THE ORIGIN AND SPREAD OF QANATS IN THE OLD WORLD

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INTRODUCTION

Subterranean tunnel-wells (qanats) are extremely important in the history of irrigation and human settlement in the arid lands of the Old World.1 Apparently originating in pre-Achaemenid Persia, tunnel-wells spread to Egypt, the Levant, and Arabia in Achaemenid times (550–331 B.C.). The Arabs carried qanats across North Africa into Spain and Cyprus; they are also found in Central Asia, western China, and on a more limited scale in dry regions of Latin America. In modern times, more than twenty terms are used to identify these horizontal wells; the Arabic word qanāt meaning “lance” or “conduit” is used in Iran, the Persian term kārēz is used in Afghanistan, while in Syria, Palestine, and North Africa jūgarā (pronounced foggara) is the most common term. In all of these regions, tunnel-wells are still being constructed in the traditional manner, and many settlements depend on them for irrigation and domestic water. Where used, qanats have strongly influenced village socio-economic organization and patterns of ownership and tenure.

THE NATURE OF QANATS

Qanats are gently sloping tunnels dug nearly horizontally into an alluvial fan until the water table is pierced. Once constructed, ground water filters into the channel, runs down its gentle slope, and emerges at the surface as a stream (fig. 1). In excavating these tunnels, diggers must have air and tunnel spoil must be removed, so the tunnels are connected to the surface with a series of vertical shafts spaced every 50 to 150 meters along its course. The tops of these shafts are rimmed by piles of excavated dirt to form a “chain-of-wells” on the surface, a distinctive feature of the arid landscapes of qanat-watered regions (figs. 2, 3). This system of water supply is widely used in the deserts of the Old World for several reasons. First, unlike other traditional irrigation devices such as the counterpoised sweep (shaduf), the Persian wheel (dulab), and the noria (nawrah), qanats require no power source other than gravity to maintain flow.2 Second, water can be moved substantial distances in these subterranean conduits with minimal evaporation losses and little danger of pollution. Finally, the flow of water in qanats is proportionate to the available supply in the aquifer, and, if properly maintained, these infiltration channels provide a dependable supply of water for centuries.

Qanats vary considerably in size. Those in mountainous areas are usually short, shallow tunnels only tens of meters long and several deep, which draw surface water from small patches of alluvium. Others are major engineering feats such as those which supply water to the Iranian cities of Kirman, Yazd, and Birjand. At Kirman, qanats extend more than 50 kilometers southward to penetrate the water table at the base of the Kuh Jupar (fig. 4).3 Literally thousands of vertical shafts, the deepest 100 to 125 meters, dot the Kirman Plain marking the courses of an unknown number of galleries which carry water to the city (fig. 2). Yazd is watered by some 70 qanats, 30 to 45 kilometers in length, with mother wells (that shaft furthest from the point where water emerges

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Fig. 1. Diagram of a typical qanat. Profile, cross sections, and aerial view illustrating the varying dimensions of a tunnel-well.

at the surface) 50 to 125 meters deep. The deepest reported qanat is located at the village of Gunabad near Birjand. Though only 27 kilometers long, its mother well lies at a depth of more than 300 meters.

QANAT CONSTRUCTION

Most qanats in Iran are constructed by a class of professional diggers (muqannis) who inherited this task from the slaves and captives of the Achaemenid and Sassanian kings. These men form a community of traveling artisans, migrating from place to place as floods destroy qanats in one area or a lowered water table demands that qanat tunnels be lengthened in another. The tools of the muqanni are primitive: a broad-bladed pick, a shovel, and a small oil lamp. His profession is well paid but hazardous. The muqanni must work with water flowing around him, ventilation is poor, and the chances of cave-ins are great. Today, qanats are still being built by these muqannis and the techniques of construction have changed little.

Site selection is the first step in the construction of a qanat. Local slope conditions, ground-water supplies, and the proposed location of the new settlement determine this decision. These factors are weighed by an expert, usually one of the older, more famous muqannis, who decides where a trial well should be dug. Favorable sites often lie near the mouth of a wadi, but where the water table is deep and the qanat long, the general topographic setting and variations in vegetation are used as indexes of the likely location of underground water supplies.

