Old World irrigation technology in a New World context: *qanats* in Spanish colonial western Mexico

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Spanish colonists imported ancient Arabic irrigation methods into Mexico. Even though historians have made little of the qanat *systems, archaeological research in Jalisco has revealed their significance in the colonial economy of Mexico.*

Key-words: irrigation, Spanish colonies, economy, *qanat*

Introduction

A *qanat* is a subterranean conduction device designed to tap the water table and bring the water to lower lands for irrigation, and is therefore a form of underground aqueduct. These features are an early example of technology transfer from the Old World to the New, and were already in use in various locations in Spanish Colonial America by the end of the 16th century. This paper documents a *qanat* system from Guadalajara, Jalisco, in western Mexico. We present a basic description of the *qanat*, an analysis of its hydraulic properties, and the evidence for its construction during the Colonial period (1521–1821) and continued maintenance in this century. The discovery of such an extensive, yet historically undocumented, irrigation system, in a region whose Colonial-period economy is still poorly understood, underlines the importance of investigating rural agrarian features as well as the urban communities that are the focus of so much of historic archaeology in Mexico. An appreciation of the importance of *qanats* and other Colonial irrigation features has been slow in coming, but recent works (e.g. CEHOPU 1993) indicate a growing interest.

Qanats in the Old and New Worlds

The term *qanat* literally means 'lance' or 'conduit' in the original Arabic (English 1968: 170). A *qanat* hydraulic feature is defined as a horizontal channel dug into an alluvial fan until the water table is pierced or a spring is tapped. The ground water then flows downslope to emerge from the channel mouth as a stream. In addition, access shafts are dug at regular and frequent intervals, to facilitate the original construction of the conduit as well as to allow ventilation and entry for cleaning and maintenance (*cf.* English 1966; Forbes 1956; Drower 1954; Wulff 1967: 1968; Glick 1970). *Qanat* engineering is a major investment in agricultural intensification and is usually restricted to arid lands where water for irrigation is extremely scarce.

It has been postulated that they originate in Armenia, where tunnel digging employed in mining has a long history (Forbes 1956: 666; English 1968: 175). In the 1st millennium AD, *qanats* spread further throughout the Near East and the Mediterranean basin, and were brought to Spain after the Arab conquests of the 8th century (Gonzalez Tascón & Vazquez de la Cueva 1993). The Spanish brought *qanat* engineering overseas to the Canary Islands and, during the 16th century, to colonies in the New World. *Qanats* are found in various areas in Peru and Chile (Barnes & Fleming 1991), and in central and northern Mexico (Glick 1970: 352; Henao 1980; Kjell & Whiteford 1989; Wilken 1990), where they date from the 16th–20th centuries. The Persian examples are still the best studied, and some 37,500 *qanat* systems in the 1950s and 1960s irrigated approximately 15 million acres, which gives some indication of the *qanat*'s modern contribution to agriculture.

Considerations of scale aside, the actual technology applied to *qanat* design and construc-

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Received 6 August 1998, accepted 4 December 1998, revised 15 February 1999.

ANTIQUITY 73 (1999): 440–46

tion has changed little over the millennia or over space. Since there are no direct records concerning the *qanat* systems in western Mexico, a brief summary of *qanat* design and construction from other areas seems appropriate. While *qanat* construction is expensive (see the cost discussions in Wulff 1967; 1968), it is not as labour-intensive as one might imagine. Because of the physical constriction of the tunnel/well environment, construction teams seldom have more than 6–10 members, half of them on the surface and half underground. In the Persian case, the *qanat* excavators are a hereditary class of professionals, and highly respected (English 1966: 136–7).

The master digger decides where the mother well (a misnomer as this is not actually used as a well) should be dug. This vertical shaft is dug at or near the top of an alluvial fan, and is meant to determine the depth of a permanent and reliable deposit of ground water. Once this point is reached, a calculation can be made as to where the mouth of the channel should be located, and how much land can be irrigated from the projected *qanat*. Armed with picks, shovels, baskets and small lamps, the diggers begin to extend the tunnel from the mouth toward the mother well. String alignments and levels are all that most master-digger engineers need to keep the channel at the correct angle of incline, the maximum gradient being around 1:1000 to 1:1500 metres, and thus nearly horizontal. The tunnels are seldom more than 1 m wide and 1·5 m high, but may continue for kilometres. As the channel is small, the master digger does most of the actual excavation, aided by a few workers behind him to haul away the spoil to the nearest shaft. On the surface, other workers haul up the material from the excavation below. The shafts are often dug ahead of the channel's course, thus immediately facilitating both access and air-flow into the tunnel as work progresses. Shafts are regularly spaced from 15 to 150 m apart, and are typically less than a metre in diameter. The deepest ones are over 100 m.

