What lessons can be learnt from studying a Roman hydraulic structure in a little village in Southern Italy?
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ABSTRACT

The aim of this paper is to study a Roman hydraulic structure in a little village in Southern Italy in order to learn some lessons from the past and identify potential ideas for implementation. Despite increasing global urbanization a significant percentage of people inhabiting inland areas need critical infrastructure service including water supply systems. The fountain system under consideration in this paper is a good example of a sustainable use of the local territory, which is desirable for modern development of infrastructure. In terms of capital investment and management costs, it is better to try and solve supply issues locally in inland areas rather than to construct mega hydraulic works. During the late Roman Republic, some small inland villagers were obliged to think as well as to act locally. The Roman system investigated here highlights the use of local building elements (and traditional construction techniques) in a sort of ‘zero kilometre’ philosophy.

Key words | cisterns, fountains, galleries, Roman, sustainability

INTRODUCTION

Although one of the principal characteristics of Roman domination was the preservation and respect of the traditions of occupied territories, there was one thing that the Romans disseminated broadly, that is, hydraulic infrastructure. This occurred in both major and minor centres. While the remains of ancient hydraulic structures present in the major cities are widely discussed in current literature, those in smaller cities and villages are often marginalized or forgotten. Study of these hydraulic structures can promote rediscovery of ancient, yet cost-effective solutions to current problems (e.g. water supply). The current global economic crisis has impacted small, inland towns acutely as populations migrate to cities in search of work and consequently abandon little villages. In light of these considerations, this paper focuses on the remains of a hydraulic complex dating from the late Roman Republic period, located in the village of Frigento, in the Campania region of southern Italy. One of the specific aims of this paper is to learn some lessons about the engineering significance and sustainable construction of a small-scale Roman water infrastructure built for the benefit of an inland community.

HISTORICAL FRAMEWORK

The village of Frigento is located in an area known as Hirpinia, which was an ancient Samnite colony. According to legend, during its colonization, a wolf (hippo) appeared among the Samnites. The area was consequently known as the land of wolves (Altheim 1938; Devoto 1951; Alinei 1997). One of the first villages in Hirpinia was Eculano, the ancient name of Frigento. The name subsequently became Fricento or Frequentum in Latin, but it is not known when this change occurred or why. The name may have originated from a volcanic phenomenon characterized by the presence of bubbling sulfur ponds (still extant) that appear to be frying (‘friggere’ in Italian). In addition, it is assumed that the origin may be derived from the Latin frigescere, for the bitter cold that is manifested during the
winter months (Forgione & Giovanniello 2002a, b; Forgione & Fedele 2008).

The Romans during their expansion encountered the Samnites, and the conflict between the two civilizations produced cruel wars that lasted several decades, ending with the eventual defeat of the Samnites. All the territories, Fricento included, were significantly weakened by the long military engagement. Subsequently, Frequentum allied with the Romans to win the war against the population of Marsi (in the so-called ‘Guerra Sociale’, social war, or ‘de Marsi’, 86 BC). In order to thank their occasional allies, the Romans declared Frequentum a Roman Colony as evidenced by the coat of arms consisting of three mountains surmounted by the letters F.R.C. which means Frequentum Romanorum Colonia (Forgione & Giovanniello 2002a, b; Forgione & Fedele 2008).

The Romans constructed important roads, such as the via Appia, during the late Republican period. Cicero passed along the via Appia while leading his troops to Brindisium. Virgil visited the Ansonto Valley between 29 and 22 BC, where he wrote some verses of the Aeneid. Virgil made particular note of the spectacle of mephitis, that is, the emission of mephitic or sulfurous vapours (Aeneid, Book VII, Verses 565 and following). The cisterns investigated in this study were constructed during the late Republican period (probably 86–31 BC). Fricento enjoyed several centuries of prosperity and peace, becoming a coveted tourist destination due to the area’s beautiful environs and healthy air, which are still evident to this day. The entire area was subsequently invaded by barbarians. The arrival of the Lombards in 591 AD led to the reorganization of the territory and Fricento recovered a major role in regional affairs. In 986 AD, a terrible earthquake damaged the urban structure of Fricento. The village’s recovery began slowly in the early decades of the eleventh century. After the Lombard occupation of the Ansonto Valley, the Normans continued to fortify the villages perched on the highest peaks because they were easier to defend (Forgione & Fedele 2008).

In 1496 AD, the village suffered a devastating fire caused by Aragonese looting, and was completely destroyed. After this destructive fire, the village was not rebuilt according to its original form. Instead, the village was reconstructed in a manner typical of ancient Roman camps. The urban scheme was configured with a major street and perpendicular lanes lined with rows of houses. The 15th century planning of the village is particularly relevant in the context of this paper because of the provision for wastewater collection. In the centre of the major street (the so-called square), a channel was located to collect wastewater. In the 17th century, other adverse events occurred such as the plague of 1656 AD, which decimated the population, as well as other subsequent earthquakes. The village of Frigento arrived up to the present day with alternating periods of great prosperity and devastation (Forgione & Giovanniello 2002a, b; Forgione & Fedele 2008).

