacked water. The aim was to choose a site naturally easy to fortify and the issue was above all to prevent the Mediterranean torrential rains from destroying the urban structures.[5] So, one of the main concerns of the local authorities was first to drain and channel the waters and store them for redistribution. The search for drinking water was left to the care of individuals. Greek governments seem to have realized the importance of the issue as the city became more structured

1 Pl. Leg. 5, 747d.
2 Aristot. Pol. 1330 b.
3 See Gruber, this volume.
4 I have developed these aspects in previous papers: Bouffier 2014; Bouffier – Brunet forthcoming.
5 See for example the city of Locri Epizephyrii: Elia 2019.

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and organized. The progressive establishment of community rules also applies to water resources, because water is conceived as a resource to which every citizen has the right of access and which cannot be bought or exchanged, unlike other products. Some political regimes, such as the Greek tyrants, understood the challenge for their visibility and sustainability and developed great hydraulic programmes, as we shall see in this paper about the city of Syracuse.

Syracuse, founded by the Corinthians in the second half of the 8th century BC, on the island of Ortygia and the nearby mainland of Achradina, grew rapidly, to the point of expanding inland, where it built secondary colonies as far as the southern coast of Sicily. At the beginning of the 5th century BC, the tyrant of Gela, the Deinomenid Gelon, seized the city and transferred his capital there, wishing to transform it into a megalopolis. To this end, he initiated a policy of concentrating eastern Sicilian populations in the city of Syracuse and launched an urban extension programme designed to welcome these people and to provide the necessary community services for their welfare. His successors continued this policy and the city evolved during periods of autocratic regimes and civil and foreign wars.[6] It reached its definitive territorial control in the late 5th century BC, when the tyrant Dionysius the Elder surrounded the entire Epipolai plateau with a fortification of more than 21 km in perimeter, which was, nevertheless, a long way from the experience of intensive urbanization.[7] Between the beginning of the 5th century BC and the final Roman conquest in 212 BC, the urban space expanded from an area of 50/60 ha to over 1,800 ha, although probably only 250 ha were densely occupied. The population boom that resulted from the original Syracusan synoecism and enrichment of the city necessarily forced the authorities to take into account the question of water supply and to consider a comprehensive plan for water management. The various governments, whether the Deinomenid tyranny or successive powers, also had to monitor this issue closely.

Originally, the city had an easily accessible low depth water table and several sources inside Ortygia,[8] and in particular an abundant source, Arethusa, which gave rise to an exceptional myth.[9] Individual and public wells also supplied the population. On the mainland, a dozen sources have been identified on the perimeter of the Epipolai plateau,[10] resulting from the geological configuration of the substrate, such as the sources of Tonnara, Targia, Acqua Colombe; it is a significant number, but in the current state of research, their use in ancient times has not been confirmed. Furthermore, they are rather distant from the settlement. Historiography, from the 16th century AD, reported the presence of ancient aqueducts, more or less known with certainty:[11] the aqueducts of Ninfeo, the Paradiso, Tremilia, within the urban space, and the most impressive, the Galermi Aqueduct of nearly 30 km in length. Authors from the Dominican Father Tommaso Fazello[12] to contemporary times have questioned the actions of the various leaders of the city of Syracuse. Most scholars and historians have attributed these aqueducts to the Greeks,

6 Finally, on the various phases of the urban network: Basile 2012; Guzzardi 2011.

7 Literary sources differ from the archaeological documentation provided by Dieter Mertens and the German Archaeological Institute in Rome regarding the perimeter of the fortification of Epipolai plateau. According to Strabo, the fortification reached the length of 180 stadiums or 33 km (Str. 6, 2, 4). According to Mertens, it should be evaluated at 21 km. But these figures reflect only the intramural territory. One should also consider the entire area of influence of the city. According to Pietro Griffo, who gives an estimate a little higher than that of Julius Beloch, Syracuse would have included an area of 4300 km^2 with a population of 240,000 people of which only 1/3 lived in the town proper: about 80,000/100,000 in the 5th century BC; in the 3rd century BC under Hieron II, the city would have counted 150,000/200,00 inhabitants.

8 Bouffier 1987; Bouffier 1992.

9 Bouffier 2019.

10 Arena et al. 2018, 7 f.; Aureli et al. 2005, 8–10; Aureli et al. 1989.

11 Cf. the state of the art, in Bouffier 2000; Bouffier et al. 2018, 303–305.

12 Fazello 1558; Bouffier et al. 2018.

especially Gelon, considered the great architect of the Syracusan expansion and the extension of the ancient city. The existence of hydraulic works is confirmed by the historian Thucydides in the account of the siege of the city by the Athenians in 415 BC: *Meanwhile the Athenians destroyed their pipes which ran underground into the city and supplied it with drinking water*.[13]

Nevertheless, some discordant voices wanted to see traces of the Romans in the lineage of the important known works in the peninsula.[14]

Today, new work has allowed us to know more about these important amenities. A team from Aix-Marseille University launched an interdisciplinary and diachronic programme on the most emblematic of the aqueducts of the ancient city, the Galermi, which covers a distance of nearly 28 km from the Hyblaean Mountains to the ancient city, where, nowadays, it flows into the Ninfeo of the Greek theatre. Meanwhile, a local team, consisting of a geologist, a hydraulic engineer and a speleologist, explored the known galleries in the limestone substrate of the Syracusan plateau to map the area.[15] This article will explain this new research to contextualize the developments of Syracuse and to situate them in the policies of its leaders during Antiquity. In addition to this chronological and political context, which will allow us to identify potential users, it will be necessary to examine the processes of construction and technical maintenance of these aqueducts, and their function. We should also have to calculate how much water they could provide to ancient consumers. Finally, we will be able to state their technical specifications that reflect scientific knowledge and specific skills. Unfortunately, the answers depend on the available documentation, which is more or less reliable. The more crucial problem is the date of these pipes, which we do not know for sure: it forces us to be cautious and adopt a topographical and technical structure of our paper. We will be able to understand the context of their construction only after examination of their peculiar characteristics.

The aqueducts inside the city wall

Within the ancient city, several aqueducts were documented from the testimony of Fazello: in the southern part of the Epipolai plateau, and in a north to south direction, those of Tremilia, Ninfeo and Paradiso; in the north, Targiuni, Targia, Bosco and Targeta.[16] Investigations by Francesco Saverio Cavallari, Cristoforo Cavallari and Adolf Holm emphasized three of them:[17] Paradiso, Ninfeo and Tremilia (Fig. 1), but they were largely lost after the rapid growth of urbanization from the 1960s. I will analyse only them, even if a lot of small pipes have been identified within the city, without any connection actually with public monuments or urban settlement. The easiest to link to the urban centre are the aqueducts of Ninfeo and Paradiso.

13 Thuc. 6, 100: *Οἱ δὲ Ἀθηναῖοι τούς τε ὀχετοὺς αὐτῶν, οἳ ἐς τὴν πόλιν ὑπονομηδὸν ποτοῦ ὕδατος ἠγμένοι ἦσαν, διέφθειραν* (translation by Smith 1959). <http://www.perseus.tufts.edu/hopper/text?doc=Thuc.+6.100&fromdoc=Perseus%3Atext%3A1999.01.0199> (25. 05. 2018).

