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Technical observations about a possible new portion of the *Aqua Iulia* Roman aqueduct in the municipality of Ciampino (Italy).

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Abstract. An intersection of two roman *glareatae* roads and an underground stretch of a Roman aqueduct (*rivus subterraneus*) were found in the locality of Colle Oliva, during an emergency archaeological investigation (between 11/2018 and 3/2019). The aqueduct has been detected in several test trenches and some profiles have been obtained. These data shade some light about the Roman hydraulic technology and they show how the land morphology affected the shape and the path of the aqueduct.

1. Introduction

The aqueduct was discovered on the northwester slope of a low hill called *Colle Oliva* (fig. 1). A Villa, which has been dated from Roman Republican to Imperial age, stands at the top of the hill (Blanco et al., 2013). The

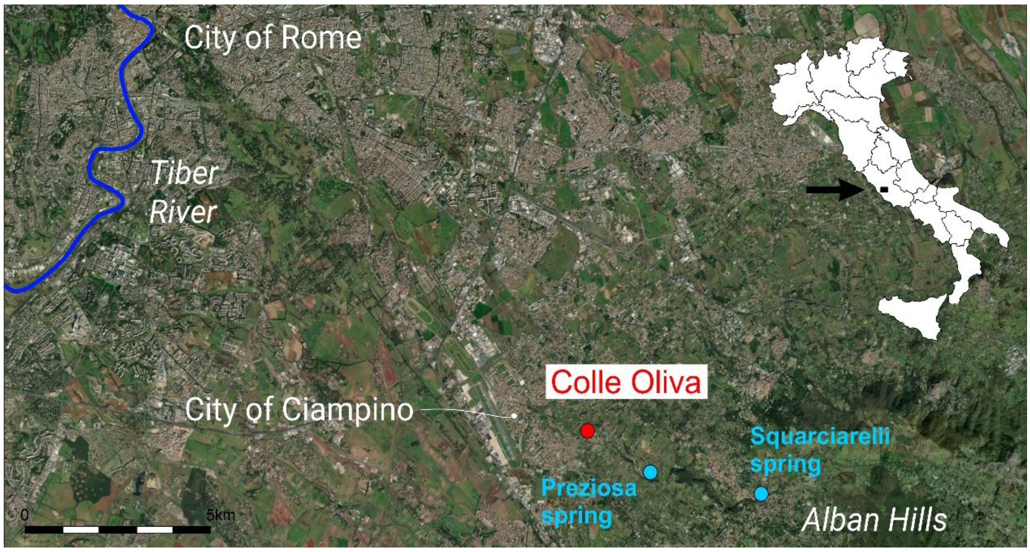

Figure 1. The Colle Oliva aqueduct and the possible taken resurgences in the Alban Hills, according to the *Frontino*'s *De aquaeductu Urbis Romae* (I century BCE)

