An ice house, *yakhchal*, like this one in Meybod, was used to store ice in underground chambers throughout the year, Wikimedia, Ggia, released under a Creative Commons Share-Alike 3.0 license

Chapter 3
The Qanat System: A Reflection on the Heritage of the Extraction of Hidden Waters

Negar Sanaan Bensi

Abstract This chapter focuses on a traditional Iranian water infrastructure, the *qanat* system, a technical solution to the problem of accessing water for irrigation and urbanization that has shaped the landscape and organized the territory. The qanat was the basis for habitation, construction, and prosperity (*abadani*). It is also a key to understanding the culture and civilization of the Iranian Plateau and has evolved as a form of cultural heritage. Therefore, preserving this heritage is more than protecting an old technology. Rather, it requires a deeper understanding of the territory in which the qanat operated and of its limitations and possibilities. Discussing a historical work, *The Extraction of Hidden Waters* by Muhammad Al-Karaji (953–1029), this chapter explicates the multivalent role of the qanat system in managing and organizing the territory, society, life, and culture in the Iranian Plateau; this multiplicity of aspects and scales shapes its consideration of qanats' heritage today.

Keywords Iranian plateau · Territory · Qanat · Al-Karaji · Heritage

Introduction

The current severe scarcity of water in Iran and its surrounding region has necessitated a revision of the ways in which water resources are used, managed, and consumed, especially, as they appear in urbanization, planning, culture, and everyday life. Since the middle of the twentieth century, forces influencing the administration of water resources in Iran have included: excessive use of new pumping technologies and the abandonment of traditional ways of dealing with water, too many new dams, easy access to water for an increasing population and production sector, ongoing regional conflicts, and political pressures and instability. Indeed, these forces led to the current

Georg Gerster and the world of his photography.

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water crisis, shifting the culture of water management and, more largely, how we inhabit our territories.

Controversially, several scholars have recently argued that a disorganized bureaucracy is to blame. For example, Kaveh Madani, a civil and environmental engineer and water resources expert who has himself worked in Iran's government, said that "Iran's water problems are not due to a lack of access to technology or technical expertise, as some decision makers claim. Indeed, Iran is suffering from disintegrated decision making and problem solving by knowledgeable experts who act independently" (Madani 2014). Isa Kalantari, the recently appointed head of Iran's Department of Environment, points to the Iranian Force Ministry's dam-making and vast transition projects as the main reasons for today's water problems. If continued, he observes, this mismanagement will destroy the country's major water resources within the next 15 years. In fact, the technocratic approach has ignored the significance of the vital and scarce resources of water in human-made, cultural landscapes and the heritage values of water infrastructure like qanat. This amnesia has led to an undesirable governance structure and to a practice of ignoring the effects of development on the environment in favor of short-term benefits (Madani 2014; Ardakanian 2005).

The current water crisis forced scholars in various disciplines to rethink and reconsider ways of managing and inhabiting territories. In this regard, it is helpful to look critically at water heritage: its infrastructure, its spatial and physical dimensions, its culture, and the complexity inherent in its managerial systems. This chapter focuses on the qanat system as cultural heritage. The qanat is a traditional technique for accessing and managing underground water; it shaped the Iranian landscape and was the basis for inhabitation, construction, and prosperity (*abadani*). If we look at the qanat system purely as a technique, it might appear to be an obsolete system that is unable to keep up with the increasing speed of urbanization. But the qanat system is more than a technical solution to the problem of accessing water for irrigation and urbanization; it is a key to understanding culture and civilization in the Iranian Plateau. The heritage value of the qanat system is related to the preservation of an ancient technology; more importantly, it can provide a deeper understanding of the limitations and possibilities of the territory and its cultural, social, political, and legal complexity.

This transition to a holistic understanding of the qanat is well expressed in the work of Henri Goblot, a French geologist. Goblot went to Iran in 1940 at the invitation of the king at the time to prepare a plan for the underground water sources and give advice on modern irrigation technologies. At the beginning of his stay, he spoke against using qanats, as he considered them an obsolete technique; he suggested instead using deep wells and new pumping technologies (Goblot 1992). However, he came to appreciate the complexity of the qanat system and, slowly became so fascinated by qanat that he stayed for 20 years in Iran and wrote a book on the subject. His extensive and valuable treatise, *Les qanats: une technique d'acquisition de l'eau* (1992), is an important contribution to the study of the qanat system—its history, technology, and geography. Goblot understood the context in which the qanat could operate, where it was historically placed, and what it does.

As a technique, qanats have been used throughout history in different parts of the world—in the Middle East, around the Mediterranean, in the Americas, and even in west China (Yazdi and Khaneiki 2017). Although its exact history and origin is disputable, it is believed to be an Iranian invention and has been in use in Iran for thousands of years.

