First results of a study of the Etruscan tunnel and other hydraulic works on the Ponte Coperto stream (Cerveteri, Rome, Italy)

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ABSTRACT

The Etruscan tunnel called Ponte Coperto is located NW of Rome, near the town of Cerveteri. The Ponte Coperto tunnel, mapped for the first time during the present research and dug mainly in volcanic tuff lying below the lava flow, was built to drain a valley of about 8.5 km², probably between the VII and VI century B.C. Before the tunnel construction, part of the valley was occupied by a swamp, whose reclamation was carried out by digging a long rectilinear canal of about 800 metres to the tunnel opening. Several hundred metres upstream of the tunnel entrance a secondary canal flows into the main one; this tributary canal drains a secondary valley, next to the principal one. Nowadays the Ponte Coperto tunnel, 170 m long, looks much larger than its original shape due to natural erosion that has widened and deepened it: during the dry season its discharge is negligible, but some calculations show that the peak discharge can be in the order of several dozens of cubic metres per second. The efficiency of the Ponte Coperto system is outstanding, as the hydraulic setup of the area is still that left by the Etruscans engineers more than two millennia ago: the tunnel and the canals keep draining both the surface and the ground waters from the more permeable rocks, and the valley is still healthy and cultivated. The Ponte Coperto system is a good example of the fact that Roman water engineering has its roots in Etruscan technology.

Key words | Cerveteri, Cisra, cuniculi, Etruria, history of hydraulics, reclamation, tagliate

INTRODUCTION

The aim of this paper is to present the first results of a study regarding the Etruscan hydraulic works which reclaimed the basin of the stream called Ponte Coperto (“Covered Bridge” in English). The catchment (Figure 1) is near the town of Cisra, the ancient Etruscan name of the modern town of Cerveteri (Bonfante & Bonfante 2002), at about 50 km NW of Rome, a few kilometres from the Tyrrenian coast. The Ponte Coperto hydraulic system consists of a main tunnel, a long canal plus some minor works; the system is mentioned by various authors but has never been studied in detail (Judson & Kahane 1963; Busana & Basso 1997; Quilici & Quilici-Gigli 2000). As it is known the Etruscan civilization flourished in central Italy from the VIII century B.C. onwards (for example: Starr 1975; Barker & Rasmussen 2000; Haynes 2005; Torelli 2005). In the history of technology the Etruscan civilization is important for its hydraulic technology, which had its roots in the near East, was passed on to the Romans who, after absorbing the Greek achievements, developed it to such an extent that it became one of the characteristics of Roman civilization. The Roman hydraulic technology, spread all over the Roman Empire, survived the collapse of the Empire and...
remained throughout the Middle Ages and the Renaissance as the reference point for most of the important hydraulic works built during two millennia. Practically the Roman hydraulic technology, directly descending from the Etruscan’s, remained unsurpassed till the end of XVIII A.C. (Castellani & Dragoni 1997). The Etruscan capability for water and land management is demonstrated by the existence of an imposing number of land reclamation
works (tunnels and canals) spread over their territories of Latium and, to a lesser amount, of the other Etruscan areas (Judson & Kahane 1965). Etruscan territories are often of a volcanic origin, constituted mostly of tufs and, more rarely, of lavas. The region has a fairly high rainfall (at present around 800–1,000 mm/year), the volcanic landscape is characterized by closed depressions, due to volcanic craters and lava flows that intersect and block pre-existent valleys; all that, coupled to the low permeability of the paleo-soils, often present between a tuff layer and the other, made the area naturally humid, with frequent swamps and soils too wet for cultivation (Judson & Kahane 1965).

The typical Etruscan land reclamation system is constituted by a set of tunnels and canals that drain subterranean and surface waters and channel them. The tunnels having a small section are known as *cuniculi* or *cuniculus* (singular); the typical width and height of a *cuniculus* being around 0.5 m and 1.75 m respectively). The Etruscans reclaimed whole valleys, drained lakes and swamps and obtained agricultural cultivation in areas where the water table naturally surfaced or was too close to the surface. The total length of these reclamation works, which have only partially been discovered and studied, is of the order of at least one hundred kilometres. The tunnel *Ponte Coperto* is the final part of one of these land reclamation works. For an in depth discussion on Etruscan reclamation works, on the *cuniculi* and on the not unanimous opinions about their functions, the interested reader is referred to the vast literature on the subject (for example: Judson & Kahane 1965; Ward Perkins 1963; Ravelli & Howarth 1984; Potter 1985; Ravelli & Howarth 1987; Castellani & Dragoni 1991; Bergamini 1992; Castellani 1999; Quilici & Quilici-Gigli 1999; Quilici & Quilici-Gigli 2000; Bersani & Castellani 2005; Zapicchi 2006). Many of the listed studies consider the area of Cerveteri, which is exceptionally rich of Etruscan hydraulic works.