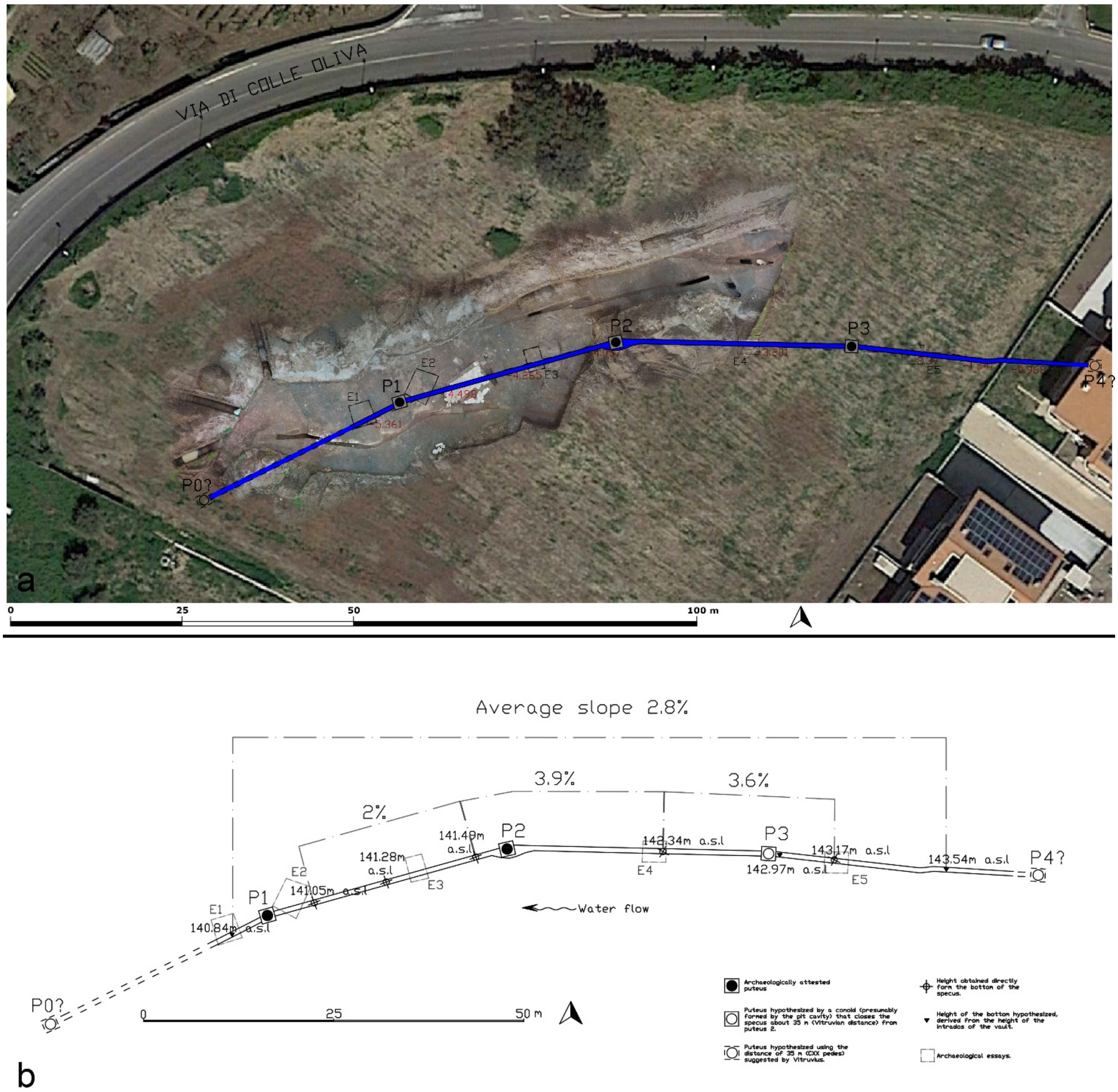

Figure 2. The aqueduct path. a) Aerial view; b) Slopes. E, archaeological essays; P, *puteus*

area is located on the passage line of two important aqueducts of republican age, *Aqua Tepula* (125 BCE) and *Aqua Iulia* (33 BCE) which diverted water from the Alban Hills natural springs to Rome (fig. 1: Squarciarelli and Preziosa, respectively) (Lanciani, 1880; Ashby, 1935; Panimolle, 1984; Blanco and Sebastiani Del Grande 2019). The ancient Via Cavona is running few hundred metres to the East (Aglietti, 2000) crossing the Via Latina *ad X miliarium* (De Rossi 1979; Pancotti 2012), about 1 km to the North.

2. Methods

With regard to the setting up of the survey it is necessary to point out some details:

- The points on the body of the aqueduct were surveyed with a Leica TCR 805 Power total station using the impulse rangefinder integrated in the instrument itself.
- Where possible, the points were collimated by both stations, both to improve the estimate of the plano-altimetric positions of the points themselves and to improve the reliability of the relative orientation of the two stations.

Figure 3. a) The *specus*; b) the *puteus* P1

- Some points could only be collimated by one station and therefore it is not possible to verify their accuracy and estimate their variance.
- The GNSS receiver has detected only the two points stationed with the total station, allowing on the one hand to verify the correct relative position of the two stations, and on the other hand to position and orient the entire network detected with the total station in the reference system of the GNSS network of support, which in this case is RDN2008, EPSG:7792 (EPSG, 2021)

It can be deduced that the relative positions of the points have their own accuracies of the total station alone, which, over such short distances, certainly have values of less than 2 cm. The slopes and the other quantities that we have estimated for the hydraulic reconstruction of the aqueduct are calculated only based on the relative measurements and therefore have the indicated accuracies.