Modern studies of the qanat system first focused on the functional outline of its technology and the justification for continuing to use it to manage water (Jomehpour 2009). In the last three decades, scholars have also addressed its history and importance in different regions (Hu et al. 2012; Lofrano et al. 2013; Martínez-Santos and Martínez-Alfaro 2014) and expressed concern about its preservation and protection (Yazdi and Khaneiki 2017; Ghasemi et al. 2013; Jomepour 2009; Harandi and de Vries 2014). More recently, scholars have proposed the importance of developing a wider cultural understanding of the qanat system and the role of its heritage values in the planning and design of cities (Agah 2014; Safi Nezhad 2017; Beheshti and Najar Najafi 2017).

The chapter is structured to transit in scale and content: between landscape and object, between surface and depth, and between territory and thing: the qanat. According to Elizabeth Grosz, "the thing is the precondition of the living and the human, their means of survival, and the consequence or product of life and its practical needs. The thing is the point of intersection of space and time, the locus of the temporal narrowing and spatial localization that constitutes specificity or singularity." (Grosz 2001) To discuss the qanat as a thing, then, means to consider it in a reciprocal relation with the territory which accommodated it. In this way, the text pays simultaneous attention to a multiplicity of levels.

In order to understand the fundamental role of the qanat system and the management of the underground hidden waters in the formation of life in Iranian Plateau, it is important to state that the city—and any settlement within the Iranian Plateau—had to establish an intimate relationship with its territory, landscape, and geography. This study opens its analysis with a look at that relationship, reflecting on the archeological works and aerial photography of Erich Schmidt. Next, the specific geographical and geological conditions of the Iranian Plateau are briefly described, with a focus on the qanat system. Drawing on Muhammad Al-Karaji's historical treatise, *The Extraction of Hidden Waters*, further reflection follows, on the multiple aspects of the qanat which should be considered when its heritage value and related preservation strategies are discussed. Heritage considerations can also shape responses to the current and future water crisis, not necessarily to solve them, rather to avoid short-sighted solutions and, as Madani suggests, in that way, to focus on and identify the causes of particular problems by formulating better questions (Madani 2014).

Flights Over Territory: Between Landscape and Object

One of the most fascinating studies on the relationship between the city and its territory was carried out by Erich Schmidt, a German scholar who used aerial photography, drawing, and mapmaking to conduct archeological surveys in Iran in the

Fig. 1 Aerial photograph at the right side shows a vertical view from the site of Persepolis; "In the form of a plastic map the system of fortifications with its towers, the complex of palaces, and the physical environs of the royal site are spread below." Aerial photograph by Erich Schmidt, 27 September, 1935. The left map is the edited version of the vertical view photograph in which the relation between elements—i.e., the topography, fortification, water infrastructure (qanat), road and other elements—are highlighted on a tracing paper. *Source* Schmidt, Erich Friedrich. *Flights over ancient cities of Iran* 1940. PLATE 2: Vertical View of the site of Persepolis; April 20, 1936; 7:39 A.M.; altitude, 2440 meters; 1/100 se.; no filter. Courtesy of the Oriental Institute of the University of Chicago; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

1930s. *Flights over Ancient Cities of Iran* (1940) is his most well-known and fascinating publication; it combines descriptions of his flights over a large landscape (noting the relation between topography, roads, water infrastructure, agriculture, and settlements) with description of architectural elements and archeological objects found in each excavation site. This attention to the concurrence of issues is present in Schmidt's literal act of tracing in the drawings of excavation sites over his aerial photographs (shown in Fig. 1).

Schmidt's text constantly shifts between scales and between history, geography, and anthropology. Schmidt was genuinely interested in more than what he saw; he looked into the relations between things. He wished to know something about the ways that the territory was inhabited in a general sense. "Schmidt's publication elevated archeological surveying to a new art form", employing aerial surveying, photography, and prose to look at archeological excavations and discern relationships between objects, landscape, as well as history in their "enigmatic story" (Sobti and Hosseini 2016).