**GEOGRAPHICAL AND GEOLOGICAL SETUP OF THE AREA**

In describing the geographical and morphological setup of the area we shall refer to Figure 1, and in giving the names of the streams we shall use the Italian term *Fosso* (stream, little river) as reported on the Italian maps. The *Ponte Coperto* tunnel drains the homonymous stream which, upstream of the tunnel, has a catchment area of about 8.5 km². The *Ponte Coperto* basin has an elongated shape on the North-South line, a length of about 7 km and an average width of about 1.2 km. The average altitude of the basin is 225 m asl, whilst its maximum altitude is 310 m asl near the Poggio Molare relief, on the northern boundary of the catchment. The stream length is of about 6,800 m, measured from near Mount Uomo Morto to the end of the tunnel, whilst its average slope is 1.7%. The stream, even if with a flow of only few litres/s during the summer, is perennial, the water flow being sustained during the dry season by groundwater. The stream drained by the *Ponte Coperto* tunnel is known as *Fosso dell’Aspro* in the northern part and *Fosso Cupinaio* further South; the stream takes the name of *Fosso di Ponte Coperto* after it merges with the *Fosso Fonte dei Santi*, its largest affluent which is about 1 km North of the tunnel entrance. For the area here considered, different authors give different estimates of the yearly average rainfall, which appears to be between 800 and 1,100 mm/yr (Boni et al. 1988; Ventriglia 1988, 1989). Such values are rather high for the Mediterranean area, especially when so close to the sea. The closest pluviometric station is at Lake Bracciano (about 2 km upstream of the basin), where a good set of rainfall values, since the first decades of 1900, is available: this allows carrying out some estimation of the peak discharges in the area’s streams. According to our field investigations and to the published geological maps, the outcropping rocks are Pleistocene volcanic tuffs and lavas, produced by the Sabatini Volcanic Apparatus (Servizio Geologico d’Italia 1967; APAT 2004). In particular about 80% of the basin surface is covered by tuff (phonolitic-trachytic ignimbrite), of a consistency going from lithoid to almost uncohesive: the two types are known respectively as Peperino and Pozzolana. This tuff can reach a total thickness of 30 m. In the zone where the *Ponte Coperto* tunnel was dug the tuff, practically horizontal, is covered by a very hard tephritic-leucitic lava flow. This rock is traditionally used for making paving stones (Sampietrini and Bastardoni); an old quarry, with a vertical front of about 10 m, is still visible a few metres from the downstream exit of the *Ponte Coperto* tunnel (Figure 2). According to our reconstruction, the lava flow dams the valley, so that
previous to the building of the tunnel, upstream of the lava flow there was a shallow lake or a swamp, which flowed downstream over the lava, through a small waterfall or a rapid. The tunnel (dug into the tuff with the lithoid consistency) produced the following effects: a) the lake dried out and made new land available for agriculture; b) the tunnel became a sort of road bridge, still in use two millennia later (a modern road passes on top of it); c) the draining of the swamp probably had healthy effects on the inhabitants of the area, as since at least the V century B.C. the swampy places in the Tyrrhenian coast were affected by Malaria (Hays 2006).

**THE HYDRAULIC WORKS**

The hydraulic works in the basin of Ponte Coperto are all part of the same project, which aims at draining and reclaiming the land of the southern part of the catchment. The main reclamation works were a deepening and straightening out the bed of Fosso di Ponte Coperto, and the two tunnels: Ponte Coperto and that on the Fosso Fonte dei Santi (Figures 2 and 3).

Upstream from the entrance of the Ponte Coperto tunnel, for almost one kilometre, the natural bed has been carved into a large artificial trench that has straightened and deepened the natural stream, which, in the last part, was deviated in order to be conveyed into the tunnel (Figures 1, 2 and 4). This type of trenches are common in Etruscan territories due to the ease with which tuff may be dug while, at the same time, the trenches keep their shape stable even with very steep walls. These trenches are known specifically as Etruscan tagliate (tagliata if singular); the tagliate were used for roads or canals. In our case the tagliata lowers the stream bed, bringing it towards the tunnel; at the same time it drains the layers of tuff and lava thereby lowering the superficial water table. That helps to
maintain the soil dry for cultivation. The distance from the tunnel's entrance to its exit is 170 m, but originally, as a recently collapsed portion just upstream of the tunnel's entrance indicates, it was at least 30 m longer (Figure 5).

