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KĀRIZ IV. ORIGIN AND DISSEMINATION

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Where, when, and how was this very complex technique first developed, and what were the paths and stages of its diffusion? These questions are still far from being completely resolved, but at least the broad outlines are already clearly apparent. As with every invention, the fundamental problem is to determine whether the kārēz has one unique initial source (monogenism) or several distinct centers (polygenism). As there has been significant confusion regarding the technique itself, it is necessary to begin by studying more closely the definition of the phenomenon under consideration in order to elucidate its meaning.

(1) *Pseudo-kārēz.* Far simpler techniques of water adduction involving underground channels must be clearly distinguished from kārēz, although they are often grouped together.

One very common technique is an underflow channel in a river valley (Planhol and Rognon, pp. 101-3; Goblot, 1979, p. 53). The underflow channel captures water from the shallow aquifer formed by seepage from the watercourse, whether it be intermittent or continuous. This technique is always subject to significant variations, because it depends on the surface

flow. The level of the channel lowers when the watercourse stops flowing, so that it is tempting to try to find the watercourse again. When the slope of the thalweg is appreciable, a horizontal drain, open to the air downstream and serving to gather the underflow water, can be extended upstream, sinking below the surface of the ground until it reaches the water table. This process is, for example, used in the Sahara in the valleys of the Hoggar (Capot-Rey, p. 328). In Spain, such channels have been known at least since the Middle Ages under the popular name of *cimbras*, although the scholarly term is *galerías filtrantes* (Bazzana), while as far as southern Peru, in the Nazca oasis, they have been in use since pre-Columbian times (Kinzl, 1963; Goblot, 1979, pp. 143-46). In central Iran, in an alluvial water table, this type of water capture (*havābin*) is very frequently practiced (Boucharlat, 2001, p. 157; for the term *havābin*, see Bonine, 1982, p. 145). The underflow channels can reach an appreciable length, although the depth of the shafts is always very short, generally several meters at most. The trench supports are very rudimentary. There is never a mother well, and the excavation is carried out exclusively from the downstream end of the channels. Above all, these channels are solely located in fluvial valley bottoms where the water flow is more or less permanent. As no excavation into the bedrock is necessary for the construction of these channels, this technique is very different from that of the kārēz. Much simpler and ubiquitous, the underflow channel has certainly been an independent invention just about everywhere since the development of irrigation from flowing water.

In contrast, one finds very short underground channels, of a few tens of meters at most and without excavation shafts, in mountainous regions where they open onto valley slopes (Figure 7).

These allow access to a subterranean aquifer in order to use its water for irrigation and generally have a very weak output of a few liters per second. Outside the Iranian lands short underground channels have been described in the hills of Judea (Ron, 1985, pp. 152-53; 1992) under the names of “spring tunnels” and “spring-flow tunnels.” In the southeast of the Hazārajāt in central Afghanistan (Balland and Brognetti), they are locally known as kārēz, even though they are not comparable to the complex constructions of real kārēz. In Judea these elementary tunnels seem to date back at least to the 9th-8th century BCE, well before the period of Persian domination, when real kārēz were introduced into the Mediterranean Levant (see iv (3), below). But in the Hazārajāt the population was surely composed in part of refugees from the

neighboring piedmont, where the real kārēz technique had long been in use, and such tunnels could have been influenced by their memories of that technique or be imitations of it.

Finally, there are partially or completely subterranean adduction channels. Tunnels of every kind that carry water from a river or spring to a settlement are known in great number at least since the 1st millennium BCE in various areas of the Near East and the Mediterranean. It has been suggested that the kārēz technique might have been their precursor (Grewe, 2003). But this returns us to the basic problem.

