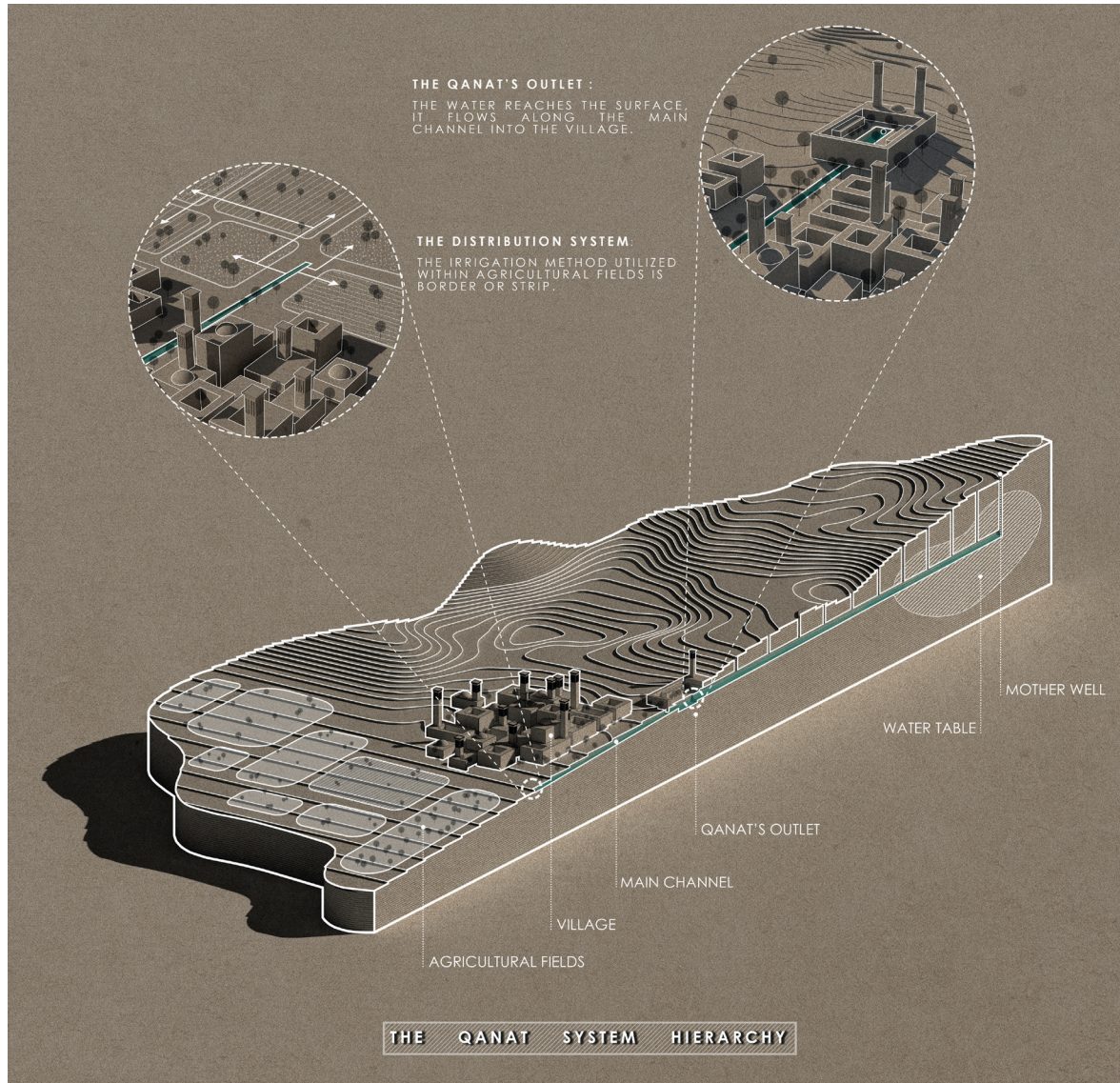


WATER AND URBAN TISSUES: THE QANAT SYSTEM AND THE FORMATION PROCESS OF YAZD, IRAN

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Yazd, Iran: an urban morphological analysis reveals the systematic influence of the *Qanat* system on four distinct morphological scales, the territorial scale, urban scale, urban fabric scale, and building scale. In arid areas where agriculture depends on irrigation, water shortage was one of the main motivations for many innovations, such as the underground watercourse, referred to as the *Qanat* system. This system played an important role in maintaining and developing civilization on the Iranian plateau (Bouzarjomehri, Khatami, 2018). The city of Yazd is in the central part of the Iranian plateau, and it consists of a widespread network of *Qanat* channels, exists under the city at various depths (Bonine, 1979), (Mohandesin Moshaver Armanshahr, 2008). The *Qanat* system is comprised of a nearly horizontal subterranean conduit that commences from the underground water table situated at an upper elevation, and the gravity facilitates the flow of water through this conduit (Bonine, 1982). These *Qanats* flow towards the agricultural lands, surrounding the city or to villages situated downslope (Bonine, 1979). Through the irrigation system, the water from *Qanat* systems is distributed from the primary branches to various