After the expert has chosen the site, a vertical shaft deep enough to penetrate the permanent water table is dug. The muqanni must be certain that this well has penetrated the permanent water table or has struck a constant flow of ground water on an impermeable stratum. If there is doubt concerning the water supply's permanence, more test holes are dug to determine the extent of the aquifer and the depth of the water table. When a trial well has sufficient water, it becomes the starting

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point for the construction of a qanat. This shaft will be called the mother well (madari chah) of the qanat, though the term is misleading because water is not removed from the ground at this point. The length of the qanat is measured from the mother well to the point where water surfaces. The depth of the mother well may vary from ten to several hundred meters.

The muqanni next establishes the alignment and grade of the qanat and this is the most difficult
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Fig. 3. Detailed aerial photograph (1:3,000) of qanats at the southern margin of the city of Kirman, Iran. Note their passage through abandoned fields in the lower center.

The qanat is aligned so that a gently sloping tunnel from the water-filled base of the mother well will surface above the irrigated fields of the settlement. If the tunnel emerges far from the settlement, water will flow on the surface in an open channel to the houses and fields. In such cases, evaporation and seepage become major problems, as at Turbat-i Haidari in eastern Iran where only one-quarter of the qanat water actually reaches the fields. If the gradient of the tunnel is too steep, water rushing down the tunnel will erode the walls and soon destroy it. The maximum gradient in a short qanat is approximately 1:1,000 or 1:1,500; in a long qanat the tunnel is nearly horizontal. Using a string as a level, a skilled muqanni can

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6 This process was not observed in the field. It is described in: ibid., pp. 196-197; Philip H. T. Beckett, op. cit. 40 (1953): pp. 48-49; Hans E. Wulff, op. cit. (1966), pp. 252-253.

dirt is transferred from one bucket to another at this point.

The major problems in constructing a qanat occur when the tunnel enters the water-bearing section, where many muqannis are drowned or suffocated each year. In some cases the shafts fill with water before having reached the proper depth and the muqanni must dig upward beneath this pool and avoid the rush of water when a breakthrough is made. If the tunnel passes through an area of soft sand, clay hoops are inserted in the tunnel to prevent collapse (fig. 1). Where ventilation is poor, extra vertical shafts are dug to prevent suffocation. Every muqanni carries a castor oil lamp; when the air no longer keeps its flame lit, he leaves the tunnel and another shaft is built. In Yazd, where the qanats are very deep, vertical shafts are built on either side of the tunnel. A lamp is placed at the bottom of one shaft to create an updraft which draws air down the other shaft and improves ventilation.\(^8\) Sometimes twin qanats are built side-by-side, enabling the muqanni to move from one to the other.

The time required to build a qanat varies with the capital of the owner, underground soil and water conditions, the amount of water desired, and the skill of the muqanni. Two new qanats recently built at the villages of Javadieh and Hujatabad south of Kirman can be used as examples. The Hujatabad qanat is only one kilometer long, with a mother well 45 meters deep, but it was under construction for twenty-seven years because of three changes in ownership. Construction on the Javadieh qanat began in 1941 and one team of qanat-diggers worked daily for seventeen years to bring water to the surface. In 1958, when small amounts of water began to flow, the owner hired a second team to work at night. Now the Javadieh qanat is 3 kilometers long; its tunnel bifurcates and has two mother wells at 50 and 55 meters respectively. Most of the tunnel had to be lined with clay hoops because of loose sand. It cost $33,000 to build this qanat and it now irrigates about one-half acre of land every twenty-four hours.

On this basis, qanats cost about $10,000 per kilometer to build. The Javadieh qanat cost more, $11,000 per kilometer, because the tunnel was lined. The expense of this relatively short qanat indicates the monumental costs of constructing a new long qanat. Such a one to Kirman, 40

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\(^8\) The diagram illustrating this device in E. Noel, op. cit. 31 (1944): p. 198 has been printed upside down.
kilometers long with a mother well 90 meters deep, cost approximately $213,000 when completed in 1950. Because of inflation and higher wages, the capital costs of constructing this qanat today would be about $387,000.

THE DISTRIBUTION AND DIFFUSION OF QANATS

Qanat technology apparently originated in the highlands of western Iran, northern Iraq, and eastern Turkey some 2,500 years ago, possibly in connection with early mining ventures in that region. Laessöe has argued that qanats supported a flourishing civilization near Lake Reza’iyeh (Urmia) which was destroyed by Sargon II in his eighth campaign in 714 B.C., but unfortunately this information is based on a badly damaged tablet. It is certain, however, that later Assyrian cities, particularly those on the Tigris River, relied on qanats for their drinking water. One qanat built during this period bears the inscription of Sargon’s successor, Sennacherib (705–681 B.C.); this conduit, some 20 kilometers long with shafts spaced every 45 meters, still carries water to the city of Arbil. The capital city of the Medes, Ecbatana (modern Hamadan), was also watered by qanats in the seventh century B.C. and Darius’ capital at Istakhr may also have used this water supply system.