The other works in the basin are the cuniculi of the Fosso Fonte dei Santi, described further on, and a few other cuniculi reported in Figure 1.

Ponte Coperto Road runs over the tunnel, as did an old Etruscan road that followed the same route, permitting communications between Cerveteri and the near Etruscan town of Veio (Quilici & Quilici-Gigli 2000). Remains of a paved road and support walls made of rectangular blocks, probably belonging to a bridge were found just upstream of the tunnel of Ponte Coperto. We found, upstream of the confluence with the Fosso Fonte dei Santi, remains of rectangular blocks, not hitherto mentioned in the literature, probably belonging to the supporting walls of a bridge on the main course of Fosso di Ponte Coperto, (Figure 4). The Ponte Coperto tunnel was dug without any intermediate shafts. The map of the tunnel indicates, as usually happened, that two teams dug the tunnel, one starting downstream and one upstream, following a technique often used in the ancient world to favour the meeting of the two teams: the two teams met in the central tract by swerving the digging towards the same direction, in this case towards NW (Castellani & Dragoni 1991; Kienast 1995; Castellani 1999). Nowadays the difference in altitude between the entrance and the exit of the tunnel is about 4.5 m of which 3 m are in the first 48 m (Figure 1).

The tunnel has withstood considerable floods for over two and a half millennia: at present this is shown by the presence of large tree trunks and the remains of a car inside the tunnel. On the basis of morphometric and geological data and the Rainfall Intensity-Duration Curve for the area, estimated from the historical Bracciano series, various empirical formula for estimating floods show that the Fosso di Ponte Coperto can have peak discharges over 50 m$^3$/s. Time and floods have deeply eroded the floor of the tunnel, and erosion has been estimated to be about two metres at the entrance of the tunnel and even more further downstream: indeed a deepening of about two metres is also visible for several hundred metres on the floor upstream of the entrance to the tunnel. Currently the entrance to the tunnel is about 5.8 m high and about 4 m wide: it is probable that the original dimensions where in the order of 3.5–4.0 m high and 3.0–3.5 m wide.

This estimate is on the basis of an original portion of the vault which has survived, and on the position of two small cuniculi on the hydrographic left, just upstream of the tunnel and of what are probably remnants of the original floor. (Figures 2, 6 and 7).

The height of the tunnel stays around 3–5 m (Figure 8) until it reaches a large chamber in proximity to the exit (Figure 9). Currently the tagliata upstream of the tunnel’s entrance is 12 m wide. Next to tunnel's entrance begins another short tunnel, which is 3.1 m high and 3.6 m wide. This secondary tunnel swerves and merges into the main tunnel after a few metres (Figures 5 and 7). The reason for this second short tunnel, which houses a portion of original vault, is unknown. The minimum thickness of the rock of
the vault can be estimated to be of around 9 m. At the exit of the tunnel the ruins of a large wall lie, built out of lava blocks (Figures 1, 9 and 10). According to Quilici & Quilici-Gigli (2000) the wall is probably the ruin of a Roman dam of the late republican or imperial era. However the perfect conservation of the plaster makes this dating dubious and, in our opinion, it should be confirmed by some further evidence. In any case, considering the thickness and the shape, there is little doubt that the wall served to store water during the dry summer months, inside the large exit chamber, and it is likely that the reservoir was used and plastered until recent times. Figure 1 and the sketch on Figure 3, taken from the field note book, shows that the tunnel of Fosso Fonte dei Santi is the end part of this stream, which merges with the Fosso di Ponte Coperto, known as Fosso di Cupinaio in that tract. The tunnel is about 50 m long but probably, originally, downstream it was a few metres longer. Figure 11 shows the vault can be estimated to be of around 9 m. At the exit of the tunnel the ruins of a large wall lie, built out of lava blocks (Figures 1, 9 and 10). According to Quilici & Quilici-Gigli (2000) the wall is probably the ruin of a Roman dam of the late republican or imperial era. However the perfect conservation of the plaster makes this dating dubious and, in our opinion, it should be confirmed by some further evidence. In any case, considering the thickness and the shape, there is little doubt that the wall served to store water during the dry summer months, inside the large exit chamber, and it is likely that the reservoir was used and plastered until recent times. Figure 1 and the sketch on Figure 3, taken from the field note book, shows that the tunnel of Fosso Fonte dei Santi is the end part of this stream, which merges with the Fosso di Ponte Coperto, known as Fosso di Cupinaio in that tract. The tunnel is about 50 m long but probably, originally, downstream it was a few metres longer. Figure 12 shows 19 m, and ends up in the Fosso Fonte dei Santi; this appears, at least in the initial tract, to have been artificially enlarged. This tagliata was clearly made with the aim of conveying the waters of the Fosso Fonte dei Santi, and of the overlying land, into the Fosso di Ponte Coperto. The dimensions of the tunnel of Fosso Fonte dei Santi are probably similar to the original ones, thanks to the gentle slope and to the limited extension of its watershed (about 1 km²): these characteristics produce only limited peak flows, having a low erosive capability. It appears that the purpose of all the works on the Fosso dei Santi is to drain the undulated plains on the orographic right of the water divide of the Fosso di Ponte Coperto. The water divide is approximately located where the shaft of the Fonte dei Santi tunnel was dug.