14 Wilson 2000.

15 Arena et al. 2018.

16 Fazello 1558, 83.

17 Cavallari – Holm 1883, 95–142. pls. 2. 6. 7. 9. 15.

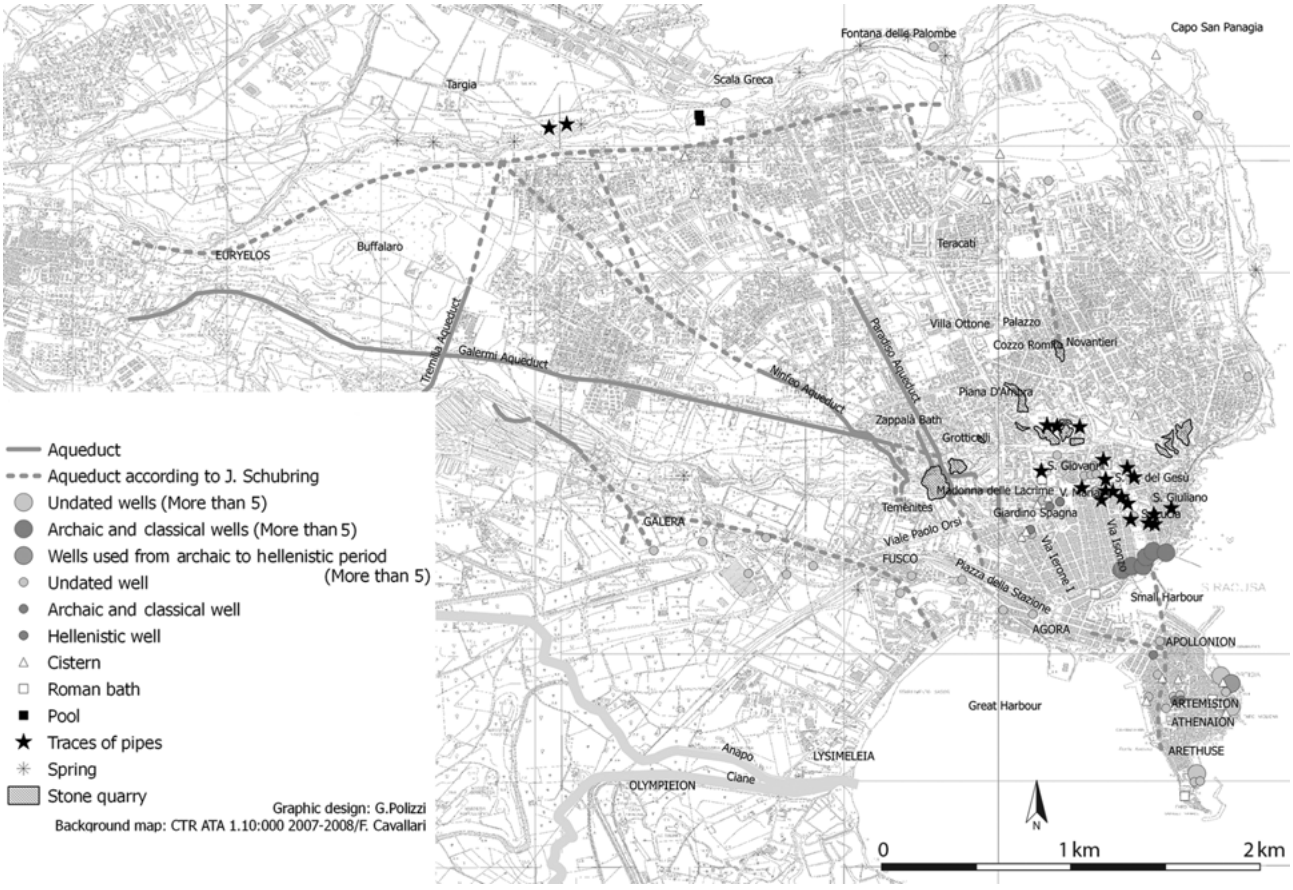

Fig. 1: Map of the Syracusan aqueducts.

The Ninfeo aqueduct

The Ninfeo aqueduct, of a known length of 1,385 m, flows from the north into the Ninfeo fountain located on the upstream terrace of the Greek theatre in the north-east part of the ancient neighbourhood of Neapolis (Fig. 2).[18] It was dug into the limestone plateau and was available, at the time of Cavallari and Holm, by vertical inspection shafts up to 30 m deep. Cavallari and Holm calculated its slope to be about 0.7 %.[19] Recent explorations[20] have confirmed this information, in particular the irregular layout of the aqueduct, while the other two known aqueducts in the city, the Paradiso and Tremilia, follow a rectilinear path. This peculiarity is difficult to explain, given the homogeneity of the limestone substrate[21] at the Epipolai plateau. It can be an archaic specificity, which shows the technical difficulties in carrying out the work, reaching sometimes a depth of 30 m. As we show in the case of the Galermi aqueduct, the workers dug from one shaft to one another and in the same direction to be sure to meet. It is just possible that the Ninfeo had to serve different places, and perhaps, buildings which have completely disappeared today. Nevertheless, as it supplies the so-called Ninfeo, which was created, in its current form, as early as the 3rd century BC, we can propose that it was part of a larger urbanistic programme, which included the construction of the monumental fountain and the theatre below. As first phase of the theatre is dated to the 5th century BC, and the present state of the monument dates back to the Hellenistic era, the Ninfeo aqueduct can date back to either one

18 Cic. Verr. 4, 53.
19 Cavallari – Holm 1883, 124 f.
20 Besides our team's work, see the survey of the Syracusan speleologist group: Arena et al. 2018.
21 Arena et al. 2018, 8 f.

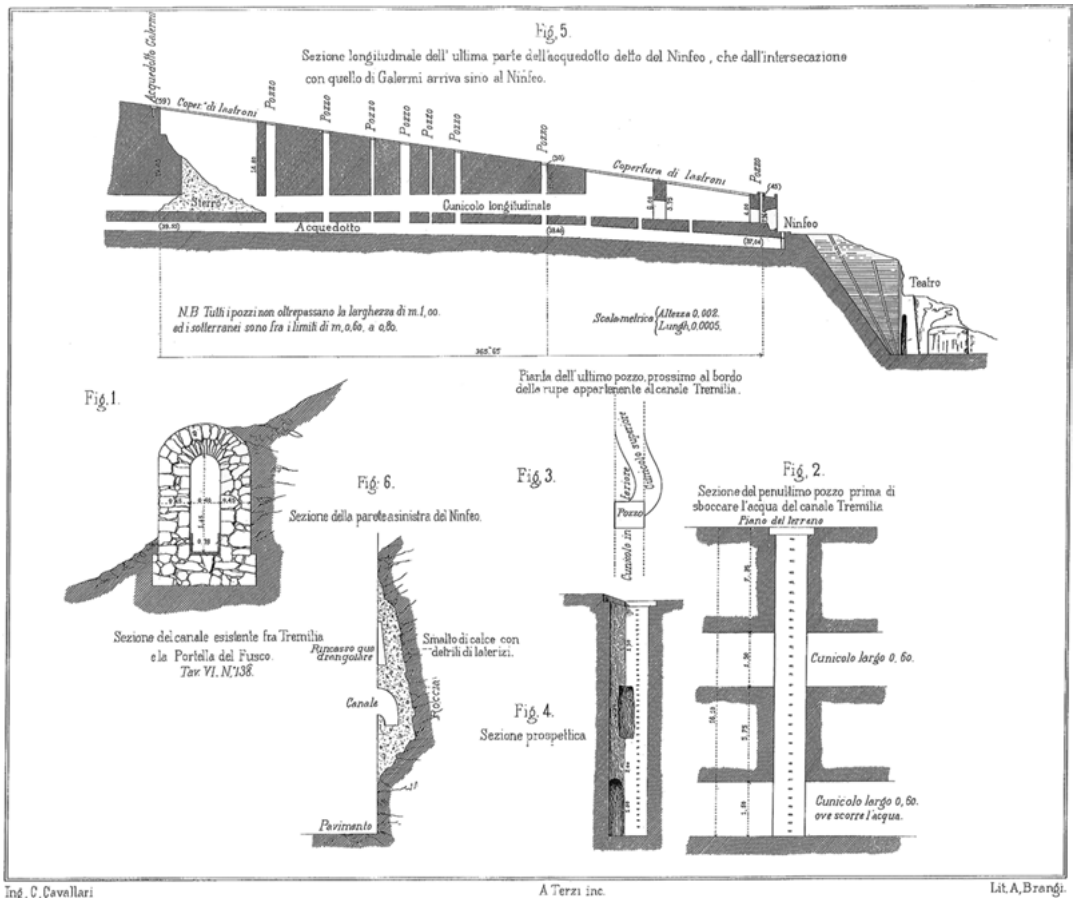

Fig. 2: Syracuse, section of Ninfeo Aqueduct.

of these periods. In the first case, it could have been conceived in the general project following the politics of the Deinomenids and was intended to supply the growing population in the new districts of the town below. In the second one, it could have been one of the components of the great project of King Hiero II in this part of Syracuse.

The Paradiso aqueduct

The Paradiso aqueduct, which takes its name from the homonymous quarry in which it terminates, of a known length of about 3000 m today, also presents a north/south direction and vertical inspection shafts of a depth of 4 m downstream to almost 30 m upstream, but the intermediate distance can vary from 14 to 30 m.[22] The rectangular inspection shafts were enclosed by large slabs of limestone, some of which have been incised with the Greek letter Λ. At the level of the Paradiso latomia, the aqueduct splits into several branches to supply various sectors. The main pipe feeds a tank near the amphitheatre (the so-called Roman pool of San Nicolò) and heads towards the amphitheatre, where it supplies a recently identified fountain.[23] Another ramification goes eastward and towards the domestic and artisanal districts of Neapolis, and perhaps the fountain in Piazza della Vittoria. Cavallari and Holm had calculated its incline at 0.6 %. With the state of the art in this aqueduct, we have no idea of its date, nor its potential customers nor its

22 Cavallari – Holm 1883, 125 f.; Guzzardi 2000; Messina 2009; Arena et al. 2018, 8.
23 Arena et al. 2018, 8.

urban function. We can just suggest that it was able to supply the mainland quarters of Achradine and Tyche.

The aqueduct Tremilia

The third aqueduct, Tremilia, is offset relative to the other two and is not directed towards the ancient city, which raises several questions about the topography of Syracuse, and the allocation and function of this hydraulic equipment. It is known over a distance of more than 800 m.[24] Installed in the western part of the Syracusan plateau, it also adopts a north/south orientation and has vertical inspection shafts with a depth varying from 14 m to about 34 m,[25] which follow one another at approximately 38 m intervals. The inspection shafts are enclosed in strong slabs of limestone. The angle of its slope poses a problem, because from what Cavallari and Holm had determined, the slope would be only 0.03 %, which would cause big flow problems. We can note the incongruity of the direction of the aqueduct, that travels outside of the plateau and down to the plain of Syracuse, where no habitat has been identified so far. It is unlikely that it was used for irrigation of the plateau, as I have suggested in the past,[26] since its exceptional depth was difficult to reach from the surface and we do not know of an example of a similar irrigation technique in a Sicilian environment. However, we should question the possible presence of a suburban neighbourhood such as archaeological research has begun to identify in some ancient cities of Sicily.[27]

A technological and stylistic relationship

The similarity of the three aqueducts was revealed from the first field studies.[28] They exploit the slope of the Epipolai plateau towards the south in more or less the same direction, feed from the depths of the limestone layer, at the junction of the clay substrate, have no waterproofing coating, thus allowing the percolation of water through the rock. The typology of galleries is approximately rectangular and has variable dimensions that allow, most of the time, for a man to stand upright, but recent research has also highlighted in the Tremilia Aqueduct, extremely reduced galleries and different depths that show, it seems, digging and fitting errors, made necessary by the need to ensure the smooth flow of water.