Schmidt also relied on some important geographical histories of the Medieval Islamic period–such as Le Strange's *Lands of the Eastern Caliphate*, Al-Muqaddasi's (945–1005 CE) *Ahsan al-Taqasim* and al-Tabari's (838–923 CE) *Tarikh al-Tabari* (Sobti and Hosseini 2016)—to render the multiplicity and interconnection of settlements with their immediate landscape and the larger region. For example, he captures the historical settlement of Band-e Amir within its territory in relation to the larger irrigation system and the *band*, or, dam, built over the Kur River in the Fars region in Iran during the Buyid dynasty (934-1055) (Fig. 2). Schmidt offers Le Strange's observation that: "Ten great water wheels raised the water to such a high level that

Fig. 2 Historical settlement of band-e Amir. *Source* Schmidt, Erich Friedrich. *Flights over ancient cities of Iran* 1940. PLATE 43: Bustam (Bastam), A place of pilgrimage in Northern Iran; September 23, 1935; 7:27 A.M.; altitude, 610 meters; 1/140 se.; yellow filter. Courtesy of the Oriental Institute of the University of Chicago; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

three hundred villages could be supplied with the water, so precious in Iran; and at each wheel there was a flour mill" (Schmidt 1940). His aerial photograph of Turut (or Torud), a small village south of the Salt Desert of Damghan, captures a clear border between inhabited territory and the desert that absorbs the hidden underground water from the heart of the mountains. In the caption of this photograph (Fig. 3), Schmidt writes: **"**Turut is one of these places at the rim of the infernal *kavir* [desert]. It is actually wedged between two salt deserts, the *kavir* of Damghan and the 'great *kavir'*. It owes its existence to a threat of sweet water breaking from low range of hills, which partly separates the lifeless plain" (Schmidt 1940).

This multiplicity of scales and relation between architecture and territory in Schmidt's writings and photographs goes beyond a purely formal and visual presentation of landscape. He depicts a complex relation that is present at various social, cultural, economic, and legal levels. Schmidt was well aware of the delicate geographical and geological condition of the Iranian Plateau and its determinant role in the formation of its civilization, culture, and built environment.

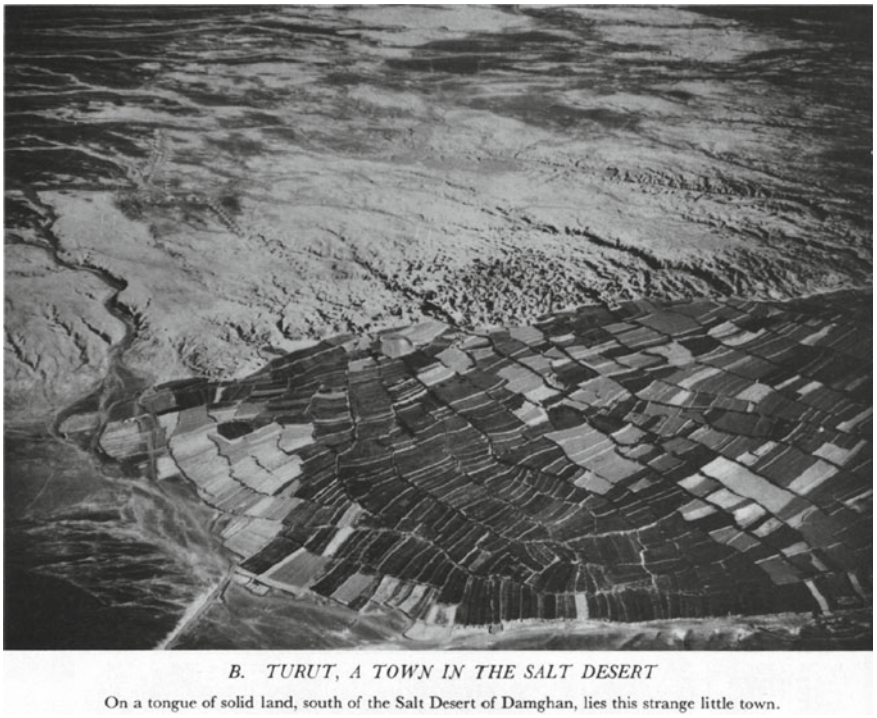


Fig. 3 Turut (Torud), a town in the Salt Desert. The rows of *qanats* are visible on the top of the photograph. *Source* Schmidt, Erich Friedrich. *Flights over ancient cities of Iran* 1940. PLATE 46 B. September 23, 1935; 8:10 A.M.; altitude, 610 meters; 1/140 se.; orange filter. Courtesy of the Oriental Institute of the University of Chicago; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

An Insight into the Geographical and Geological Condition of the Iranian Plateau: Between Surface and Depth

Geologically, the Iranian Plateau was formed and shaped by the uplifting and folding of three giant plates: the Arabian Plate, the Eurasian Plate, and the Indian Plate pressing against each other (Harrison 1968; Fisher 1968) (Fig. 4). As a result, a series of chain mountains, primarily in the north and southwest, enclose the interior basin of Iran. This central basin includes the central deserts, *Dasht-e-Lut* and *Dasht-e Kavir*, currently two of the driest and hottest spots in the world.