The core area of qanats then lies in the realm of the Persians whose language is rich in words relating to qanat technology and where qanats are very old, very numerous, and construction techniques are fully developed. Qanat technology was widely applied on the Iranian plateau by Parthian times on the numerous piedmont alluvial plains, where near horizontal tunnels can intersect sloping water tables, which provide an ideal setting for qanat construction. In modern times, most of the major cities in Iran including Tabriz, Qazvin, Sāveh, Tehran, Yazd, and Kirman rely on qanats for domestic and irrigation water and chains of wells radiate outward from each of them (fig. 4). It is estimated that nearly 15 million acres of cultivated land, one-third to one-half of the irrigated area of Iran, are watered by some 37,500 qanats of which an estimated 21,000 are in fully operating order and 16,500 are used but need repair. Their aggregate length has been placed at more than 160,000 kilometers; their total discharge at 20,000 cubic meters per second. The Nishapur Plain near Mashhad alone is reputed to have “12,000 springs fed by 12,000 qanats.” Though these figures are suspect, having never been verified by field work, there is no doubt that qanats are the major source of irrigation water in Iran.

The first diffusion of qanats out of this core area occurred in the Achaemenid period when the Persians established an empire extending from the Indus to the Nile. To the west, the Persians car-
ried qanat technology across the Fertile Crescent to the shores of the Mediterranean and southward to Egypt and Saudi Arabia. In the Iraqi foothills of the Zagros, qanats water the cities of Kirkuk and Arbil.18 Deeper in the foothills, the city of Sulaymaniyah receives its entire water supply from tunnel-wells.19 In Palestine and Syria, qanats are found in the Jordan Valley, in the Qalâmûn region of eastern Syria, near Palmyra, and northeast of Aleppo.20 Recently, several qanats have been uncovered in the Wadi Arava south of the Dead Sea at the oases of Ein Dafeh, Yotvata, and Ein Zureib; the Ein Dafeh qanat empty into a reservoir used in Persian and later Roman times.21 In Syria accurate dating is a problem because some qanats are ancient, others were constructed in the Byzantine period, and a few are recently built. At the village of Michrîfe-Qatna, which occupies the site of an old Hittite fortress 18 kilometers northeast of Homs, a qanat-like canal apparently supplied water to the town very early.22 The more elaborate Byzantine qanat systems at Moufagar, Amsareddi, and Ḥadeym (ancient Acadama) are Roman or repaired Persian constructions.23 Qanats on the Seleimiya Plain, however, have been built and renovated by the Ismailis who settled this region in the 1870’s.24

28 G. F. Walpole, An Ancient Subterranean Aqueduct West of Matruh, Survey of Egypt 42 (Cairo, 1932).
Persian workmanship, as the name of a nearby ridge, Firzan, attests.31  

East of Iran, qanats are used in Afghanistan, Central Asia, and Chinese Turkestan (Sinkiang). Here, qanats are called by their Persian term (kariz) rather than the Arabic qanat, yet whether this technology spread eastward during the Achaemenid diffusion or at some later period is uncertain. In Afghanistan qanats are a major source of irrigation water in the south and southeast, especially around the city of Qandahar.32 In Pakistani Baluchistan, approximately two-thirds of the water in the city of Quetta is supplied by qanats, which also irrigate some 90,000 acres of land in the vicinity.33 Qanats were apparently used in western China as early as the second century B.C., yet Huntington claims that they were not used in the Turfan Basin, which has one of the most extensive qanat systems in the world, until the eighteenth century.34 In modern times approximately 40 per cent of the people in this region depend for water on qanats dug by imported Turki laborers.35  

In a second major diffusion, qanat technology spread with Islam and the Arabs across North Africa into Spain, Cyprus, and the Canary Islands in the seventh and eighth centuries A.D. In North Africa qanats (here called fuqarā) are widely distributed, though having been built and maintained by Negro slave specialists, new constructions are rare.36 In Libya they are found in the Kufra oases and in the Fezzan, particularly at Ghadames.37 In Tunisia qanats have been reported north of the Chott Djerid38 and in Algeria, on the borders of the Tademait Plateau in the Touat and Tidikelt districts south of the Great Western Erg.39 In Morocco qanats are called khettara or rhettara and are used on the northern slopes of the Atlas, particularly around the city of Marrakech,40 and south of the Atlas in the Tafiltalt.41 It is in these last three regions, in the Tademait district of southern Algeria, near Marrakech, and in the Tafiltalt of Morocco, that qanats reach their greatest development outside the Persian core area.  