A double gallery

Moreover, the first publications had highlighted the presence of a double gallery: ‘Questi tre acquedotti offrono la particolarità di avere ognuno due gallerie, una sovrapposta all’altra e sul medesimo asse [...] La galleria superiore (specialmente quella dell’acquedotto del Paradiso) è profonda metri 23 circa sotto il piano di campagna, e poco distante dall’altra ove scorre l’acqua:

24 Cavallari – Holm 1883, 123 f. It was recently investigated by the Syracusan speleologist group: Arena et al. 2018, 9–13.

25 But these dimensions are based on the current level of the inspection shaft and not on the original part. We must therefore take into account a certain thickness of sediments impossible to evaluate without an archaeological dig.

26 Bouffier 1987, 685.

27 About Himera, Vassallo 2005, 66.

28 Schubring 1865; Cavallari – Holm 1883, 127 f.

esse indistintamente sono in comunicazione con i pozzi, i quali, attraversando quello superiore, vanno a comunicare con l'altra sottostante, però sempre sull'asse di esse'. This description by Cavallari and Holm[29] was adopted and repeated by historiography which sought the causes without providing convincing ones. The first two editors suggested that the upper gallery served the maintenance and repair workers, who could travel along the aqueduct without harming the quality of the water flowing into the lower gallery. Renate Tölle Kastenbein gave a hypothetical reading which has a consensus of opinion, proposing that the upper gallery allowed the soil pressure on the runoff gallery to be limited, particularly seismic movements that could damage the pipe.[30] Sicily is a particularly sensitive zone from this point of view, as shown by the traces of post antiquity earthquakes on the Galermi Aqueduct.

Marks of digging?

First editors noticed that two of these aqueducts, Ninfeo and Paradiso, showed some Greek incised letters: one lambda on some blocks of the Ninfeo wells[31] and one alpha in the Paradiso aqueduct.[32] According to Julius Schubring, these letters represent either the name or the number of the aqueduct, the abbreviation of the name of the architect, or the date of construction of the installation. According to Cavallari and Holm, they characterize the channel. We also know that these quarry marks appear frequently on blocks at the exit of the quarry and can correspond to the work carried out by the worker, or to the control of the foreman or the worksite manager, or to the owner of the block, or to the name of the magistrate in charge of the equipment.[33] In the Castello Eurialo, Mertens observed these quarry marks on blocks.[34] In some Greek aqueducts that have been investigated elsewhere in the Aegean world, Greek letters have been interpreted as marks of the work of a particular mason, maybe in order to claim payment, as in Megara[35] and Samos.[36] These marks are the only epigraphic clues for dating the water installations, which thus seem to have been realized during the Greek period.

The fact that we have observed two different letters in two aqueducts encourages us to favour the hypothesis that they refer to the characterization of the aqueduct: lambda could be an abbreviation of the ancient name of Ninfeo, while alpha would be that of Paradiso, names unknown to us for now. None of them evokes the terminology of hydraulics: we would have expected the letter omicron for *ochetos*, a term used by Thucydides to refer to the underground pipeline, upsilon for *hydragogion*, a pipe or any other compound from the root *hydor*, water. Another interpretation is to read the alpha and lambda as the initial anthroponym of the sponsor or the aqueduct project manager without being able to explain more. Finally, the letters could refer to a layout number: Paradiso would be the first aqueduct on the inventory, and the Ninfeo the eleventh; we would then have to identify the other ten and integrate them into a coherent system, established in the same urban project. The few sections identified in the urban space until now[37] could enter into this capillary network. If this reading is correct, one must assume the existence of a genuine water project, which could be precisely that of a centralized government designing a global policy of major urban works.

29 Cavallari – Holm 1883, 127.
30 Tölle-Kastenbein 1990, 72–74; Wilson 2000.
31 Schubring 1865.
32 Cavallari – Holm 1883.
33 Frontin. Aq. 105–113.
34 Beste et al. 2015.
35 Avgerinou 2019, 44.
36 Kienast 1995, 193 f.
37 Arena e al. 2018, 13–17.

The Galermi Aqueduct, testimony of a gigantic programme

The best-known aqueduct today is the Galermi, first because it has survived centuries to meet the different needs of the Syracusan population: drinking water supplier in ancient times, hydropower for flour mills in modern times, and for a power plant in the 20th century, and today an instrument for irrigation (Fig. 4).[38] It is in an exceptional state of preservation. Furthermore, our team has conducted excavations, topographic, architectural, photogrammetric and 3D surveys since 2012 there.[39] To identify the ancient parts, we focused our attention on the first few kilometres of the aqueduct, dug into the limestone of the Hyblaean Mountains, because these are the best preserved sections of the development. On the plain, frequent landslides have forced successive users of the aqueduct to rework the pipeline, to strengthen or even move it, sometimes by a few metres. The last part of the aqueduct, near the theatre, was diverted to feed the Nymphaeum theatre in the 19th and 20th centuries. Its original layout and its technical configuration are no longer known today.

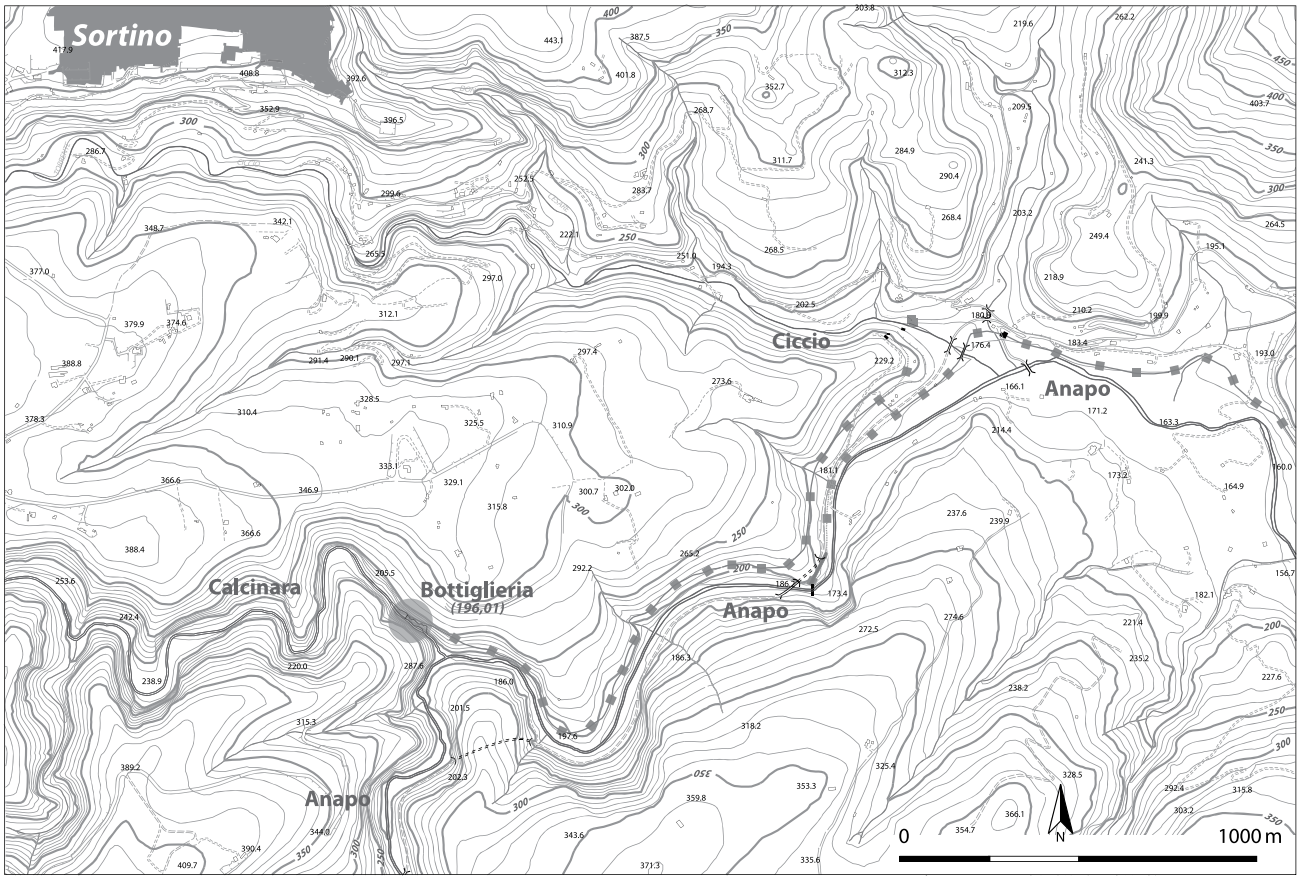

Fig. 3: Syracuse, ancient catchments of the Galermi aqueduct.