The uniqueness of Iran is the result of the encounter of two extreme geographical conditions, as historian Heinz Gaube points out. On one hand, the country is part of the Eurasian mountain belt that "runs from the Iberian Peninsula, through the Alps, the Balkans, the Carpathians, the Taurus and Pontus, and the Iranian highlands rims of the Elburz and Zagros" (Gaube 2008). On the other hand, Iran is also part of "the arid belt of the Old World which stretches from the Sahara in the west across

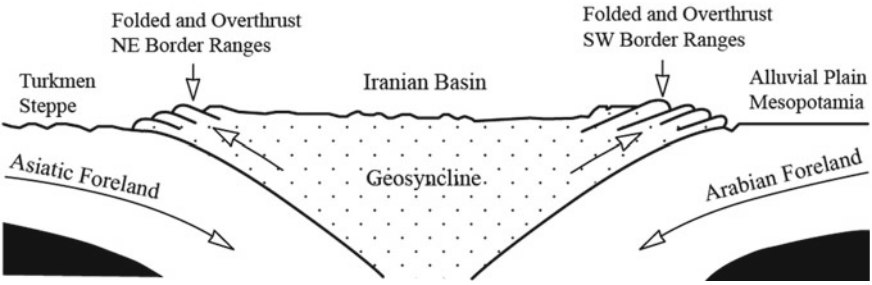


Fig. 4 Diagram of the Iranian Orogen by Harrison, J.V. *Source* Harrison, J.V. 1968. Geology. In the Land of Iran, vol. 1 of The Cambridge history of Iran. ed. W.B. Fisher. Cambridge: Cambridge University Press: 183. [© Cambridge University Press, 1968]; This figure cannot be reproduced, shared, altered, or exploited commercially in any way without the permission of Cambridge University Press, as it is copyrighted material and therefore not subject to the allowances permitted by a CC-BY license; all rights reserved

the Arabian Peninsula and the Iranian Plateau to the deserts of Central Asia in the east" (Gaube 2008). Although the main part of the plateau is covered by dryland, a considerable amount of water is stored between the layers of folded ground and faults. Hence, most Iranian settlements have been sited in a piedmont zone between mountain and desert in large alluvial fans (Kheirabadi 2000).

Water is the source and precondition of life. With few permanent surface water sources in this harsh environment, subsurface water reservoirs made human settlement possible here. People devised an underground water infrastructure, the qanat system, to access fresh water, using it both for irrigating farms and gardens and for drinking. This was territorial management operating on spatial, physical, legal, social, and cultural levels.

On the Qanat: Between Territory and Thing

The qanat system is a subterranean infrastructure that gave access to the hidden water at the foot of mountains. Vertical shafts of successively increasing depth were connected by a horizontal underground tunnel (*dehliz*), which directed the water from subterranean water sources down a slight slope to gardens, farms, and settlements (see the images in Fig. 5). However, the vertical shafts are not themselves used for accessing water. Rather, they are important, first, for calculating the right direction and proper angle of slope for the horizontal tunnel. Later, during excavation, they are used for faster removal of dug materials, as well as for regulating pressure and oxygen for workers. Finally, after the completion of construction, these shafts are used for maintenance, providing workers an easier way to get at the underground horizontal tunnels for repair.