**GEOGRAPHICAL AND GEOLOGICAL FRAMEWORK**

Frigento is one of the highest villages in Irpinia (911 m above sea level), and is located in a dominant position along a ridge that marks the watershed of the valley of the river Ufita to the north, and the river Calore to the south. Frigento received the epithet of ‘nave’ due to the centrality of its location midway between the Tyrrhenian and the Adriatic Seas (Forgione & Fedele 2008). The importance of its location has been well understood by prehistoric man, since the Palaeolithic age, as highlighted by the discovery of a fragment of the femur bone belonging to a Homo sapiens (Forgione & Fedele 2008). The privileged position of Frigento was ideal for controlling the territory, and apparently also for the sighting of large wild animals such as hippopotamus and elephants that inhabited the valleys below. The numerous pools of water located along the slopes of the hill were suitable for the temporary encampments typical of Palaeolithic man. In this territory, stone tools attributed to the Palaeolithic age, usually made of ‘Pietra di Frigento’, have been found (Frigento’s stone) (Forgione & Fedele 2008).

Due to its complexity, in the site under study, there are lands of different ages and palaeography, which is why the several outcrops visible are defined as ‘Frigento units’. Along the northern sector of the outcrop, at a few metres of relief, there are calcite rudite, marl and calcium siltstone (Fedele et al. 2009). To the east, at a depth of over 100 m, there are lists and limestones with chert nodules (Fedele et al. 2009). These are presented with lists calci lutite gray with dark flint with a thickness of a few decimetres.
(Fedele et al. 2009). There are also limestone and red and green marl silicifere (Fedele et al. 2009). Siliceous shale formations are present in the upper layers. They are clay rich in silica, dark red, characterized by a multifaceted cracking. On siliceous shale soils, there are Flysch Galestrino soils consisting of slow silicifere shales. These formations are the result of a slow deposition in a deep marine environment (Forgione & Fedele 2008).

Frigento stone is made up of a complex heterogeneous marly-calcareous-arenaceous-clay, with varying silicon content. Manganese and iron are the minerals present in the greatest percentages: according to their presence, the shades of the stone vary from gray to black and from yellow to red. The silicon content is responsible for the hardness of the stone, the hardness generally being high. If the clay nature prevails, the stone is virtually unusable because it flakes easily, but if the calcareous component prevails it can be used in the construction sector. The use of this stone, at times so easily fragmentable as to be called ‘dead stone’, was common in the past, since it was not easy to import limestone. If the schist–siliceous component prevails, the stone can be fractured into dihedrals with sharp edges, feared by builders due to the ease with which it procures cuts and abrasions. All these properties ensure a good seal over time, as witnessed by the use of the stone in the construction of the Roman cisterns examined in this study (Forgione & Fedele 2008).

DESCRIPTION OF THE CISTERNS

The structure of the Roman cisterns of Frigento, as shown in Figure 1, consists of four galleries of which only three are partially accessible (galleries ‘a’, ‘b’ and ‘c’). The fourth gallery/tunnel, which is located to the right of the entrance (gallery ‘d’), is almost entirely filled with debris. The accessible part of the galleries is rectangular in shape with a length of about 21 m and a width of 2 m. The vertical walls are approximately 2.50 m high. The galleries are spanned by barrel vaults with a diameter of approximately 1 m. The maximum height of the galleries, including the walls and the barrel vaults is approximately 3.50 m. The floor has a slope of about 1%, which is the same in all three galleries so that the water flows toward the entrance area.

The entire structure is constructed in opus caementicium, consisting of layers of stones cut and used as found in nature, overlapping in a more or less regular pattern. The construction is not so precise as to form a lattice or a geometric design. The non-geometrical use of natural stones is inferred to be intentional so as to avoid creating a preferential pathway for water to leak through gaps or joints between the stones. The stones are interspersed with abundant layers of malta. In particular, pozzolana, a known cementing agent was added to make the construction water tight. The size of the stones employed is 30–35 cm, while the thickness of the wall is about 60 cm. ‘Frigento stone’ was used as the base material. The floor consists of the same materials.