Description of the Qanat La Venta

The *qanat* system discussed here flows from north to south, exiting directly to the north of the town of La Venta del Astillero. This town, in turn, is about 15 km northwest of Guadalajara, in the highlands of Jalisco, Mexico. We first became aware of portions of the system in the mid 1970s, during our surveys of caves and mines in the area. However it was only when one of us began a prehistoric archaeological survey in the region that we began to recognize the *qanat*'s scale and significance for irrigation (see Beekman *et al.* 1996 for a more detailed report). Today the Qanat La Venta is a tunnel cut into a scarp behind La Venta del Astillero, burrowing into the agricultural plain for over 400 m before a heap of modern refuse blocks the passage. On the surface, a series of regularly spaced shafts follow the path of Segment A below, before splitting into two branches beneath a modern farm (Segments B to the northwest and F to the northeast) (FIGURE 1). From this point, we could only trace the path of the *qanat* by the shafts on the surface, through aerial photos, and through interviews with residents who remember the system. Segment F bifurcates after another 490 m into Segments G and H, which can only be traced further on the aerial photos and by scattered surface indications. Segment B divides into two more segments (C and D), both of which continue to the northwest and towards the piedmont along Tepopote Mountain. A final Segment E is visible only on aerial photos, but is found in the same general area, and on the same overall trajectory (FIGURE 2).

There is evidence that the shafts were the starting points of the excavations, and we suggest that certain strategies in the use of labour can be deduced. The shafts were excavated from above at very regular intervals of 11·8 to 13·3 m in Segment A (FIGURE 3), but are more widely and unevenly spaced in Segment B (12·3 to 15·0 m). The workers dug straight down to a relatively horizontal geological stratum, presumably a softer one, that lay on average 7·2–7·5 m below the surface. The tunnels linking each shaft left wide grooves visible on the ceiling throughout Segment A. These grooves tend to meet unevenly and off the direct line between the shafts, indicating that in this section, at least, the tunnels were excavated from the shafts outwards. Being lowered into a 60–80-cm diameter shaft to a point over 7 m below the surface, and then being required to dig in that position, must have been highly unpleasant at first. After some initial digging, however, more individuals could descend and begin excavating towards the next shaft in the sequence. The availability of plentiful unskilled labour, or time constraints, may have affected the decision to