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parts and structures within the city (Petruccioli, 1994). The agricultural lands are arranged in clusters within cultivation areas, regularly situated down-slope from the settlements. Therefore, after fulfilling the village's water requirements, the *Qanat's* water is directed to these cultivated areas for irrigation (Bonine, 1982), (Figure 1).

The theoretical approach of this study, like Caniggia's methodology, aimed to achieve a comprehensive understanding of the relationships between the urban components of the city of Yazd by reconstructing the city's formation process throughout its history (Caniggia, Maffei, 2001). According to the examination of historical maps, remaining structures, documents, and written sources, this research has retraced the various phases that the city of Yazd went through during its formation process. Interpretation based on the reconstruction of the formation process, leads to a design of reality that represents the entirety of associations among

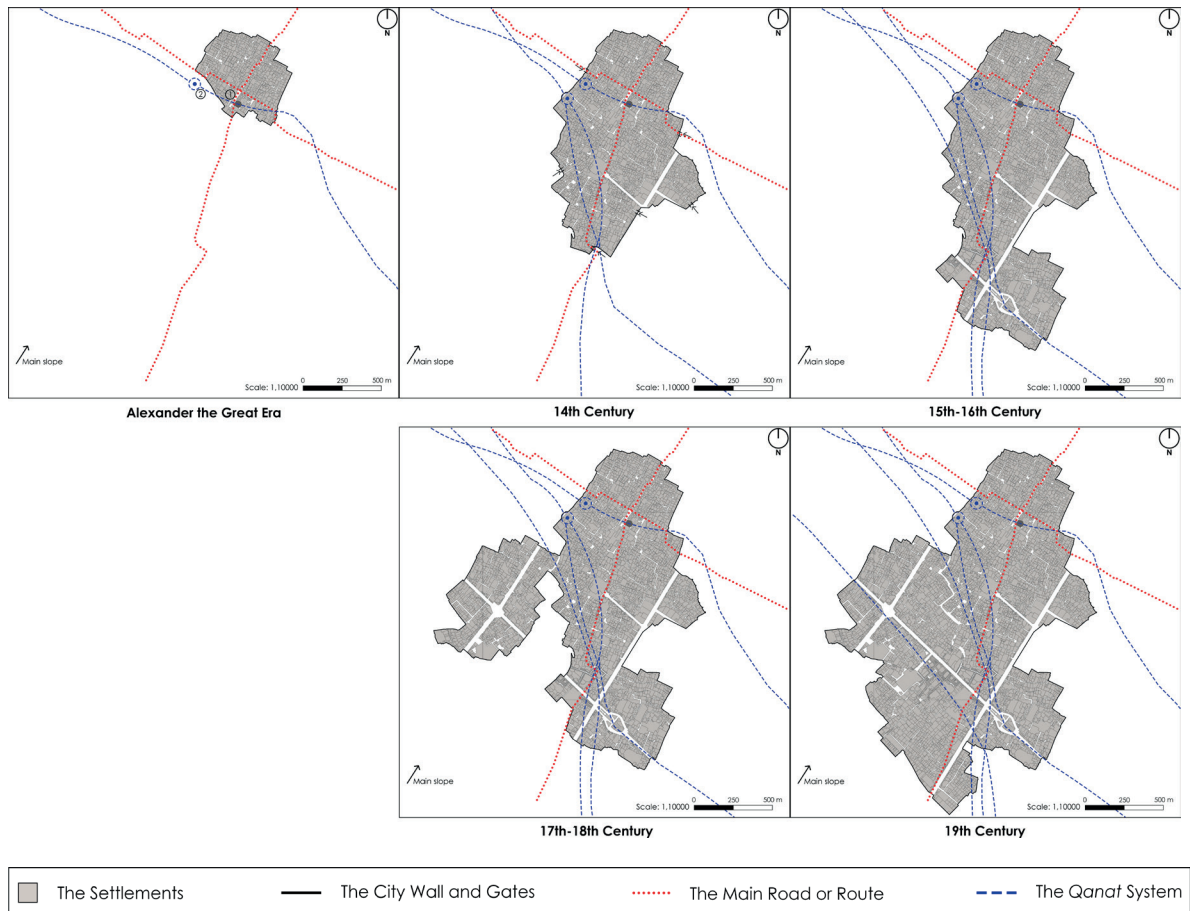
Figure 1. The irrigation system diagram.