38 Besset – Bouffier 2017; Bouffier – Wateau forthcoming.
39 Bouffier 2018; Bouffier et al. 2018; Bouffier et al. 2019.

Several catchments in the Hyblaean Hills

The Galermi's source is in several parts of the Hyblaean Mountains, located in the hinterland (Fig. 3). This vast limestone massif serves as a reservoir for the entire region, giving rise to a river system that feeds the coastal plain from Syracuse to Cape Passero and the southern coast to Camarina, west of the headland. In our case, the Anapo river is fed by several tributaries that the ancients exploited by installing at least two catchments, installed in two tributaries of the river, the Calcinara and Ciccio, over 25 km from the ancient city.

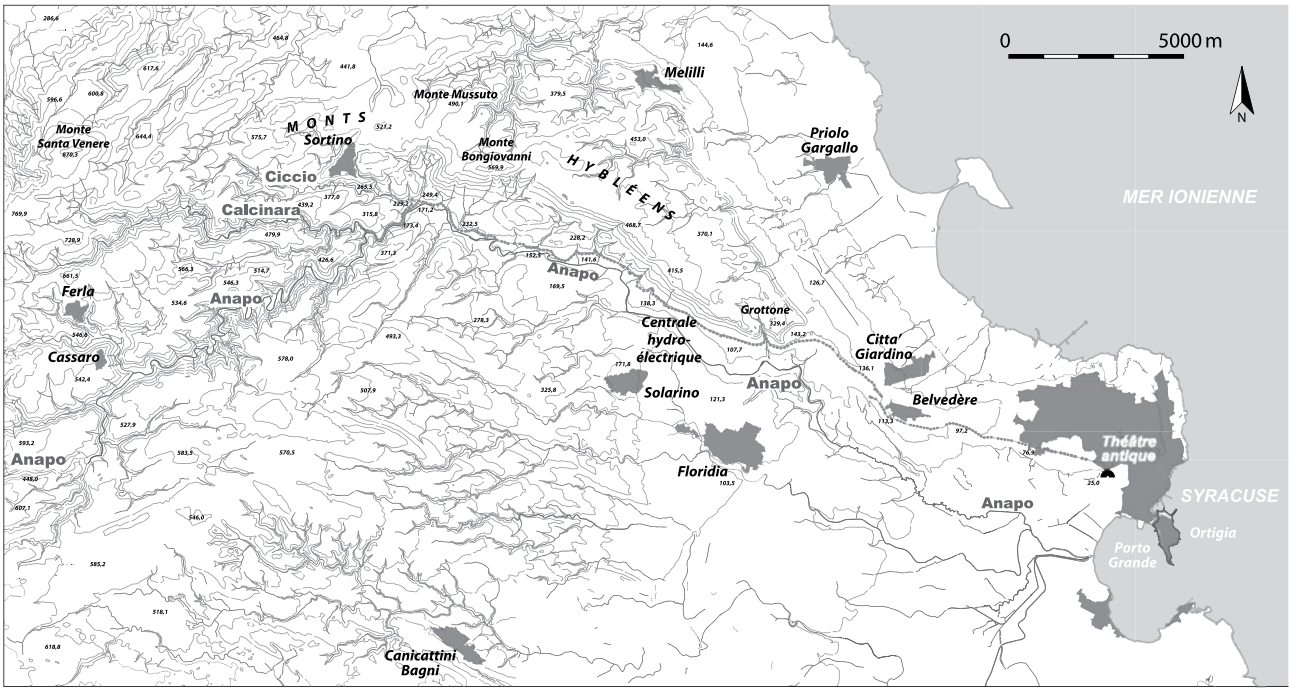

Fig. 4: Syracuse, map of the Galermi aqueduct.

The Ciccio catchment

In a bend of the Ciccio or Torrente Santa Sofia, the ancient designers opened a first gallery of 2.35 m high and 0.60 m wide (Fig. 5). The topography of the catchment had both the advantage of receiving the entire flow of the river and the disadvantage of being directly accessible to the waste carried by the river in the case of flooding: so they protected it from the intrusion of bodies likely to clog the pipeline by using gratings, of which only the centre plates of the hinges remain.

A trapezoidal niche pediment, of paramount importance for dating and the interest that the designers or the aqueduct users gave it, was dug at the top of the catchment (Fig. 6): it is similar to the ones we can observe in the Archaeological Park of Neapolis in Syracuse. An inscription was incised on it, but it is barely legible today. Perhaps we can decipher some letters: ι (iota), ε (epsilon), ω (omega) and maybe an isolated end of the line δ (delta). Their place on the line encourages a reading of 'hiero' which could refer to the sponsor: Hieron, either a dedication 'I am devoted to' or 'with'. The name of who it is dedicated to is unfortunately unreadable, unless the delta is one of the marks.

The gallery's horizontal inspection shafts punctuate the cliff at more or less regular intervals (every 15 m approximately) (Fig. 5, F1, F3, F5). They are of virtually identical dimensions with a height varying from 1.85 to 2.05 m, with a width varying from 1.15 to 1.40 m, and an average depth of 2.30 to 2.90 m. At a later, or even modern, period, new inspection shafts were built with far less care (F2, F4, F7).

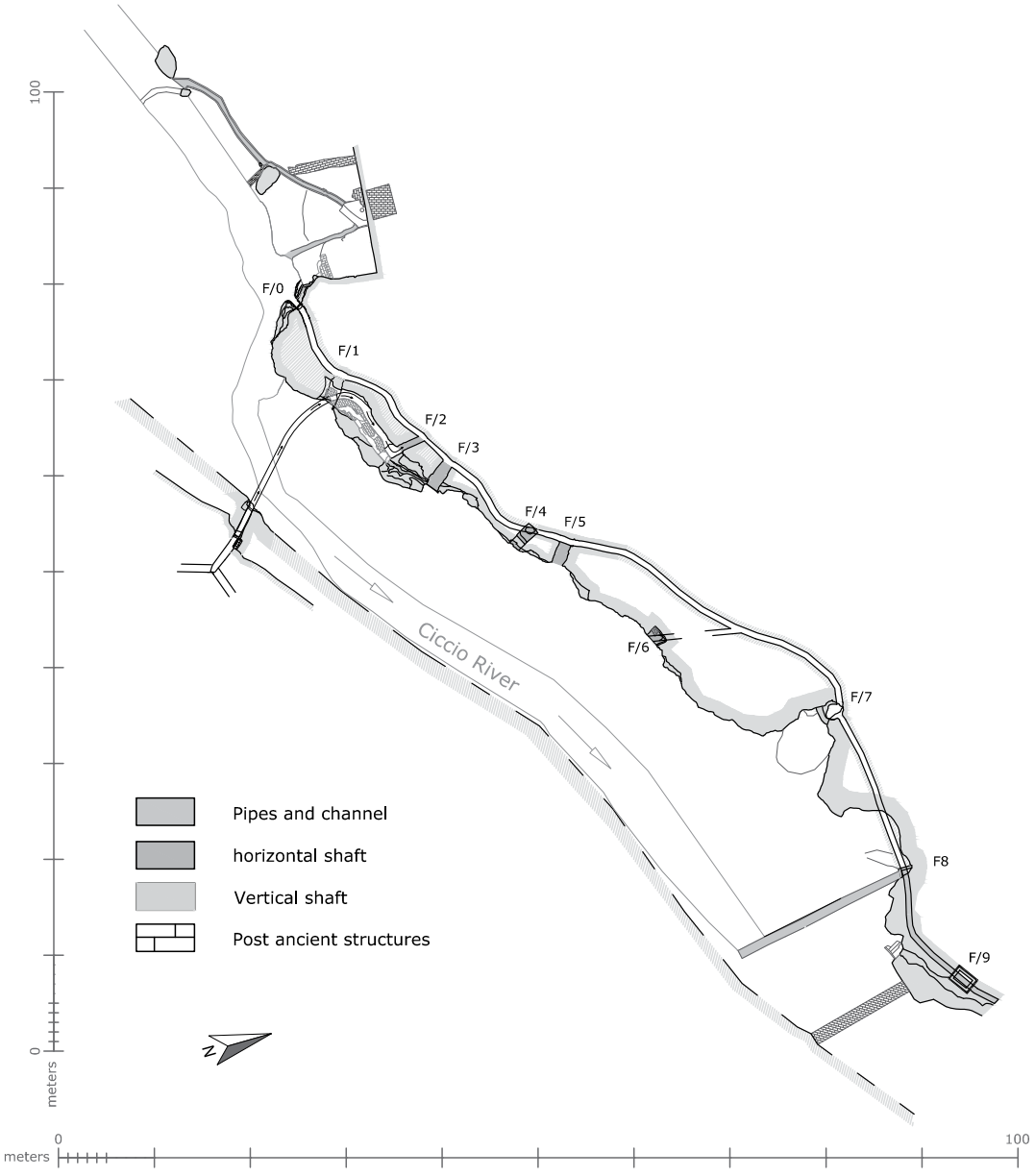

Fig. 5: Syracuse, map of the Ciccio branch (Galermi aqueduct).