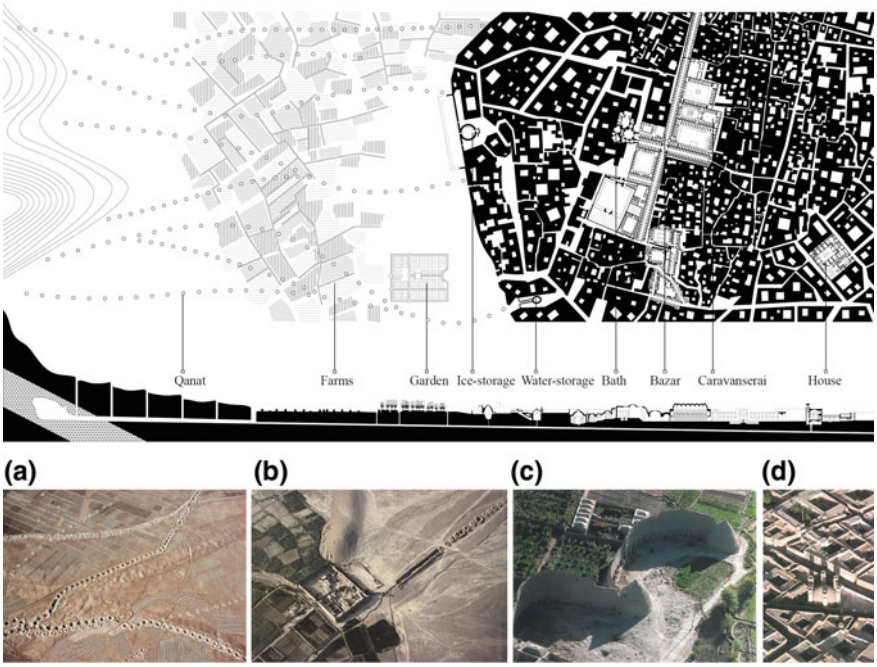


Fig. 5 **a** Drawing of a hypothetical territorial section showing how the *qanat* system and various architectural constructs such *bagh* (garden), *ab-anbars* (water storage), and *yakhchal* (ice storage) provided water for settlements and farms. It established a system that supported life in the territory. Courtesy of Negar Sanaan Bensi and Raul Forsoni; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. **b** Aerial photograph by Georg Gerster, 1976–1978 at Yazd, Iran. "A palimpsest of qanats crisscross an area of recently formed fields." The aerial photograph depicts different types of qanat structures: rows of several qanat with a single row of shafts at various distances and qanat with double shafts to facilitate cleaning and maintenance. It also exhibits faint traces of much older qanats, now replaced by new ones. *Source* Mousavi. Ali et al., *Ancient Iran from the air* 2012: 26; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. **c** Aerial photograph by Georg Gerster, 1976-78 at Golpayegan, Iran. The Point at which "a qanat comes to surface, having carried pristine water deep beneath bare, uncultivated *dasht* [desert]". It also depicts "an initial walled stretch of the surface stream, three separate irrigation channels then serve to direct the water toward the adjacent fields. *Source* Mousavi. Ali et al., *Ancient Iran from the air* 2012: 176; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. **d** Aerial photograph by Georg Gerster, 1976-78 at Yazd, Iran. Depiction of an *ab-anbar*, water storage feature, ringed by six tall wind-catchers designed to capture wind from various directions so as to ventilate and cool the water. At its foundation, a perimeter wall protects the base of the dome of the water feature and after occasional heavy downpour guides run-off into the cistern. *Source* Mousavi. Ali et al., *Ancient Iran from the air,* 2012: 168; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. **e** Aerial photograph by Georg Gerster, 1976-78. at Sirjan, Iran. The picture shows a *yakhchal*, an ice making and storing structure. Two tall curved walls shade shallow over pools located in front "where, in winter, qanat water was turned into ice, chopped out, and then stored in deep pits beneath the stepped, domed ice houses". *Source* Mousavi, Ali et al., *Ancient Iran from the air* 2012: 163; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

The location of the motherwell, distance between vertical shafts, proper slope for the horizontal tunnel, and length of the qanat were carefully examined during the process of construction. According to Goblot, the slope of the underground tunnel must be around 0.5/1000 to minimize the erosion of the inner surface of the horizontal tunnel. This is an important technical issue, as slope directly influences the point at which water emerges on the surface called *farhang*. In Farsi f*arhang*, means 'culture'. Both *culture* and *farhang* in their etymological roots refer to the cultivation (of land), the training or improvement of the faculties, care (of a monument), upkeep and the cultivation of the acquaintance (of a person). (*Oxford Latin dictionary*, 1968, "cultūra" and *Dehkhoda Dictiony* under فرهنگ). Such an implicit interwoven relationship between *farhang* (or culture) and water thus is not by chance (Najar Najafi 2015). The farhang affects the exact placement of a settlement, farm, or garden. Hence, the slope of the ground has a direct impact on how the water is managed. Where the slope is steep, water moves in linear fashion; it is then difficult to direct the water through the network of water systems. Gardens and distributing ponds or *moqassem*, directed the water into networks toward the city. In sum, qanats formed a low-tech system based on the interaction of gravity, minimal waste of materials, sources of water, and labor. Knowledge of its construction was embedded in daily life and taught, in practice, from master to pupil. It was also a long-term measure which created a constant flow of water within a harsh, dry environment.

This system can be presented in a hypothetical territorial cross-section through a city, including various architectural elements: garden, *bagh*, for distribution; water storage, *ab- anbar;* or ice storage:—or *yakhchal*—literally the ice-hole—along with the settlements and farms that were where the water was destined to be consumed (Fig. 5a). The importance of the qanat system lay in the way in which it organized territory through a process of revealing water to surface and, thereby, providing the possibility of habitation.

The multivalence and complexity of this territorial management become clear when we refer to treatises that accumulated and organized the knowledge of water management and the construction of qanats historically. These treatises are important objects of cultural heritage, though they have not yet been thoroughly investigated. Inbat al-miyah al-khafiya, by the Iranian Muslim mathematician and engineer of the late tenth and early eleventh centuries Abu Bakr Muhammad Al-Karaji, is one of the oldest surviving manuals on hydraulic and water supplies. In his treatise, Al-Karaji demonstrates his familiarity with contemporary concepts and principles of the hydrological cycle, classification of soils, description of aquifers, and the search for groundwater (Abattouy 2014). He observed these processes and practices during his lifetime and organized them scientifically and according to his educational background in the form of a treatise.