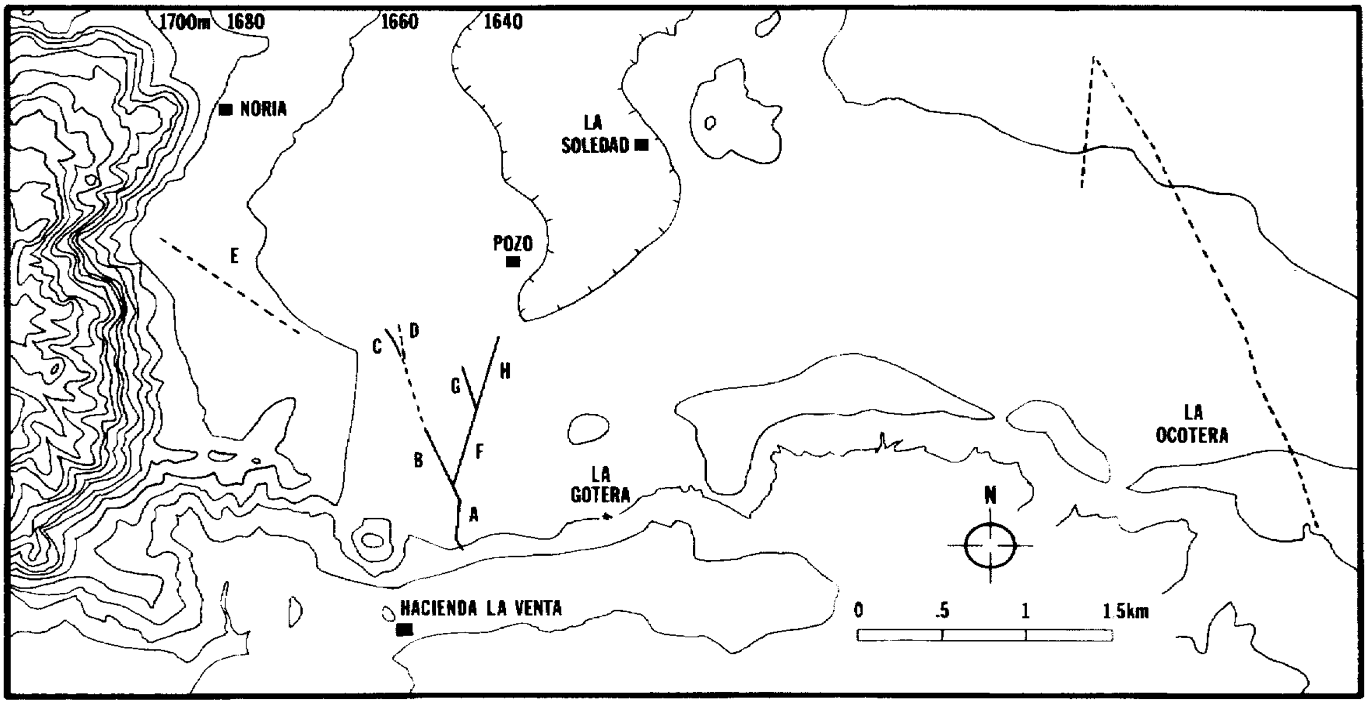

FIGURE 1. *Map of all known segments of the Qanat La Venta, and its relationship to local geography. Letters correspond to Segment numbers used in the text. 20-m contour interval.*

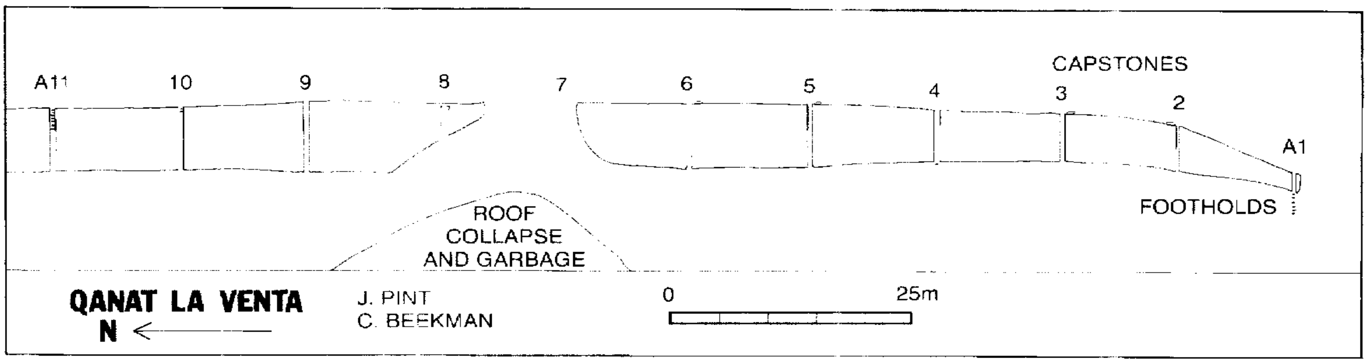

FIGURE 2. *Section of the the entrance to Segment A, Qanat La Venta. Letter–number combinations designate shafts.*

excavate outwards from each shaft, as this would have allowed larger numbers of labourers to work simultaneously. Excavating the *qanat* in the more traditional Near Eastern manner of digging the channel from point A to point B would have been slower, but this strategy works well with only a few professional diggers and requires no real overarching organization or direction. Unlike the shafts in Segment A, those in Segment B are unevenly aligned on the surface. Therefore. this section of the channel appears to have been excavated first, winding around difficult or dense areas in the matrix, and the shafts were excavated afterwards.

The channel itself ranges from 12·9 to 5·9 m in height in Segment A, decreasing markedly as one gets further from the channel mouth (FIGURE 2). At a point shortly before the split into Segments B and F, the channel of Segment A became impossible to traverse due to flooding and mounds of refuse tossed down from the shaft openings above. We therefore cannot comment on the form of the channel beyond this point. Nevertheless, Segment A is quite informative. Unlike the upper reaches, the lower section of the channel is relatively straight, suggesting that the irregularities in the original tunnel were smoothed out as the channel was deepened, and the marks of small flat digging tools are still to be found in many areas. The present width of the channel varies from 0·6 to 1·0 m in those areas where toolmarks are preserved along both eastern and western walls. These are, of course, the only sections that we can trust to represent the width of the channel at the time of its construction. The section closer to the mouth of the channel is considerably wider, but no tool marks could be discerned. Following the pattern of *qanats* elsewhere, we might expect the area closer to the mouth to be wider to form a reservoir, but the obvious deterioration of this section leaves the matter unresolved.