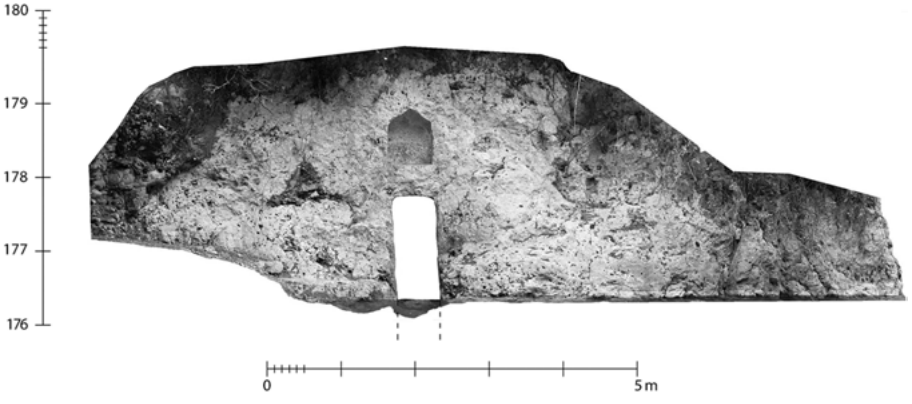

Fig. 6: Syracuse, the Ciccio catchment of Galermi aqueduct (photogrammetry elevation).

However, this first catchment had a certain number of disadvantages. First, it was at an altimetry too close to the river, and despite the project managers having installed gratings or a barrier, whose existence is shown by the vertical grooves built into the inspection shafts (Fig. 5, F1), the gallery must have been too often flooded during floods and thus carried materials likely to block circulation and impair the quality of the water. Second, it could not have provided a sufficient amount of water. Indeed, the Ciccio is a torrential type river, with an irregular flow. There was an attempt to increase the quantities of water carried by the aqueduct, by adding a supplementary catchment (Fig. 5, F6), but it seems that this was not enough.

The Bottiglieria catchment: an elaborate system

The ancients then installed a second catchment, that of Bottiglieria, a perennial karstic river, of much better quality and abundant flow. They exploited a height difference in the current and created a reservoir by installing an artificial dam that today has disappeared under layers of calcareous concretions, common in this river with the evocative name of Calcinara, that which carries lime (Fig. 7). At a height of 3.50/5 m and a width of 9 m, this dam created a reservoir of about 20 m in length for the same width approximately as the dam, that is a surface of about

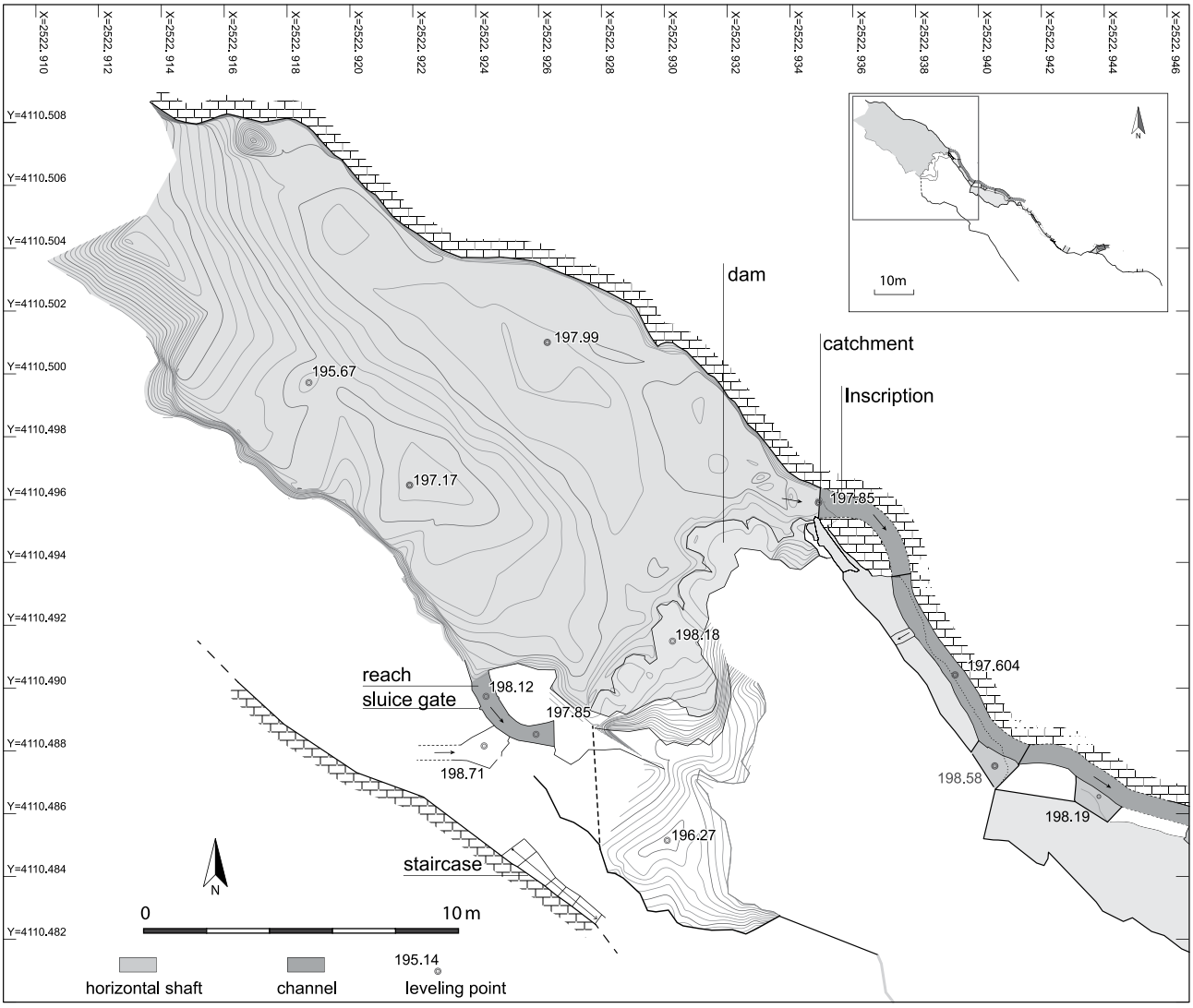

Fig. 7: Syracuse, map of the Bottiglieria catchment.

180 m^2, but we are unable to measure its capacity in the absence of reliable estimates of the river's capabilities in ancient times. On the north cliff of the river, the aqueduct's designers developed a catchment gallery dug out of the limestone, of a roughly rectangular shape (height 2.20 m, width 0.90 m), and to which a channel arranged at the bottom of the retainment area brought water. On the opposite side, a branching structure with a valve for opening or closing the dam to maintain the desired water level and carry out the necessary maintenance operations was installed.

The route of the Galermi aqueduct: a good knowledge of local geology

The aqueduct then followed a zig-zag path along the cliff, alongside, first, the Calcinara, then alongside the Anapo, before exiting the gorges of the hinterland to enter the coastal plain. It thus travelled partly through the limestone rocks of the Hyblaean Mountains, Mount Climiti and the Epipolai plateau of Syracuse. For the remainder, it crossed alluvial and sedimentary loose ground, which suffered landslides, necessitating repairs throughout its history. It was formed in several ways, depending on the ground it passed through: it could be wholly or partly rupestrian; but could also be dug as an open trench and present diverse types of coverage (either semi-circular arches, or horizontal slabs). The aqueduct's dimensions also vary, depending where it is sited: they are usually the height of a man, around 1.70/1.90 m, but can be several metres high, as under Mount Climiti, where the channel seems to have exploited a geological fault between two limestone layers. Its width varies from 0.40 to 1.35 m. But on average, a section has a width of 0.70 m, with a height of 1.80 m.

The digging technology

At irregular intervals, it is pierced with inspection shafts: first horizontal, in the cliff of Calcinara-Anapo; these were opened from the watercourse. They are located at variable heights (from 3 to about 20 m), and have dimensions ranging from 1.45 to 1.65 m in width, from 1.20 to 1.50 m in height, from 0.80 to 1.50 m in depth. In addition to the horizontal inspection shafts, the aqueduct is accessible by vertical inspection shafts, more or less rectangular (1.40/1.80 m), circular or trapezoidal, which differ according to the period, and follow one another at irregular intervals, from 25 to 35 m in distance (Fig. 8). First used to dig the gallery, they were then used for maintenance of the aqueduct. In the cliffs of the Hyblaean Mountains, inspection shafts are found to be both vertical and horizontal. This dual opening is due to the difficulty in digging the original gallery. The vertical inspection shaft was used to direct the orientation of the gallery with *dioptra*, while the horizontal inspection shaft allowed not only the evacuation of sizeable quantities of waste with the slightest effort, but also ensured the necessary ventilation to provide oxygen to the men assigned to digging the gallery.

The zig-zag path of the aqueduct testifies to the digging methods used by the builders of the structure (Fig. 8). To assure work teams linked together and to not risk piercing towards the exterior of the cliff, workers dug from one window to another, always working towards the interior of the rock mass. The anomalies identified in the gallery attest to the presence of many errors and failures by the teams in linking together that reflect both digging difficulties and differences in the pace of the workers. Many cavities, already found in other aqueducts, are seen in the walls: they housed oil lamps used to illuminate the gallery during its excavation and later, during maintenance of the aqueduct.