Qanats were introduced into the Touat and Tidikelt districts of Algeria several centuries before the Arab conquest by Jews or Judaized Berbers fleeing from Cyrenaica during Trajan's persecution in A.D. 118.42 These refugees were the first Jewish colonists in the Tademait region, establishing their capital at Tamentit south of Adrar.43 Having absorbed the fundamentals of qanat technology during their long stay in Persian territory, first in Palestine and later in Cyrenaica, these Jews introduced qanats into the Western Sahara. In this region today, more than 1,500 kilometers of qanat tunnels can be found.44 Near Aoulef al


34 Huntington's evidence, which was based on local interviews, is given negative support by the lack of any references in Chinese sources to qanats in the Turfan Basin down to T'ang times and even later. Ellsworth Huntington, The Pulse of Asia (New York, 1907), pp. 310, 317; Aurel Stein, "Note on a Map of the Turfan Basin," Geographical Journal 82 (1933): pp. 236-246.


43 Cressey estimates that there are now 40 kilometers of qanat tunnels in Tamentit with mother wells 60-75 meters deep. George B. Cressey, op. cit. 48 (1958): p. 44.

44 Estimates vary. Gerster, for example, states that there are about 3,000 kilometers of tunnels on the borders of the Tademait with a total yield of 600 gallons per second. Georg Gerster, Sahara (New York, 1961), p. 74.
Arab, forty qanats now produce about 7,000 gallons of water per minute to support some 8,000 people scattered over 31,000 square kilometers. At the oasis of In Salah, the upkeep of existing qanats alone cost the administration more than 115,000 working days each year.

Qanats were first built in Marrakech in the eleventh century A.D. during the reign of the Almoravides. Today some 85 qanat systems are found on the Haouz plain, 40 of which are functioning and carry water to the city. Most of these systems are rather short; the largest lie to the south of the city, are 4–5 kilometers long, and reach a maximum depth of 70 meters. In the Tafilalt, qanats are most numerous in the oases of Tadrha, Ferkla, Jorf, and Siffa south and west of Ksar es Souk. Margat found 273 qanats in this region, 145 in good condition, providing 1,100 liters of water per second to irrigate some 850 hectares of palm groves.

Qanat technology spread into Europe with Arab culture; they were used marginally in the Spanish province of Catalonia and at Madrid and are still a major source of water in Cyprus and the Canary Islands. Recently, abandoned qanats were discovered in Central Europe, in Bavaria and Bohemia, though when or how qanats spread into that region is unknown. In Cyprus the total flow from all qanats amounted to 9.25 billion gallons in 1950 with an additional capacity of 1.85 billion gallons then under construction. In the Canary Islands, Tenerife and Gran Canaria are literally dotted with galeries, as qanats are called here and in Latin America. Until recently, it was assumed that the New World qanats which are found in Mexico at Parrás, Canyon Huasteca, Tecamachalco, and Tehuacán and in the Atacama regions of Peru and Chile at Nazca and Pica were introduced into the Americas by the Spaniards. It appears, however, that the qanat systems of the Atacama region may predate the Spanish entry into the New World; thus qanats have become an additional item in the continuing pre-Columbian trans-Pacific diffusion controversy.

SOME SOCIO-ECONOMIC CONSIDERATIONS

Qanats are expensive to build and expensive to maintain, but their distribution in the dry lands of the Northern Hemisphere is nearly circumglobal, because for centuries qanats have been the most economic means of water supply in regions where water is the critical scarcity. Most qanats were built by powerful political rulers and in countries like Iran each leader was evaluated on the basis of the number of qanats (and mosques) constructed during his reign. The qanat was built of local materials; slaves were given the task of constructing them and maintenance was solved by a corvée. In recent times, however, deep wells which have several advantages over qanats have been introduced into qanat-watered regions. Deep wells are not limited by slope or soil conditions and can be placed at locations convenient in terms of transportation, market, or other considerations; they draw water from the permanent aquifer thereby eliminating seasonal variations in flow. Nor is water wasted when demand falls short of supply. But altering or replacing the qanat system with deep wells requires major adjustments in social patterns, customs, and laws that have developed around this water-supply system; thus a conflict between these two technologies is developing.