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on the ceiling vault of the tunnel a shaft, considerably widened by erosion (the shaft is reported also in the sketch of Figure 3). Upstream from the shaft the tunnel has a length of about 19 m, and ends up in the Fosso Fonte dei Santi, this appears, at least in the initial tract, to have been artificially enlarged. This *tagliata* was clearly made with the aim of conveying the waters of the Fosso Fonte dei Santi, and of the overlaying land, into the Fosso di Ponte Coperto. The dimensions of the tunnel of Fosso Fonte dei Santi are probably similar to the original ones, thanks to the gentle slope and to the limited extension of its watershed (about 1 km²): these characteristics produce only limited peak flows, having a low erosive capability. It appears that the purpose of all the works on the Fosso dei Santi is to drain the undulated plains on the orographic right of the water divide of the Fosso di Ponte Coperto. The water divide is approximately located where the shaft of the Fonte dei Santi tunnel was dug.

**FINAL CONSIDERATIONS**

The results here presented are only preliminary as all the surveys were carried out only by compass and tape, and are far from exhaustive. However these results suggest the following considerations.

- The time when the work was built is unknown, but considering similar works nearby and the fact that Cerveteri was at its maximum splendour between the VII and VI century B.C., one can presume that the work is of that period or later.
- Figure 12 helps imagine what the area would have looked like without the Etruscan works: the photo shows a small lake, which lies about one kilometre downstream from the Ponte Coperto tunnel, which was created probably by blocking up an Etruscan *cuniculus* or tunnel in a tributary of the Fosso di Ponte Coperto. This
cuniculus is reported in Figure 4 of a paper by Judson & Kahane (1963), where it is identified with the number 4; the authors do not report and do not mention the lake, which was therefore presumably created after the paper by Judson and Kahane was written. It is clear that, without the Etruscan works here described, the landscape would be quite different, and it is also clear that the main purpose of these works was to reclaim the land.

- The efficiency of the Ponte Coperto system is outstanding, as the hydraulic setup of the area is still that left by the Etruscans more than two thousands years ago: the tunnel and the canals keep draining both the surface and the ground waters from the more permeable rocks, and the valley is still healthy and cultivated as the Etruscan engineers wanted it to be.

- The precise function and topography of most of the minor cuniculi of the Ponte Coperto basin remains unknown and will probably stay so for a long time, as the minor cuniculi are mostly collapsed, full of debris and not practicable: it appears unlikely that it will be possible in the near future, due to lack of funding, to start extensive geo-archaeological and geophysical investigations that could give more information. However it would be possible, even through further traditional field surveys and investigations, to gain further information on the overall significance of the Etruscan hydraulic works. These ought to be studied also considering climatic changes, which have occurred in the past three millennia. It is very probable that these works were carried out when the climate was colder and rainier than now (Dragoni 1998). Currently we are going towards a new arid phase (cf. for example IPCC 2007; Dragoni & Sukhija 2008) and it is possible that in order to store water these works may be voluntarily blocked up. Considering the beauty and the importance of the subject, this process should be guided in a rational way and not left entirely to private initiative.

- A technical investigation would be appropriate to verify the general state of the Ponte Coperto tunnel, from the point of view of safety. As we have already mentioned, the tunnel is subject to intense erosion and a modern road runs over it, carrying loads that were not conceivable when the tunnel was built, even when its overall state was quite different from today.

Figure 11 | Shaft in the vault of the Fosso di Fonte dei Santi tunnel. The shaft appears to be strongly enlarged, and presumably the debris has been cleared out artificially in the course of the centuries in order to keep the system working.

Figure 12 | Small reservoir on an influent of Fosso di Ponte Coperto, probably made by blocking an Etruscan tunnel. At this stage the authors were not able to inspect the place.

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