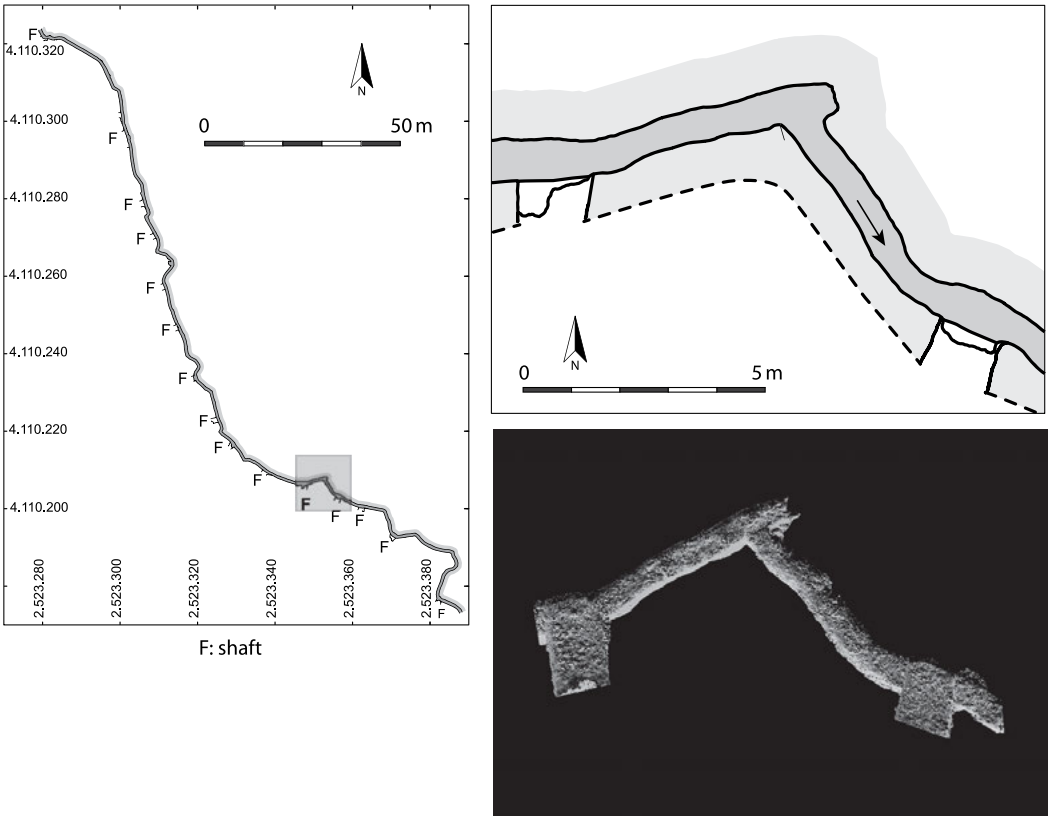

Fig. 8: Syracuse, error of layout in the Bottiglieria branch (by 3D survey).

In Bottiglieria, the aqueduct begins at 198 m above sea level and its outlet in the Nymphaeum is at 57 m. The slope calculated by Cavallari is 0.5 %, which was confirmed by our calculations, but with large variations depending on the location. For example, in the locality of Grottone, its slope varies from −0.87 % to 1.1 % with no logical sequential continuity; while we saw an even more pronounced slope in the Bottiglieria (over 5 %).

A project built in several periods

These technical features of the work show an ancient arrangement: a completely underground route, zigzag galleries, no siphon and a path that follows the contours of the plains and valleys by following a regular slope to promote the proper flow to the city. It is reasonable to return quite far back in time to the creation of this extraordinary aqueduct in the Greek world. But the two catchments do not appear to be contemporary and epigraphic evidence unearthed in their galleries seems to emphasize this.

The inscription of Ciccio, mentioned above, which was damaged by successive coatings that local people applied in the niche, appears to date back at least to the Hellenistic period, if not earlier. At about 50 m from the catchment, the stretch of the Bottiglieria passes through an almost rectangular chamber, with an area of about 3.70 m^2 (Fig. 9). On the south wall, there is a sort of shelf. It is not known if it belonged to the original phase and was a bench, or if it is the remnant of the original level of the area before the hydraulic gallery cut into it. On the northwest wall of the room is carved the relief of a door, surmounted by an architrave more or less trapezoidal, moulded, whose jambs were delimited by a painted red background. Inside the relief, a carved cartridge contains two suspension holes for supporting a *pinax* which would hold an inscription or a lost image, or both. The chronology of this relief can be traced back to

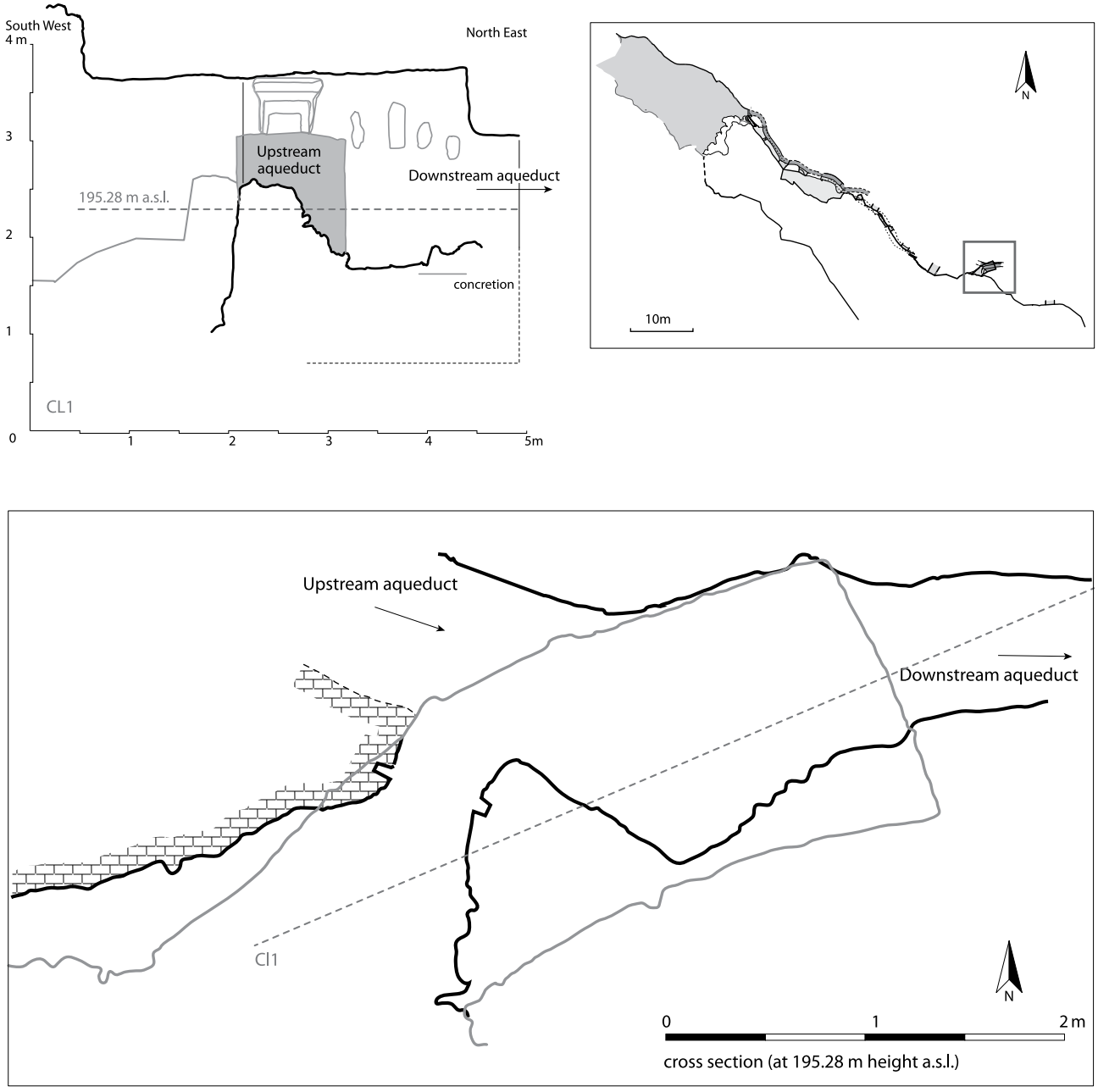

Fig. 9: Syracuse, map and section of the Bottiglieria chamber.

the late 5th century BC, but when compared to reliefs built in regional sites (particularly in the Archaeological Park of Neapolis), it most likely dates back to the Hellenistic period, which allows us to date the aqueduct at the earliest to this era.[40]

Moreover, in this same section of Calcinara, inside the horizontal inspection shafts, at least three hollow reliefs or incised frames have been identified, comparable to *tabulae ansatae,* the dovetail panels that were intended to bear *pinakes* or inscriptions that have now disappeared (Fig. 10). *The tabulae ansatae* are known in Sicily, especially in the southeastern triangle of Sicily, where they bear inscriptions: for example, at Buscemi, close to the aqueduct.[41] They are

40 The function of this small room is far from clear. On this subject, see Bouffier et al. 2018, 313–315; Bouffier 2018, 44–47; Bouffier et al. 2019, 83 f.