The title itself contains a word that is worthy of some relevant comment. According to Mohammed Abattouy, "The inbat, like istikhraj, means precisely 'extraction' of underground water, to show what is hidden and to extract ground and hidden waters for economic and social benefit. The term may have to do with the mathematical concept of istinbat, meaning 'deduction by reasoning'. If this is verified, the link between the two is natural, as Karaji would have coined the term in the aftermath of

his long experience as a mathematician" (Abattouy 2014). Karaji himself wrote, in the introduction, "I know no profession more beneficial than the extraction of hidden water, as it gladdens the earth and makes life possible." (Al-Karaji 1994, 22). He further explains that he wrote this book after his return from Baghdad to the iqlim of Jabal–mountain region–on the heights full of farms and villages, with cold, clean, and tasty water from several sources.

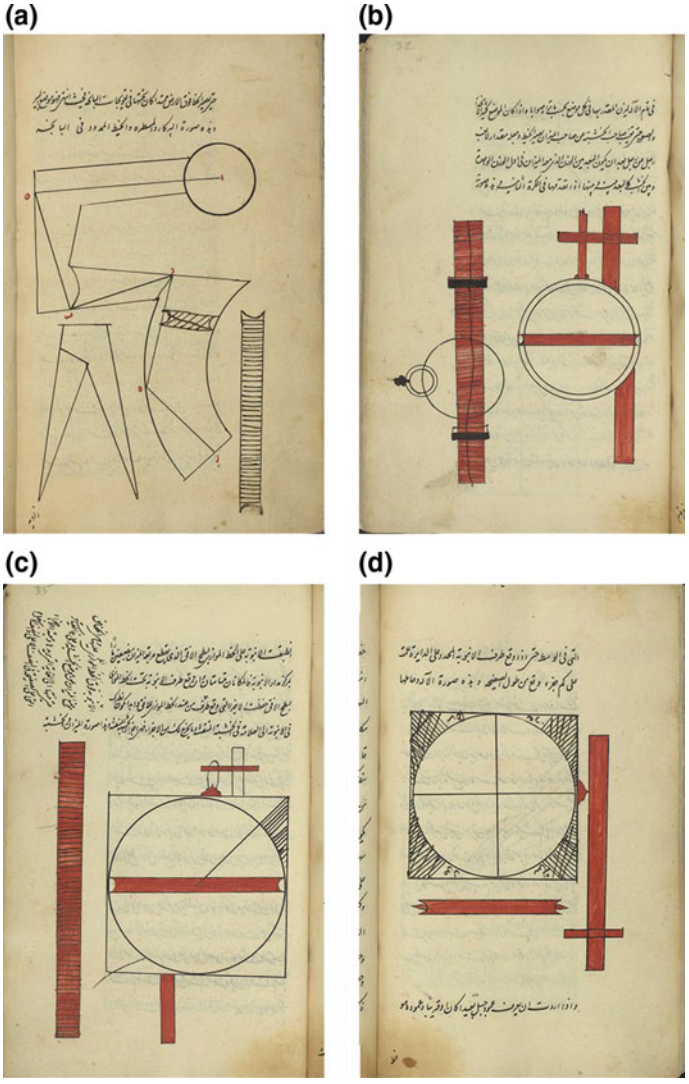
Opening first with a contextualizing of hydrology within "the larger field of natural science and geology" (Abattouy 2014), the book compiles a vast knowledge on the modes of finding and treating water as well as the methods and instruments used in building and preserving qanats (shown in the images in Fig. 6). The first few chapters introduce water as a system that is fluid: transmitting a liquid substance from one place to another and able to change its form in the water cycle. This understanding of water as a system is fundamental to the development of qanat as a non-pervasive technique that works with water itself as a renewable resource. Qanats facilitate water transit from source to destination, even as, since the level of the underground water table controls the flow, the qanat system does not drain an aquifer (English 1998).

Al-Karaji describes how to find underground water sources. This survey ranges from the geological conditions that influence where the water is naturally stored underground; the topography, type, and color of soil and stone; vegetation in the proximity; and other indicators. In the next chapter, he describes kinds of water, their sources, use, and ways of cleaning and purifying them. He, then, addresses miscellaneous topics related to water, including how earthquakes influence water underground or how to determine whether a well still contains water. The relationship he brings forth between the location of a qanat and earthquake lines is particularly important, as many Iranian cities are characterized by intertwining of a seismic landscape with arid and semi-arid areas—to form landscapes of risk and resilience (Ibrion et al. 2014).