Currently, it is possible to enter directly into gallery ‘a’ through a stairway that was built in modern times. The barrel vaults are perfectly preserved, with clearly visible traces of the wooden ribs used during the vaults’ construction. The galleries are connected by four transverse openings, whose width varies from 46 to 63 cm. The height of the three transverse openings is approximately 1.5 m. The opening located immediately to the left of the entry ladder (situated between gallery ‘a’ and ‘b’) is approximately 2.60 m high. The adjacent galleries are connected by two passages that open along the common wall. However, in the wall of the inaccessible gallery, a passage exists which is partially walled and from which it is possible to observe the debris that blocks the entrance. The arches of these openings are made of squared travertine blocks. In gallery ‘b’, just to the left of the entrance, there is a ventilation opening. Along the wall near the staircase that separates the two galleries (‘a’ and ‘b’), there is a channel with a diameter of 10–15 cm where the spring water flows with a flow-rate of 0.1–0.2 l/s. The water is collected in a sump where a pump raises and carries the water into the modern sewerage system. Along the walls that separate the various galleries, near the end (north direction), there are ventilation holes (about 10 × 15 cm).

In the west side gallery (‘c’), the second left of the entrance, on the perimeter wall there are orthogonal masonry elements whose height is equal to that of the vertical elements that support the barrel vault, with projections into the gallery of 90 cm. These masonry elements may serve as buttresses to counteract the force of gravity. It is
Figure 1 | The investigated Roman hydraulic structure in Frigento, Campania region Southern Italy.
possible to observe a distinct difference in materials between the wall and the vertical semi-circle that closes the barrel vault on the final transversal wall. This unique feature cannot be attributed to a possible reconstruction since the same feature is present in the other galleries.

The presence of the transverse walls that do not reach the vault suggests that they were constructed to create a sort of tank. The tank may have had two purposes, namely to prevent water flowing to the bottom of this gallery or to create a basin to store falling snow during the winter months (the so-called ‘nevere’). This gallery was certainly suitable for the latter purpose due to its situation adjacent to and in direct contact with the embankment, thereby maintaining a colder temperature than the top soil. As stated by de la Peña & Salgot (2009a, b), in the warm Mediterranean countries, artificial facilities were needed to store compacted snow or ice blocks during the winter for subsequent use in the warm summer. Ice and snow used to be stored in small buildings (ice houses) or in underground chambers or ice wells. During the winter, ice and snow were preserved in these purpose-built facilities and packed with suitable insulation such as straw or sawdust (de la Peña & Salgot 2009a, b).

On the southern part of the gallery ‘c’, closest to entrance, there is a transverse wall constructed subsequent to the late Republic period. On this wall there are several square shaped holes with dimensions of around 10 × 15 cm, located at about 90 cm above the floor and penetrating to the interior of the gallery. They are similar to those found along the longitudinal walls separating the galleries. The purpose of this system may have been to create a sort of bath that could act as a reserve from which water could be drawn from above by a bucket or other container attached to a rope.

In the vault of gallery ‘c’, there are several holes due either to natural erosion or man-made by those curious to observe what the galleries contained. They are irregularly shaped and are not large enough to allow a bucket or container collecting water to pass. These holes are blocked by large white rocks. One of these holes is nearly circular shape with a diameter about 70 cm. This hole may have been created specifically for collecting water in the tank. Presently, this hole is covered by the surrounding terrain. Finally, there is another square hole that is clearly a well of about 2 m, whose interior consists of stone and mortar, with the same construction technique that characterizes the whole structure. The tops of the galleries are protected by an iron grating, with vegetation that grows above the structure.

The inaccessible part of the three galleries continues for another 13–14 m in the same north–south direction. The elevation of the floor of this room is 3.70 m above ground level. Consistent with the accessible part of the structure, the slope constantly descends in the direction toward the street where the old conduit is located. The galleries have a length of about 33–34 m, along the longitudinal axis which is approximately in a north–south direction.

The water collected in the galleries was directed via an old conduit of which some sumps and stretches have been found. In particular, the water arrived first in a sump from which two opposite channels travelled east and west. The tops of the galleries are located about 908 m above sea level. However, the galleries are situated entirely below the road surface, therefore the altitude of the gallery floor is 904.7 m above sea level. The road on the stretch heading west is about 30 m from the sump closest to the ancient cistern; and is at an altitude of 907 m above sea level. The bottom of the channel is 3 m below the road on the stretch heading west and therefore is at 904 m above sea level. The branch directed towards the east is much steeper. The sump is 902 m above sea level; the bottom of the conduit is 899 m above sea level. Through this conduit, the water was conveyed to distribution and collection points. This configuration supports the hypothesis that the tank served as a collection and distribution system. The closing transverse walls that limit the accessible part (about 21 m) from the inaccessible gallery (approximately 12–13 m) were possibly constructed at a later date, and their construction may have coincided with the construction of the staircase. The reason why the galleries were barred at some point in their length is not known. It is probable that over time, the structure lost its original function but continued to serve as a collecting (old function) and storage (new function) facility for water. The stairs (and the entrance) were probably built in order to facilitate the withdrawal of water. The cross walls were built because there was a need to create a foundation for the building constructed above the initial part of the complex of Roman cisterns.
There is no information about the end points of the conduit carrying the water from the ancient Roman galleries. It can be assumed that the water flow was directed toward public fountains (still extant in the inner city), and to meet the water needs of the local population. It is also possible to hypothesize that water flowed toward the wells located in the courtyards (still extant) of large ancient tenements. The water-carrying conduit has a rectangular section and is covered with the remains of ancient bricks, known as bipedals (square bricks placed in a Capuchin manner in order to form two slopes on the canal that they had to cover), which are typical of Roman architecture.