41 Manganaro 1992, no. 4. fig. 13.

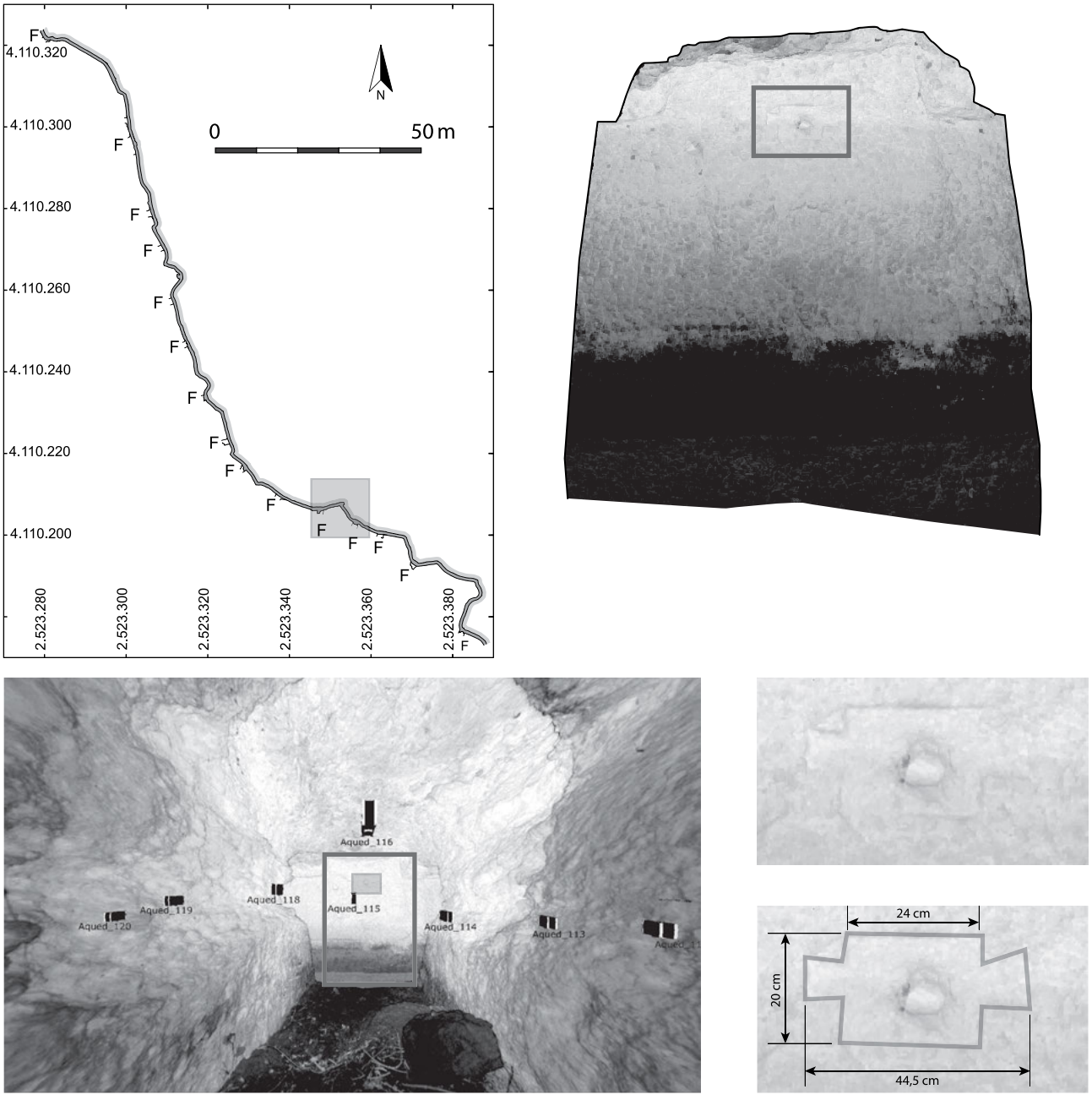

Fig. 10: Syracuse, tabula ansata in the Bottiglieria gallery.

generally used in a funerary or votive context, as shown by that of Buscemi, which offers a dedication to Apollo, Anna and Paides, dated to the end of the Roman Republic (2^{nd} – 1^{st} century BC). These *tabulae ansatae* then become the usual holders of Roman epitaphs until a late period. Their function needs to be clarified here: while they appear occasionally, without recurring regularity, did they have a technical function relevant to the digging or to the rehabilitation of the section concerned? Do they have a topographical indication, letter or number, favouring the identification in the gallery? Whatever their meaning, they indicate to us to an imperial Roman context. It is unlikely, given their location in the hydraulic gallery, that they correspond to religious dedications, although *tabulae* found in the region have a religious or funerary function.

A political will behind the hydraulic programmes

What lessons can we draw then from the renewed study of the Syracusan aqueducts? As it stands, the aqueducts of urban spaces, Ninfeo, Paradiso, Tremilia, offer little historical data, unless one interprets the Greek letters identified in the late 19th century as the marks of a counting system; if this is the case, we can propose that there was a real water policy that needs to be related to a specific time during the urban expansion of Syracuse. The first phase of urban development, as mentioned in the introduction, is that of the Deinomenids, Gelon and his brother Hieron I, who transformed the city into a megalopolis worthy of the great Aegean metropolises, Corinth firstly, but also Athens and Samos, especially as the Aegean context supports this policy.[42] The Greek cities led large hydraulic works policies, known from both literary sources and from archaeology, with fountains and drinking water pipes: in Samos,[43] Athens,[44] Naxos[45] and Megara.[46] In Corinth, the mother city of Syracuse, the Kypselid Dynasty would have constructed aqueducts and monumental fountains, what remains to be proved archaeologically.[47] These often imposing facilities have generally been attributed to tyrannical regimes of these cities between the early 6th or even the late 7th century BC and the years 480/460 BC. According to the philosopher Aristotle,[48] the aim was to put to sleep the aspirations of the people for freedom by providing work and comfort, but in reality, most known aqueducts were designed in ancient cities with booming economies and correspond to stages of monumentalizing urban centres and improving the living conditions, notably sanitisation, of the population. The model for these megalomaniac tyrants, who sought to assert their power and to ensure the sustainability of their power over their people, was the neighbouring Persian Empire, where the Great Kings habitually made the towns under their domination into *paradises,* irrigated areas that hosted fauna and flora from all their empire and appeared as a showcase of their power.[49]

In Sicily, the tyranny is confirmed later in several cities: from the first half of the 5th century BC, autocratic governments pursued expansionary policies that resulted in significant urban and monumental growth. The sovereigns of Agrigento and Syracuse, the Emmenid Theron and the Deinomenid Gelon, respectively, benefitted especially from an extraordinary bonanza, their victory over the Carthaginians at Himera in 480 BC, being the first major dispute between the city of Carthage and the Greeks of the island. This victory brought capital (booty and war indemnities) and cheap labour (prisoners) pouring in. At Agrigento in particular, the ally and also somehow rival of Gelon launched a vast programme of religious and hydraulic construction, well attested both by sources and archaeology:[50] a network of aqueducts, a gigantic pool probably to imitate the Persian paradises, but also to store water in a city with insufficient rainwater

42 Arvanitis 2008.
43 Kienast 1995.
44 Tölle-Kastenbein 1994; Camp 1990.
45 Labrinoudakis et al. 2017.
46 Avgerinou 2019.
47 Landon 1994; Robinson 2011.
48 Arist. Pol. 1313a–b.
49 Briant 1996, 94–96. 214–216.
50 Diod. Sic. 11, 25: *Most of them* [the Carthaginian captives] *were handed over to the state, and it was these men who quarried the stones of which not only the largest temples of the gods were constructed but also the underground conduits were built to lead off the waters from the city: these are so large that their construction is well worth seeing, although it is little thought of since they were built at slight expense. The builder in charge of these works, who bore the name of Phaeax, brought it about that, because of the fame of the construction, the underground conduits got the name 'Phaeaces' from him. The Acragantini also built an expensive kolumbethra, seven stades in circumference and twenty cubits deep* (translation by Oldfather 1970); see also Diod. Sic. 13, 82; Arnone 1952; Furcas 2016; Furcas 2018. According to Giovanni Luca Furcas (oral communication during the conference 'De l'Hydrologie à l'archéologie hydraulique en Méditerranée antique, colloque interdisciplinaire', Aix-en-Provence, 15 mai 2019), Diodorus Siculus is right in considering the conduits as drains and not as aqueducts.