There were 305 qanats on Tenerife in 1960. See map in: Johannes Humlum, op. cit. 16 (1965): p. 107.


After qanats came into widespread use in the Muslim World, a body of custom and law (shari'a) developed to regulate the water-supply system. The earliest known codification of this law is the Kitābī Qanī or Book of Qanats which was in existence in the eleventh century. Its original purpose was to protect qanat owners in a risky but essential investment in permanent agricultural settlement. The law of harim (“borders”), for example, gave the owner protection over territory surrounding his qanat and prohibited the sinking of new mother wells within one kilometer of existing qanats. As a result, large areas in the vicinity of cities like Tehran, Kirman, Sulaymaniyah, and Qandahar, where the density of tunnel-wells is high (figs. 2, 4), are closed to new settlement thereby stabilizing agricultural acreage in regions with growing populations. Qanat owners in these cities are suspicious of deep wells and decreased flow in any qanat leads to immediate accusations that the nearest deep well has drained the water table.

These difficulties are compounded by the pervasive influence of qanat utilization on the structure and social patterning of settlements, specifically on (1) the structural organization of the settlement around this water-supply system and (2) the fragmentation of qanat ownership among the population. In small towns and villages watered by qanats, the stream runs the length of the settlement passing by or through each household compound before irrigating the grain fields downslope. Within these settlements, the location of each household with respect to the watercourse determines the quality and quantity of its water supply, and, as a result, reflects the social and economic status of its occupants. The prosperous houses of the elite are located in the upper sections where water is clean and plentiful; the poorer households of sharecroppers and laborers are located downstream where the volume of water is less and it has been polluted by use. In many cases, the qanat enters the settlement at the house or garden of the most powerful local landlord. In larger towns, this social gradient along water-supply lines is often obscured by historical development and the maze of twisting distribution channels whose every diversion is a vestige of some past business transaction, marriage, or inheritance. In short, the social patterns of many qanat-watered settlements are oriented to water supply and alterations in one system involve changes in the other.

Further, the ownership of qanats is widely diffused throughout the population, for although qanats are built by wealthy individuals, the constant need for repairs caused by their sensitivity to natural and social disruptions leads to rapid fragmentation in ownership. Many qanats have as many as two or three hundred owners and the water of some qanats is divided into 10,000 or more time shares. In some cases, the system of dividing water goes back hundreds of years. The current division of water at Ardistan in central Iran, for example, dates back to the thirteenth century when Hulagu Khan (the grandson of Genghis Khan) ordered that water be divided into twenty-one shares with each allotted to a certain quarter. For several qanats in Kirman this process of fragmentation has progressed so far that the smallest owner has rights to only thirty seconds of water once every twelve days. Frequently, a water bailiff is appointed to administer the distribution of qanat water in time and space and it is he who settles the numberless disputes arising from its intricacies.

The qanat system, which once revolutionized settlement patterns in the dry lands of the Old World, is now a conservative force supporting the maintenance of existing settlement patterns and social and economic conditions. They have become through custom and law an organizing principle of traditional preindustrial society and resist change and retard new developments in its fabric. It seems likely, therefore, that qanats will continue to play a major role in the future economic development of settlement and irrigation in these desert regions and that they will not pass quickly into history.

SUMMARY

Horizontal wells or qanats were discovered in the vicinity of Armenia more than 2,500 years ago and rapidly spread to become one of the most
important methods of dry-land irrigation in the Old World. In parts of Iran, Afghanistan, Algeria, and Morocco, this ingenious device has made human settlement possible in distinctly marginal areas. Modern technology threatens to replace the qanat with the more efficient deep wells, but the extent to which social and economic patterns have become enmeshed with this watersupply system will make the transition difficult.

BIBLIOGRAPHY


Briggs, Lloyd C. 1960. Tribes of the Sahara (Cambridge, Mass.).


du Buisson, Messnil. 1935. La Site archéologique de Michrîfe-Qâta (Paris).

English, Paul Ward. 1966. City and Village in Iran (Madison).


Kuros, Ghomal-Resa. 1943. Iran Kampf um Wasser (Berlin).


POIDEBAED, A. 1934. La Trace de Rome dans le désert de Syrie.—Le limes de Trajan à la conquête arabe.—Recherches aériennes (1925-1932), Bibliothèque archéologique et historique 18 (Paris).
REIFENBERG, A. 1955. The Struggle between the Desert and the Sown (Jerusalem).
WALPOLE, G. F. 1932. An Ancient Subterranean Aqueduct West of Matruh, Survey of Egypt 42 (Cairo).