**THE FOUNTAIN SYSTEM**

The siting of the Roman cistern of Frigento illustrates the skill of ancient populations to observe, study and understand the phenomena around them and exploit these phenomena to their advantage (Laureano 2003).

This site was chosen because in the summit area of the promontory there was an opportunity to draw clean water from a rock that crumbled easily, and which produced cavities filled by spring water. The quantity of the groundwater at those times may have justified the construction of the cistern (Forgione & Giovanniello 2002a, b).

The galleries were fed by spring water, rainwater, and by the melting snow that fell abundantly during the long winters. During the visits to the galleries during both dry and wet periods, the authors observed that the pumping station operated more frequently during the spring season due to abundant rainfall (as opposed to infrequent operation of the pump during dry periods).

The abundance of underground water is due to the particular soil stratigraphy. Below a layer of backfill of 1.10 m deep, there is about 1 m of severely fractured marly limestone benches which permit the circulation of water. Below these benches there is a layer of about 2 m of both silty sand and sandy silt. Moreover, benches of calcareous marl lithoid alternate with silty sand to create lanes in which water can flow from where it is trapped. Globally, due to the tectonic movements which the area has undergone during geological periods, there is a large solidified clay component.

In light of the above, it is possible to understand why the area is full of small perennial and seasonal springs, mainly located along the slopes of the headland, some of which are located at the points where natural *impluviums* converge. These springs were exploited in the past by means of fountains and wells, both in the inner city as well as in the outlying areas of the village where agricultural and livestock activities were widespread.

The fountains in this area are mainly characterized by a supply system consisting of a well or tank (the so called ‘*conservae*’, approximately meaning ‘reserve’) placed behind the fountain in a place located in the immediate vicinity, with an altitude greater than the distribution point (fountains, etc.). Thus, the water reaches the terminal point by gravity. The ‘reserve’ has the task of capturing the water table and collecting rainwater, acting as a reservoir or tank which feeds the fountains through pipes or drainage paths.

**LESSONS LEARNED**

As a result of the authors’ field observations, several conclusions can be drawn. The late Roman Republic period construction highlights the use of local building elements (i.e. the Frigento stone) in a sort of ‘zero kilometre’ philosophy. This means that the Romans privileged the use of local materials in order to minimize transportation costs.

People in the past were masterful in employing traditional techniques which had been developed and improved over time, and passed down from generation to generation. For instance, traditional techniques were employed in the construction of the barrel vault. The barrel vault, typical of the Campania region, was constructed by shifting the centring (made up of wooden ribs and wedges) to allow small movements along the length of the vault. The hydraulic structure of Roman construction studied here included several aeration holes. These holes were created in order to preserve the organoleptic characteristic of the collected and stored water. Ancient works are often forgotten and neglected especially in little villages. In this case study, a structure has also been built above the Roman galleries. This kind of structure has to be evaluated in terms of sustainable tourism. Notably, many discoveries occur during the excavations that precede the construction.
of modern works, i.e. pipelines, as in the case considered here. The fountain system of Frigento, as shown in Figure 2, is a good example of a sustainable use of the territory. This is especially relevant for inland areas where it is more cost effective to solve water supply issues locally. Local solutions to water supply issues can result in fewer environmental

Figure 2 | The fountain system of Frigento, Campania Region, Southern Italy.
impacts. The Romans of the late Republic were obliged to think as well as to act locally. It is amazing to observe how, over the millennia, a work originally created to fulfil a certain function may dramatically change its purpose-built use, often due to the need to respond to emergency needs (e.g. water supply after catastrophic events such as earthquakes, floods, wars, etc.). Even the study of these events may provide an opportunity to learn from the past in order to avoid repeating the same mistakes in future.

ACKNOWLEDGEMENTS

The authors wish to thank the Superintendency for Archaeological Heritage of the provinces of Salerno and Avellino, Dr Sacha Anthony Berardo and Ms Meisha Hunter for their English revisions to the text, as well as the comments of an anonymous referee.

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First received 12 May 2012; accepted in revised form 13 August 2012