Later refurbishment of the Qanat La Venta

We believe that the Qanat La Venta shows evidence for a later stage of construction or modification. Two brick check dams, or flow-control devices, were found within the channel. These features appear to have functioned to create small reservoirs within the channel, and the remains of ceramic pipes lead from these dams towards the entrance. The dams would probably date to this century or the last, to judge from their preservation and similarity of the bricks to other materials in the town of La Venta. Several local informants also confirmed that there had been ceramic pipes leading from the *qanat* mouth to an *hacienda* building in town early this century.

The shafts on the surface also suggest later modifications. Several of the shafts, particularly in Segment B, retain the vestiges of mortared brick linings around the mouth and for about a metre down within the shaft. Shaft F-3, from the northeastern branch, was actually sealed with a horizontal cap of mortared brick. We suggest that the linings were added to keep the upper edges of the shaft from crumbling, and the one sealed shaft suggests some kind of maintenance, in which some shafts are being repaired and others are sealed off. The similarity in materials and technology between the brick linings and the brick dams within the channel is clear, and strongly suggests that these modifications are generally contemporaneous.

A comparison of our section to that published by English (1966: 31) also reveals that the Qanat

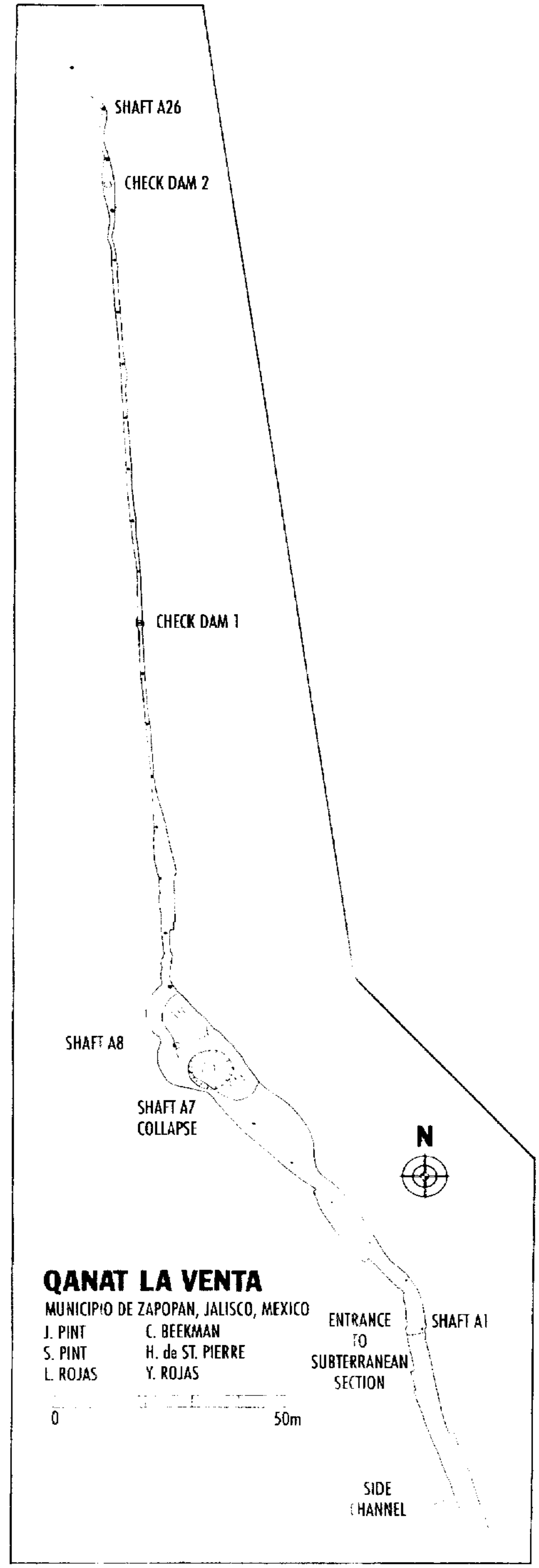

FIGURE 3. *Map of those portions of Segment A that could be entered. Letter–number combinations designate shafts.*

La Venta differs in proportions from *qanats* of the Middle East. The shafts in our example are much shorter, and the channel much taller. Vague traces of ledges often appear high up on the walls of the channel, and if the floor had been at that level, the height of the channel would be nearly identical to Near Eastern examples. On the basis of the channel proportions, the brick flow-control features and the shaft modifications, we believe that the *qanat* was deepened and generally refurbished sometime this century or last, perhaps after a period of inactivity or hydrological change. This conclusion is very much in line with historic trends of *qanat* use in Mexico, as we shall see below.