In the last chapters of his volume, Al-Karaji addresses the legal dimensions of water management, as a techno-scientific discipline closely related to society and economy (1994, 67–87). In these chapters, he establishes a legal argument according to a discourse on the various Islamic schools of law, *figh*, concerning the construction, characteristics, and use of qanats. Ownership of qanats is complex, as the surface of the land and the underlying section which holds the infrastructure can belong to different people. In other words, he unfolds a legal condition where various ownership regimes overlay and superimpose each other. According to Karaji, these legal principles differ if the hydro-infrastructure is a qanat, well, or canal and if they are constructed for the use of a farm, animal, or a city. What is the legal and ownership status when a qanat constructed by someone for the use of a city or settlement passes underneath the farm belonging to someone else? And what happens if the qanat system needs to be repaired or even accessed? These are the more fundamental questions. Moreover, different territorial ownership principles apply to different geological conditions, for example, if a qanat or well is constructed in a soft porous soil or muddy or hard soil.

In this way, geometry measures not only the surface or the landscape, as its etymology literally says (*geo,* earth + *metry*, measure); it also encompasses the

whole complexity and contradiction of the act of measuring. Indeed, measurement is tightly related to the management of land. As James Corner puts it, measurement is not an autonomous and instrumental part of human technologies, used to dominate and control the world; it is a way "to reveal culturally significant forms of order" (Corner and Alex 2000). He adds, critically, that modern technologies, steeped in efficiency and utility, characterize only an instrumental aspect of measurement or of the means taken to secure a particular end. This explication of the concept is close



◀**Fig. 6** Pages from the book *The Excavation of Hidden Water* by Al-Karaji. **a** (indicated in the archive as page 45v) is related to a chapter discussing the tools and methods of digging the underground tunnel connecting the wells in the construction of a qanat. The drawing is a diagrammatic plan of this underground tunnel. It shows how to project the underground tunnel on the surface of the ground to be able to site and dig the well. The drawing shows a compass and a ruler. **b** (indicated in the archive as page 32r) and **c** (indicated in the archive as page 35r) are illustrations of leveling tools. These figures are included in a chapter which explains the leveling tools and techniques for surveying the ground. This surveying process for understanding the topography and height differences along the qanat's path is crucial in the construction process. **d** (indicated in the archive as page 37v) is an illustration of a tool for measurement of topographical distances and it is part of a chapter which describes the ways and tools for defining the height of a mountain, the distance between a mountain and where an observer stands and as well the distance between the summit of different mountains. *Source* Title: [Inbāṭ al-miyāh al-khafīyah] [manuscript]. Kitāb Inbāṭ al-miyāh al-khafīyah; Origin: [Iraq or Persia], A.H. 1084 (1674); Physical Description: 49 leaves: paper, col. ill.; 193 × 125 (138 × 70) mm. bound to 193 × 128 mm. Manuscript Location: LJS 399, Rare Book & Manuscript Library University of Pennsylvania LJS 399; Available online: http://hdl.library.upenn.edu/1017/d/medren/9948256513503681. Courtesy of Lawrence J. Schoenberg Collection of Manuscripts, Kislak Center for Special Collections Rare Books and Manuscript, University of Pennsylvania; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

to the Heideggerian understanding of technology as a way of revealing and grasping the world (Heidegger 1977). And qanat as infrastructure stem from this geometrical knowledge of the management and measurement of the territory.

One of the important legal notions relating to the qanat system is the law of *harim or* borders, which has given an owner protection over a territory surrounding a qanat and prohibited the sinking of new motherwells or any other construction within a defined distance of an existing qanat (English 1968). The *harim* law does not itself fix this distance. As it is clear in Al-Karaji's discussion, that distance was contingent, depending, as ownership did, on the type of hydro-infrastructure, type of qanat, its length and depth, the geological condition of the soil, the location of the motherwell and so on. Thus, the importance of *harim* is more than just the protection of the right of ownership; it defines frames for protecting underground water resources.

These are important issues to be considered for territorial and city planning—and even for a city's architecture. Historically, they are the dynamics by which the water network and the qanat system directly influenced the formation and structure of the city and the position of agricultural and farm lands (Bonine 1979; Aboutorabian et al. 2009). The lack of attention to such important issues as these in the last decades in Iran has caused it serious problems. It seems curious, for example, in Tehran, the urbanization of the northern areas during and after the 1960s often interrupted the practice and application of *harim* to older qanats: the deep foundations of many buildings blocked the flow of underground waters (Khosravi et al. 2016). One of the most problematic issues in Iran's current water crisis is the improper distribution of industry. It does not, for example, make sense to put steel mills in the central desert, which has limited water resources. Komeil Sohani, a young Iranian researcher, has recently directed a documentary that shows that the water crisis in Iran is rooted in decades of mismanagement and misunderstanding of the actualities of Iran's position.

