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Original article

A priori mapping of historical water-supply galleries based on archive records and sparse material remains. An application to the Amaniel qanat (Madrid, Spain)

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ABSTRACT

Engineering heritage refers to a broad variety of items of social, economic, aesthetic or historic relevance, including roads, dams, buildings and supply networks. Due to their utilitarian nature, their heritage value is often overlooked. This occurs even with those infrastructures that have played an essential role in underpinning the daily existence of entire civilizations. Underground water-supply networks provide an excellent example. Although there are exceptions, water networks tend to be functional in design, rather than monumental. Moreover, they present intricate linear layouts that often span several kilometres. This means they are costly to maintain once their operational life is over, and that they are prone to abandonment and destruction. Devising a priori protection strategies is important to preserve these valuable cultural assets. The following pages present a method to map linear structures based on archive records and sparse material remains. The method is illustrated through its application to the Amaniel qanat, a water-supply gallery built in Madrid, Spain, in the early 17th Century. An appraisal of the known remains was carried out first, leading to an inventory of galleries, shafts, shaft caps and deposits. This was followed by a thorough survey of over one thousand handwritten manuscripts, including physical descriptions of the aqueduct, budget accounts or water metering campaigns, among other documents. Known remains and written evidence were matched against original and auxiliary maps to reconstruct the itinerary of the aqueduct. This led to the identification of sectors where it is still possible to find remains in good condition. Thus, a priori mapping is advocated a valuable technique to locate and preserve these remains, as well as to devise non-invasive surveys and establish heritage protection zones.

1. Research aims

Mapping is a valuable technique to protect engineering heritage [1,2]. It may be used to plan excavation campaigns and non-invasive surveys, as well as to enhance our understanding of construction processes used in the past and to devise heritage protection zones [3,4]. Over the last decades, technology has brought along a variety of methods that allow researchers to map heritage sites, including aerial, land or underwater photogrammetry, satellite images, geophysical techniques or geographical information systems [5–7]. While useful, some of these techniques can be problematic within urban entourages, particularly whenever archaeological remains are sparse and buried. Such situations call for cost-effective approaches to underpin on-site investigations. The following pages explore a method to map urban underground galleries based on archive material and sparse physical remains. The goal is to identify the areas within cities where buried remains are still likely to be found. This approach, which works best for linear structures, is illustrated through its application to the Amaniel qanat, a water-supply gallery built in Madrid, Spain, in the early 17th Century.

2. The Amaniel qanat: heritage value, conservation issues and need for mapping

Urban growth poses a potential threat to cultural heritage [8]. Many ancient remains lie around or beneath cities [9] and are subject to harm from different agents [10,11]. Buried heritage is often found by chance. This is one of the main reasons why it may be damaged during routine excavation works. Due to their length and ramifications, linear structures, such as ancient water-supply galleries are particularly vulnerable to destruction.

Though hardly spectacular at times, old water-supply networks provide valuable insights on the technical prowess of our ancestors [12,13]. They also contribute to explain the pivotal role that water has played in human history, including how it shaped today's water management practices and conflicts [14]. Unfortunately, most water networks are worth maintaining only as long as they

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fulfill a purpose. This is the reason why many were abandoned as better engineering alternatives became available. It also explains why abandoned aqueducts often litter urban undergrounds.

Qanats are gently sloping tunnels used to tap and convey shallow groundwater. For practical purposes, they are best described as "horizontal wells" (Fig. 1). Qanats are suited to arid environments, where surface water supplies are unreliable. The early qanats were designed to capture groundwater from alluvial fans. This was achieved by creating a preferential drainage path (i.e. a tunnel) below the water table. Water flowing into the tunnel was led by gravity to outlets located at lower points, where people could use it. Vertical shafts connected the gallery with the ground surface, and served the purpose of directing the tunnel during the construction phase and facilitating access for maintenance tasks. Shafts were capped for safety and to prevent contamination (Fig. 2).

Qanats probably originated in Armenia and north-western Persia around 700 B.C., and spread to China, India, the Middle East, the Magreb and southern Europe over the ensuing centuries. Historically, qanats have been known to supply cities, such as Teheran, Marrakech, Palermo, Setubal or Majorca [15]. Madrid is the only major European capital to have ever relied on qanats. Qanats underpinned its daily life for nearly one thousand years, from the foundation of the city in the 9th Century to the late 19th Century. In fact, some linguists believe that the very name "Madrid" stems from an Arabic-Latin compound, *Mayrit*, which means "the place of many qanats" ("*mayra*" being a local word for qanat) [16].