Hydraulic contribution of the Jalisco *qanats*

To judge from the layout of the segments, the Qanat La Venta appears to make use of more than one form of water collection. The western branches, or Segments B–C, B–D and E, target likely high spots in the water table, and excavation of the shafts and channels almost certainly began at those points. These sections of the *qanat* therefore tend to follow the classical Old World description of *qanat* design, in the sense that they tap permanent ground-water sources at the edge of an abruptly rising hill, above and quite some distance from the mouth. The eastern segments, or Segments F–G and F–H, penetrate only the flat or slightly depressed area to the northeast, and therefore serve as simple filtration galleries. Whereas the water from the western segments would provide a continuous and regular supply, the flow from the eastern segments would have fluctuated seasonally, and hence provided a less reliable and regular flow of water. The two water-control systems come together beneath the modern Rancho el Resumidero, after which the shafts of Segment A are laid out more carefully, with slight adjustments, so as to arrive at the proper location behind the town of La Venta.

The completed Qanat La Venta was a monumental construction, and its remains allow some preliminary calculations. The various segments, once connected, add up to over 8 km of tunnels. If we use channel dimensions appropriate to the proposed first stage of construction, the *qanat* would have a volume of over 24,000 cu. m, or about 12,000 tons of fill. Persian *qanats* of this size are capable of irrigating roughly 150 hectares, presumably in the general vicinity of the modern town of La Venta del Astillero.

There are indications that numerous other *qanat* features existed in the general region around Guadalajara. Two very short and functioning *qanats* were explored at La Gotera, less than a kilometer east of La Venta. A 4-km long feature was also identified on aerial photos slightly further to the east at La Ocotera, although ground confirmation survey found only small variations in surface vegetation. In 1995, construction crews in the western part of Guadalajara encountered another channel. The dimensions as reported by informants are larger than those estimated for the original first phase of the Qanat La Venta, at 3–4 m in height and 2 m wide. The placement of this channel relative to landscape features suggests that it may have functioned as a filtration gallery more akin to the eastern part of the Qanat La Venta. In light of these discoveries, we suspect that the Qanat La Venta is simply the best preserved example of an irrigation system that once spanned wide areas of the western valley of Guadalajara.

Why build a *qanat* in central Jalisco?

There are major differences between the environmental setting and context for the Jalisco *qanats* and those from most of the rest of the world. First, the highland valleys of central Jalisco are not arid, or even semi-arid. The area is close to the well-watered Sierra La Primavera, and receives about 900–1000 mm of rainfall per year, largely concentrated between the months of June and October. Second, the *qanat* system does not penetrate an alluvial fan, but rather a very flat, semi- to fully consolidated deposit of volcanic ash, locally known as *jal*. This deposit is striated in bands of different thicknesses, and was obviously laid down during a long series of volcanic events.

Why was the *qanat* built in an area which was not even semi-arid? The seasonality of rainfall and the highly porous nature of the soils provide an answer. During the dry season (November to May), there is not enough water for winter agriculture, unless provided through irrigation. Natural sources for irrigation in the valley of Guadalajara are almost nil. In addition, the soils are so porous that only sustained rainfall, or water application, will soak them sufficiently so that agriculture is possible. Finally, the water table is fairly low, fluctuating quite dramatically throughout the year, putting reliable water sources at a premium even during the rainy season. A controlled water source during the dry season would therefore have contributed greatly to local agricultural stability.

Date and significance

Our attempts to tie the physical remains of the *qanat* into local history have been hindered by the absence of direct historial references, but some inferences are possible. Archaeologists have recently debated the possible indigenous origins of *qanats* (or *puquios*) in Peru and Chile (e.g. Barnes & Fleming 1991; Schreiber & Lancho R. 1995), so we should at least consider the possibility that the proposed early stage of the *qanat* may be of Pre-Columbian origin. Archaeologically verified methods of agricultural intensification practised in Jalisco in pre-contact times include terracing, raised fields and surface canals (e.g. Weigand 1993). *Qanat* technology shows no clear connection to these strategies. The terraces, canals and raised fields also typically occur close to or leading to native prehistoric settlements. The Qanat La Venta is spatially distinct from the archaeological sites identified during survey (Beekman 1996), but is clearly associated with the Colonial *hacienda* in La Venta del Astillero. While we watch the *puquio* debate with interest, we do not find there to be any compelling evidence for an indigenous origin for the qanat in western Mexico.