The qanat system was also involved with the social structures of local communities and cities (English 1966; Bonine 1982). For instance, wealthier families often had private and direct access to water networks, or they lived closer to the outlet or upstream of it. At the same time, the rest of a city's inhabitants used the collective and public services available in each *mahalleh*—which might include that neighborhood's water storage. Sharing and maintaining the common basic resources helped form close social relationships within a neighborhood. Furthermore, the main public institutions such as the bazaar, mosques, baths, and schools usually had direct access to freshwater. This means that the economic structure of the city had a close relationship with the qanats and the water network in general. In short, a multiplicity of interwoven factors has shaped how people construct and maintain qanats throughout the history of their use, creating specific ways of living and inhabiting the territory.

Conclusion

The word territory derives from the Latin word *territorium*, meaning the land around a town, and terra, the dryland and earth, as opposed to sea, proximate to "specifically a Roman or a provincial city" (Online Oxford Dictionaries, s.v. "territory" and "terrain"). The term *terra* itself is derived from the Indo-European word *ters,* dry or to dry and points to the very early exercise of city making, and the possibilities of life, within the wet marshy land in Europe. In Avestan *ters* became *taršna*, or thirst, in modern Iranian it transformed into *tešneh*, or thirsty (Nourai 1999). Both signal the lack of water that substance whose absence jeopardizes life itself in the arid plateau of Iran. In this sense, *thirst* both literally and metaphorically has constituted the urge and motive for people to search for ways and means to inhabit the dryland, and to extract its hidden waters. It propelled people to seek, to imagine, and to create, and to reverse obstructions to new possibilities throughout their history. The qanat system is a clear example of this life-giving dynamic. To build a qanat, one must have a holistic understanding of where and when one lives. Goblot considered the qanat system to be one of the most imaginative engineering works in the history of humankind. In fact, the extraction of hidden waters and construction of oases and gardens, the life-filled *Pardis* or Paradise within a landscape that is a seeming tabula rasa, could not occur without the presence of rich imagination.

During World War II many qanats were replaced by deep wells, introduced to Iran by the Allied Armies. The premises of this introduction were multiple that: it was more efficient to get water from a deep well than from the qanat; one could get more water faster; deep wells were separate matter from topography and soil conditions; and wells could be built without using local materials or local labor (English 1997). In essence, deep wells involve fewer constraints. However, for these very reasons, they might tax water sources and empty aquifers. Notably, the shift from qanats to deep wells represented a complete shift in the management of the territory; it was a shift from a collective legal act to exploitation according to individual interest.

As several scholars have noted, it is important to strategically conserve qanats as cultural memories. In "The Qanats in Yazd: The Dilemmas of Sustainability and

Conservation" Bharne introduces the qanats of Yazd and their decline, then puts forth several solutions: He, for example, suggests using the existing system of qanats as a gray water recycling network or renovating them as sites and vessels of cultural memory. Although these proposals seem feasible and interesting on first view, they focus mainly on an immediate alternative functional question rather than on the larger cultural and historical value of the qanat.

Some old qanats are in use still today in Iran, principally in villages and smaller towns. Qasabeh Qanat, in Gonabad, a city in the province of Razavi Khorasan at the northeast of the current political boundary of Iran is one of the oldest remaining qanat. Even though most are abandoned–and only a few are available for tourist visits–they remain complex systems that influence and are being influenced by various scales and levels of geography, society, administration, economy, and culture. The heritage value of systems like qanat consists exactly in the interwoven understanding that they can give us, not in their expression as, purely, a technical solution for the exploitation of water, nor as museums.

Perhaps the restrictions and principles embedded in systems like the qanat are necessary for the delicate geography of the Iranian territory. And perhaps, it is exactly these principles and restrictions that could establish a base for new managerial structures and decision making, planning, construction, and production. This would certainly be a difficult shift, necessitating a cultural understanding of the issue of water as well as the involvement of all levels of sectors, communities, and citizens.

Last, but not least, we preserve water infrastructure such as the qanat system, and must do so, not only for the safe-keeping of a past heritage, but in order to take the right steps toward the future. We require a deep understanding of the logic and complexity of such a system, of what exactly it was doing as a system and in its parts, and how it was doing it, the limits it was creating, and how it made a certain way of life possible and sustained a territory. Such an understanding aids us to move into the future as we harbor and live with the past.

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