Madrid's groundwater galleries were replaced by surface canals in the late 19th Century [17]. Most were gradually abandoned and destroyed as the city underground grew. Others were integrated into the water and wastewater distribution networks. The vast majority of the qanat complex, which totalled about 125 km at its prime, was lost as a result. This explains why little has come out of UNESCO's recommendation to protect what is left of Madrid's qanats [18].

While the conservation picture is bleak, vestiges of the old water network have been uncovered over the last few years. Most newfound remains belong to the Amaniel qanat, an eight-kilometre gallery that was built between 1611 and 1614 and remained operational until the 1950s. Its original purpose was to capture groundwater from the northern heights of the city and carry it to the Royal Palace.

The Amaniel qanat was built by the king and for the king. This sets it apart from Madrid's other major qanats (*Alcubilla, Fuente Castellana, Alto Abroñigal* and *Bajo Abroñigal*) because the later were intended for municipal supply. However, due to the negligent generosity of the Crown, Amaniel ended up providing water to some convents and nobles, as well as to several public fountains. Ironically, this caused water-supply problems for the kings during droughts. This is because the palace was located at the downstream end of the gallery, which means the king could only get whatever water was left after the other users had taken what they needed [19].

Amaniel provides one of the last chances – perhaps the best one – to preserve a part of Madrid's hydraulic heritage. The expansion of the city has destroyed large segments of the qanat over the last one hundred years, as pipelines, railways, garages, tunnels,

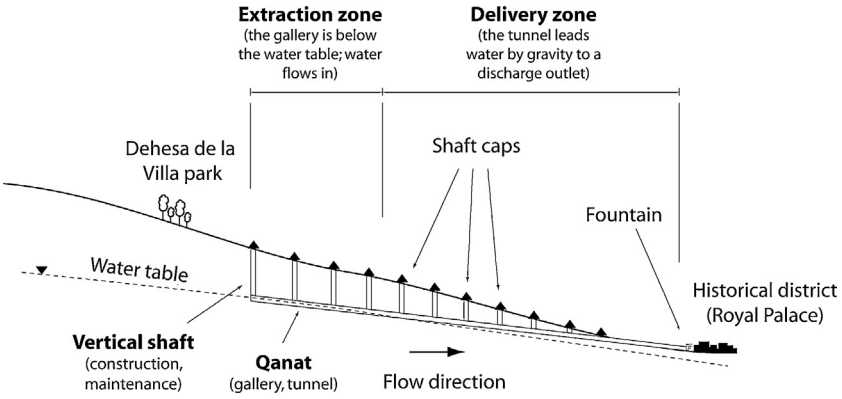

Fig. 1. Schematic overview of a qanat. Qanats were shallow underground galleries used to tap and deliver groundwater.

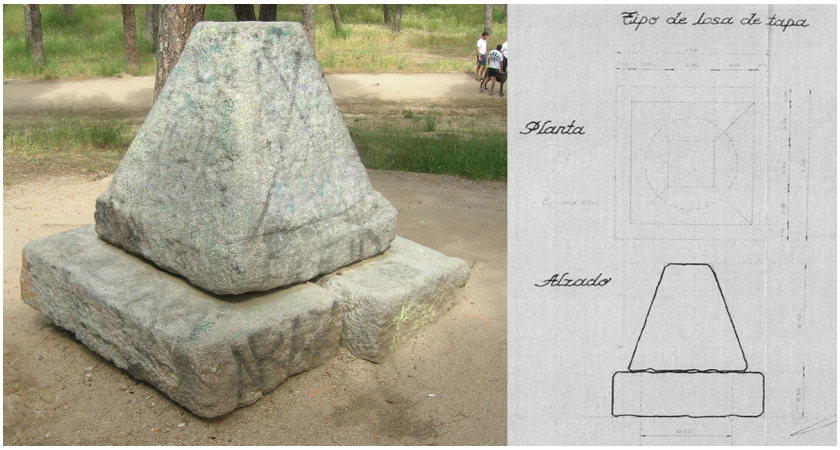

Fig. 2. Shaft caps are the most commonly found vestiges of the Amaniel qanat. The one on the right is located in the Dehesa de la Villa park. The picture to the right shows an original depiction of the shaft caps by José Bernardo Granda (1954). From the 17th Century, caps were often shaped as square-based pyramids, and were colloquially named "capirotes" (hoods).