resources and whose population had experienced significant population and economic growth.[51] The city was even described by the poet Pindar as the *most beautiful city of the living*.[52] The building of aqueducts in Agrigento initiated by the Emmenid tyrant encouraged historians to attribute a similar policy to the Syracusan leader, especially as ancient historiography attributed to him a strong international preponderance after the victory of Himera in 480 BC. Most of these major projects were part of an era of urban upheaval that transformed small colonial cities into large urban centres. According to Diodorus of Sicily,[53] and even if we should consider these figures to have been lower, Agrigento would have counted nearly 200,000 inhabitants, of which 20,000 were citizens.[54] Even though we have no figures for Syracuse, we could suggest that it was as densely populated, if not more. The Deinomenid Gelon chose to wipe out a number of rival cities on the eastern coast of the island and deport their inhabitants to the Syracuse site. Faced with Greeks who blamed him for his recent origins, he asserted himself as the spring of Greece[55] and wanted to create a metropolis to rival the great cities of the Aegean world, Athens, Samos and the Corinthian metropolis. He enlarged the city, gave it town planning and a religious architecture capable of embodying his major ambition. The urbanized area then extended from 50 ha to an area which must have been about 250 ha, according to the limits given to the city of the Deinomenids. Ortigia Island, the heart of the old city, was reserved for the tyrant, his relatives and poliades cults, and the source of Arethusa was no longer accessible to the public. We must consider other water resources and the tyrannical context of the period that encourages us to see the establishment of a true water project in the city, as well as that of monumental buildings, which is even easier, given that the Epipolai plateau water table is rich and of good quality. Moreover, it is likely that the two dynasties, who developed many ties, diplomatic and matrimonial in particular, practiced domestic policies of a similar nature. The creation of the Kolymbetra in Agrigento, this reservoir basin in which Agrigento inhabitants would have farmed fish for public banquets and swans for the pleasure of the population, must be understood in the broader context of ostentatious representation by Western sovereigns. I suggest to read this *kolymbetra* as a reproduction of the Persian paradise, set up by the Great Kings in Asia Minor and intended to show the extent of their power. Agrigento is not the only place where the Western Greeks created lush and abundant gardens, as indicated by Athenaeus in his book on luxury.[56] He cites Diodorus of Sicily and even added that the Kolymbetra was built for Gelon:[57]

> *Diodorus of Sicily, in his On the Library,*[58] *reports that the inhabitants of Acragas constructed an expensive swimming pool almost a mile around and 30 feet deep for Gelon; river- and spring-water was diverted into it, and it served as a fishpond and provided large numbers of fish to support Gelon's luxurious, hedonistic life-style. A flock of swans also settled on it, lending it an extremely attractive appearance. Later on, however, it silted up and disappeared. Duris, in Book IV of his On Agathocles,*[59] [says] *that a lovely, well-watered grove is pointed out near the city of Hipponium, and that a spot within it is known as Amaltheia's Horn and was constructed by Gelon. Silenus of Calacte, in Book III of the History of Sicily,*[60] *reports that there is an expensively planted garden near Syracuse called Mythus, where King Hieron conducted his business. The entire area around Panormus in Sicily is referred to as a garden, because it is all full of fruit-trees, according to Callias in Book VIII of his History involving Agathocles.*[61]

51 Bouffier 2000.
52 Pind. Pyth. 12, 1.
53 Diod. Sic. 13, 84.
54 Cf. De Waele 1980.
55 Hdt. 7, 162.
56 Ath. 12, 541f–542a (Translation by Olson 2010).
57 This assertion particularly deserves to be commented on.
58 Diod. Sic. 11, 25, 4.
59 FGrHist 76 F 19.
60 FGrHist 175 F 4.
61 FGrHist 564 F 2.

It is commonplace in ancient historiography to accuse the Western Greeks of engaging in the *tryphè*, this inordinate taste for luxury, or even lust and debauchery.[62] But these indications, which are a hapax in our sources, underline the interest the Deinomenids had for gardens and luxurious parks. The Paradiso aqueduct, whose name may refer to an ancient place name whose meaning has been lost,[63] could be the vector of this lushness, allowing Hieron I, successor of Gelon, to create a kind of paradise garden, like the Greeks created later with gymnasiums in large cities. If the alpha incised on certain covers to these access wells really refers to an inventory of facilities, the Paradiso aqueduct may have been the first investment of a tyrant concerned about his well-being and the ostentatious representation of his opulence and power.

From the Deinomenids to Hieron II: the Galermi aqueduct, a project of the Hellenistic King?

However, the Galermi Aqueduct, currently the best dated, does not go further back than the Hellenistic period, at least for the section of the Bottiglieria, as highlighted by the room decorated with the carved pediment and the minimal repairs in Roman times (the *tabulae ansatae*). Should we look at Hieron II's policies, who came to power around 270 BC, in an island torn apart by centuries-old conflicts with the Carthaginians? Hieron II began the last period of peace for the city, before the intervention of the Romans in 213–212 BC, which marks the end of the independence of the island. He pacified the region, and developed the territorial exploitation of his kingdom, which extended throughout the southeast quarter of Sicily. Cicero, and many contemporary historians after him, attribute to him the *Lex Hieronica* on grain, which taxed the production of cereals and enriched the coffers of the kingdom, while intensifying his relations with Rome, exporting his grain to the Italian capital.[64] On its site, the pacified city was repopulated, economic revival was reflected in the emergence of new neighbourhoods and the installation of crafts, notably ceramics, which require large amounts of water. Hieron II launched major investments in the ancient city, built gigantic monuments: the current theatre, able to accommodate between 14,000 to 17,000 spectators, or an altar dedicated to Zeus Liberator, which occupies a space that has the dimensions of an Olympic stadium, that is, almost 200 m long, and was decorated with gardens. This king blends well into the pattern of the Eastern Hellenistic sovereign, a model known in Egypt, at Alexandria, with Alexander the Great and the Ptolemies, and at Pergamum with the Attalids, who are also responsible for the creation and the beautification of new cities: temples, altars and monumental porticos, gymnasiums and libraries adorn the capitals of their kingdoms. Hieron II is no exception to this tradition. He is surrounded by a court of artists and intellectuals, including the mathematician and physicist Archimedes, who develops for his sovereign and city a number of inventions. Besides the hydraulic screw, that spread to the eastern world, and a gigantic ship so enormous no port could host it,[65] he supposedly imagined ingenious stratagems[66] to keep the Roman army in check during the siege that it led against the city after the death of Hieron II between 213 and 212 BC. Could Archimedes be the designer and great architect of Galermi? Could we then attribute the aqueduct to Hieron II? Although the hypothesis is plausible, we still lack evidence to prove it. Only the niche discovered on the Ciccio catchment could point us in this direction, but the inscription lacks monumentality when compared to those of the theatre dating from the reign of Hieron.[67]

62 See, among others, an article that is always referenced, Nenci 1983.
63 Bouffier 2011, 96–99.
64 Cic. Verr. 2. 3; Carcopino 1914; Pittia 2012.
65 Pomey – Tchernia 2005.
66 Mertens – Beste 2013.
67 Bernabò Brea 1967, 102.

The Romans, who seized the city of Syracuse in 212 BC, also left their mark on the hydraulic installations of the city, although it seemed to become a small provincial town. For now, archaeology has revealed no significant residential areas, and the use of tanks, many in the ancient city, even seems to prove that the aqueducts were no longer maintained or repaired as before. Known for being great water planners, likely to take over water infrastructure and improve, optimize and repair them, they nevertheless left their mark on one of the sections of Galermi, the gallery of the Bottiglieria, as evidenced by the *tabulae ansatae*, unfortunately silent today. The Galermi was, if not expanded, at any rate remodelled and maintained, so the aqueduct must have improved in flow and regularity.

Conclusion

So, to conclude, the recent investigations into the Syracusan aqueducts seem to confirm the implementation of a coherent network of aqueducts during the Greek period. In these conditions, it is difficult to be precise about the period in which it was conceived and done.

The aqueducts of the urban space seem prior to Galermi. One is tempted to attribute the Ninfeo and the Paradiso to the Deinomenids, because of the rough completion of certain sections, because of the incised letters, and because of the name of Paradiso.

However, the extreme technological and human effort that the Galermi represents must have been the work of a team of designers with great scientific and technical skills, such as those observed in the intellectual effervescence of the Mediterranean world during the Hellenistic period from Alexandria to Hieron II's court in the 3rd century BC, with the works of Archimedes in astronomy, his intellectual exchanges with the Alexandrian scholars and his use of instrumentation and mechanisms for thinking about the world. He thus used *dioptra* to measure the universe[68] and there is no doubt that this instrument was decisive in the design of the aqueduct, that had to overcome a large number of topographic and geological barriers. For now, the archaeological evidence is lacking to prove his work on the realization of the aqueduct, but it remains a hypothesis not to be undervalued.

However, one may question the motivations that drove the Syracusans to build this gigantic installation of Galermi. Indeed, it goes from a maximum of 1.5 km of pipes to 27.5 km with the crossing of very important, notably topographic, obstacles. Were the intra-urban aqueducts in poor condition and too expensive to restore? Had the water on the plateau dried up, or decreased? The growth of the city and its economic activities in the Hellenistic period required larger amounts of water, especially for running the ceramics workshops, discovered in several neighbourhoods. Or were there higher quality requirements, as shown by the recommendations of philosophers and hygiene doctors?[69] So many questions to bear in mind in our reflections on the Syracusan hydraulic systems in Antiquity, even if they lack answers.

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68 Di Pasquale 2013, 80 f.; Strano 2013.
69 Plat. Leg. 5, 747d.; Aristot. Pol. 1330b; Hippoc Aer.; Bouffier – Brunet forthcoming.

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