As far as the position and the absolute orientation of the aqueduct are concerned, the GNSS measurements and the correction of the geoid model indeterminacies have to be also considered. The former can be estimated considering the distance from the nearest stations of the Lazio Region GTNSS network (Lazio Region, 2021), the latter we have already mentioned to be around 2.5 cm (Barzaghi et al. 2007), which leads to conservatively consider an uncertainty of about 5 cm in planimetry and about 8-10 cm in elevation. The absolute heights on the bottom of the specus and on the intrados of the vault, inside the *specus*, were obtained using a Leica TCR 805 Power total station from two points stationed with a Topcon Legacy/e dual-frequency GNSS receiver (around 1 cm accuracy). The orthometric heights were estimated by applying to the value measured by the GNSS the undulation estimated by the ITALGEO 2005 model (2.5 cm accuracy) using the official algorithms implemented in a specific package realized by Sapienza (Baiocchi et al. 2017).

3. New data

The identified aqueduct stretch is about 100 m long (fig. 2). The water flowed from East to West. It was directly excavated both in the so-called Villa Senni Eruption Unit (VSEU) and in the Pozzolane (Giordano et al., 2006; Watkins et al., 2002), 4/5 m below the present-day surface.

Where the softer Pozzolane were encountered, the sides were lined and reinforced with an *opera incerta* wall. The specus was 0.55-0.60 m large and between 1.50 m e 2.10 m high (fig. 3a). The *specus* sides and bottom were lined by hydraulic mortar, both in the stretches excavated in the VSEU or reinforced by the *opera incerta*. The mortar was around 3 cm thick and installed up to 1.20/1.50 m from the bottom. The latter was characterised by two parallel kerbs, one each side, around 12 cm wide. Three inspection pits (*puteus*) have been found at 35 m from each other. One of them, with a rectangular plan (0.75x0.60 m), was also visible on the present-day surface and internally lined with an opera reticolata (*opus reticulatum*) wall (fig. 3b). The average calculated slope of the specus bottom was about 2.8%. The slope was irregular and varied between one *puteus* and the other. In fact, in the straight portion of the aqueduct the slope was almost 4%, between *puteus* n. 3 and n. 2, while suddenly decreases to 2% between the *puteus* n. 1 and n. 2 (fig. 5).

4. Discussion

The aqueduct might be identified with the *Aqua Tepula* (125 a.C.) or *Aqua Iulia* (33 a. C.) (*Front.*, *De Aquaeductu,* 8, 9). The *opera reticulatum* walls, which characterise the late Republican period, and the distances between the *puteus*, which equals the suggested distance of 120 Roman feet by *Vitruvio* (*De Arch*. VIII, 6, 3), who lived when the *Aqua Iulia* was realised, preferably point to the second hypothesis. Some observation may be made about the design of the aqueduct.
The main purpose of the *puteus* was to regularly check the specus and to clean it where necessary. However, as it seems clear from the figure 2 they were also used as pivot points to determine the aqueduct path: a significative change in direction of the latter can be indeed observed at each of them.
The slope is much greater than the usual slope for the aqueducts over the arches (*in opere arcuate*) which varies between 0.1% and 0.2% (Alimonti et al., 2018; Alimonti et al., 2021; Corbellini et al., 1917). This difference might be due to the different in strength between the artificial structures (the arches) and the underground portions: the latter can obviously support greater pressures.
From the characterization of the geometry of the aqueduct, the fluid velocity has been evaluated. Due to the large slopes, the estimated velocities are high between 2.4 and 3.3 m/s confirming the possibility of erosion. Considering the documented flow rate for the *Aqua Iulia*, the average height in the specus is estimated to be 38 cm.
The lower slope of the aqueduct in the stretch between *puteus* n. 2 and n. 1, could thus be a precaution to reduce the water erosion capacity at a point where the *specus* began a significant curvature. In fact, the major bend radius is located just below the *puteus* n. 2. Here the water speed could have induced a significant erosion strength on the northern side of the aqueduct. The wider profile at this point could have had the function of slowing the water speed, thus reducing the erosive power.

5. Conclusion

The new aqueduct stretch shows both some interesting technical solutions adopted to avoid erosion phenomena and how the aqueduct curves could have been planned, using the puteus as a pivot points. The data also confirm the greater slope of the underground aqueduct, compared to the aerial stretches. Further, for the first time a possible stretch of the *Aqua Iulia* has been found outside the city of Rome, partially clarifying its path between the latter and the Alban Hills spring.

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