Source: Author's elaboration using (Bonine, 1982)

the urban components. In this approach to the structures of environment, this study has reached a broad comprehension of the built environment by studying its components based on a decreasing scale (Caniggia, Maffei, 2001). Moreover, the research has explored the impacts of the *Qanats* on the city's components on each scale.

The first scale is the territorial scale. In this scale, the study has analysed the way the existence of the settlements and urban cores initiated from routes and productive structures in the central Iranian plateau. Hence, it has explored the territorial organism which is the broadest scope and comprises the most components. Through the analysis of the formation process of the territorial organism map of Yazd, a crucial factor in positioning the city of Yazd between two parallel series of top ridge routes is its utilization of the *Qanat* systems to fulfil water requirements. The *Qanats* originate from the underground water table located on the hillside. This system uses the natural slope of the land to transport water within its conduit from upstream to downstream. Therefore, valley settlements can benefit from this irrigation system. In this scale, the *Qanat* system has impact in determining the location of the city of Yazd in the valley.

The second scale is the urban scale. In this scale, the study has analysed the way the urban organism which includes basic tissues, transformed within historical periods. The city of Yazd emerged and formed under the rule of the Sassanid king, Yazgerd, at the intersection of two main perpendicular routes, the valley route and the cross-valley route. Furthermore, the initial pre-Islamic city centre, including Alexander's prison was established at this intersection (Rahbarianyazd, 2022). Through the analysis of the transformation process of the urban organism maps of Yazd within five historical stages, including the chronology of the *Qanats*, there is a strong connection between the urban growth of the city of Yazd, oriented along the main slope and towards the south and southwest, and the *Qanat* systems. Indeed, Yazd has expanded in such a way that there are favourable conditions, such as appropriate slopes and soil conditions for the construction of the *Qanats* to meet the water requirements. The correlation between the direction of the city's growth and the *Qanat* systems is a back-and-forth relationship, with each influencing the other. When inhabitants wanted to expand the city, the construction of the *Qanats* was considered as a vital issue. In contrast, when there was the potential of constructing a *Qanat*, the matter of expanding the city was considered. In this scale, the *Qanat* system has impact on the urban growth of the city of Yazd (Figure 2).



The third scale is the urban tissue scale. The urban tissues are living organisms that alter over time (Strappa, Carlotti, & Camiz, 2016). The study has analysed the typological process of the urban tissue of the city of Yazd throughout history by decreasing the scale into the aggregates that form the basic tissues. Furthermore, the research has examined the influences of the transformation of aggregates on routes and buildings. Through the analysis of the transformation process of the urban tissue maps of Yazd within three historical phases, there is a correlation between the urban configuration of the city of Yazd and the *Qanat* systems. In each phase, the urban tissue of Yazd follows a distinct urban planning methods based on diverse cultural sources. Each of these methods has its own planning logic. The *Qanat*'s act as a dividing line between three phases of the city. In addition, the main streets within the road network are parallel to the route of the *Qanats*, while the secondary streets in this network are perpendicular to the *Qanat*'s path. In this scale, the *Qanat* system has impact on the formation of the urban tissue of the city of Yazd and its road network.

The fourth scale is the building scale. The building type is the outcome of a diachronic process that begins with

Figure 2. The chronology of urban transformations of Yazd. Source: Author's elaboration using QGIS and (Noghsan-Mohammadi, 2001, pp. 67, 80)

basic buildings (Camiz, 2017). The study has analysed the typological process of historical courtyard houses in Yazd throughout history by decreasing the scale into the building that is the smallest component of the aggregates. These courtyard houses have direct access to the *Qanat's* water. Consequently, in this scale the study has analysed the architectural structures associated to the *Qanat* systems. According to the analyses, the formation process of city of Yazd is influenced by the *Qanat* systems, which is a part of irrigation system (Bonine, 1979), (Petruccioli, 1994).

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