If we shift our attention to the Spanish Colonial period (AD 1521–1821), we find that most of the land in this region was incorporated into wheat farms and cattle ranches by at least the 17th century (Gerhard 1993: 134; Gonzalez Navarro 1953; Van Young 1981), which would have created significant demands for consistent water supplies. An anonymous description of Guadalajara in the 16th century lists wheat as the major crop cultivated in the area surrounding the city, and that it was supported by irrigation (PNE 1948: 19–20). Since there are no significant streams in the Valley of Atemajac wherein Guadalajara is situated, this passage supports the existence of some kind of extensive irrigation system, although not specifically the Qanat La Venta, in the first century after the Spanish Conquest.

La Venta also lies on a pass connecting Guadalajara to much of the western part of the state. Older informants reported that the railroad, and large herds of cattle, still passed through this corridor in the early 20th century, and both would have required regular supplies of water. The 20th-century owners of the qanat may have traded its original agricultural function for one oriented towards the logistical support of those individuals transporting goods to urban consumers.

After our initial fieldwork, we began a series of public lectures to bring qanats to the attention of local historians. This has borne some fruit. Municipal Historian Salvador Silva (pers. comm. 1997) has determined that the *hacienda* building in La Venta, so closely associated with the *qanat* in the minds of local citizens, was originally the Estancia Belenitas, founded in the 1620s–1640s. The Estancia was later held by the Franciscan Fray Antonio Alcalde, the Bishop of Guadalajara, by the mid 18th century. This appears to us very significant in light of statements by Seele (1973) and Cleek (1973) who associate the original introduction of *qanat* technology to the New World with the early religious orders. This example of technology transfer somehow escaped Foster's (1960) exhaustive study of Old World transplants, but we believe that the adoption of the *qanat* occurred for functional reasons much like those he proposes for other kinds of agricultural technology (e.g. Foster 1960: 228–9). While both the need for irrigation and methods for carrying it out existed at the time of Spanish contact (*cf.* Weigand 1993), there were no indigenous techniques capable of tapping into the vast reserve of water that lay just out of reach below the surface. The introduction, or imposition, of *qanat* technology by religious orders, helped turn the previously marginal valley of Guadalajara into a centre of food production, and enabled the development of a major population centre.

The later refurbishment of the *qanat* occurred under quite different circumstances. During the 20th century, there was a resurgence in the construction of new filtration galleries throughout Mexico (Seele 1973; Wilken 1990: 281). Older *qanats* in the Puebla and Tlaxcala areas of central Mexico were commonly excavated to greater depths as an adjustment to a lower water table (Seele 1969: 3). This practice may also be linked to a decline in the maintenance of major irrigation works during the Mexican Revolution, and the renovation of these features in the 1920s. We suggest that the postulated refurbishment of the Qanat La Venta was part of a similar process in western Mexico. One elderly informant from La Venta described participating in such a refurbishment early this century, an activity almost certainly corresponding to our second stage of construction.

Conclusions

Qanats are a remarkable example of a widely distributed technology for effectively addressing basic technical problems of water availability and dependability. They have been adopted across a wide area of the world, transported by military conquerors and religious orders, and have retained their easily recognized form and function. The Qanat La Venta of Jalisco in particular shows the flexibility of this technology, and demonstrates the wide range of situations to which it may be applied.

Finally, the normative historical studies of Colonial monuments in the Guadalajara region and elsewhere in western Mexico have primarily stressed churches, the *hacienda* buildings *per se*, and a few public/administrative structures. Rural, agrarian features, such as surface aqueducts, dams, terraces and the *qanat* systems, have rarely been studied by either historians or archaeologists. Historical archaeology throughout Mexico has of course contributed greatly to our understanding of Spanish Colonial America, but we argue that the urban bias remains strong in many areas. It seems clear to us that rural and agrarian features are highly significant for understanding the economic base, but they are unlikely to be heavily represented in the historical archives or within the confines of most ordinary communities. We hope that the current paper has drawn attention to an underused resource, and will encourage historians and archaeologists alike to expand their conception of available data from the Colonial period.

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