(2) *Mining technique.* It has long been an error to try to identify the necessary water supply of human settlements and households as the first stage of *kārēz* development in all of these more or less subterranean processes of water transport (in particular Kouzine, 1956). Instead it is advisable to carefully distinguish between the invention of the underground water channel technique as such and its application to agricultural irrigation. It is to the credit of Goblot (1979, pp. 23-28, 53-54) that he clearly dissociated these two problems when he showed decisively that the technique is an invention of miners faced with the widespread problem of evacuating their underground operations after they had reached the water table. This idea had actually already been presented by R. J. Forbes, a historian of technology, who strictly confined himself to this perspective and in no way developed the geo-historical consequences of his discovery; these were set forth and codified by Goblot in a precise manner. The water channels are an essential component of mining operations (see online MINING IN IRAN), and Goblot uses the felicitous expression “horizontal drilling” because the fundamental element is the channel, and not the shafts, which serve only for the evacuation of debris and whose function is secondary, although they are the most visible component. For the ancient miners this invention was a necessity. Until the advent of mechanical pumps in the 18th century, miners had no other means to lower the water level in the mines than to drill drainage channels into the open air, wherever the exterior topography permitted them, to release water by means of gravity. This observation leads to the logical conclusion that the first underground water channels were constructed by miners with the objective of clearing their shafts of water, well before the channels’ possible role in irrigation was recognized.

In consequence, the question of the dating of this invention and its geographical location becomes practically insoluble. Given the pressing

necessity of draining the shafts of water, the invention must have followed quite closely upon the development of the first deep mining enterprises in the 3rd millennium BCE. Moreover, since the flooding of mines is a general problem of all mining operations, it seems illogical to assume that the invention originated at a single unique center. In fact, numerous instances of almost certainly independent inventions are known. For example at Liège, the city's water supply had been provided by water drained from the coal mines since the 13th century (Goblot, 1979, pp. 183-85). In the German and Czech areas of central Europe, channels date back at least to the 15th century, notably at Selb in the Fichtelgebirge (Klaubert, 1966, 1967, 1973; Goblot, 1979, pp. 185-87). These channels and their distribution are certainly connected to the Harz and the Erzgebirge, important mining regions since the Middle Ages, and they still carry today water to the cities. More recently, a first underground channel was excavated in Marseilles in 1814 to drain the waters of the coal mines in Provence (Goblot, 1979, pp. 187-88). An autonomous innovation cannot be absolutely proven for any of these examples, since local archives are missing. But the multiplicity and extreme dispersion of these geographical locations seems to argue for independent inventions and against a transfer of the technique from other regions. In other countries a transfer may have been possible. From the Etruscan period (see Goblot, 1979, pp. 188-92 about the diversionary water channels known as *cuniculi* in the Via Appia, dated 312 BCE) there were underground water channels supplying water for urban settlements or large rural estates, notably Gallo-Roman *villae*, in the Hellenistic and the Roman worlds, and references to these have continually increased in archeological excavation reports (Planhol, 1992; Kayser and Waringo; Kremer; Özis). These data document the diffusion of irrigation channels within the Mediterranean area at the same time as that of the simple subterranean tunnels whose technique had originated in the Near East in connection with the inventions of metallurgy and mining.

In sum, even though it is still not possible to determine the exact location or even the approximate date, it is certain that underground water channels were initially invented in the Near East. But no importance should be attached to the hypothesis of J. Orchard and G. Stanger that underground channels originated as early as the end of the 4th millennium BCE. Orchard and Stanger (1994, p. 87; 1999, pp. 96-103) do not have any concrete data, and the hypothesis testifies to a lack of knowledge concerning the historical development of irrigation techniques (cf. Boucharlat, 2003, p. 168).

(3) *Agricultural uses in the Iranian lands.* The use of underground water channels for irrigated agriculture originated on the Iranian plateau, and their dissemination was directly linked to the culture and political power of Iran under the Achaemenid dynasty (ca. 558-330 BCE). The hypotheses occasionally put forward concerning the existence of autonomous centers of origin in Egypt or Xianjiang (Chinese Turkestan) do not withstand examination, as can be demonstrated by a simple theoretical argument. At the beginning of the 21st century more than 80 percent of the worldwide water use by the means of kārēz occurs in Iran and Afghanistan (see below, v). In comparison, all other sites of kārēz use in the great desert zone of Africa and Asia seem sporadic, peripheral, and of altogether minor importance. Moreover, the widespread occupation of the arid and subarid piedmonts in Iran and Afghanistan was only possible because the kārēz technique has reached by far the highest degree of perfection and diversification in its uses in these two countries. This observation is in line with the general ethnographic rule that a technique's place of origin should be sought in the area where the density of its use is the greatest and its advances have multiplied.

But at what exact date did this major turn between the mining and agricultural eras occur? This question cannot be any better answered than the question of the technique's initial invention. The historiographical sources for kārēz are very late, and none offers any support for the date which Herodotus's reference to the river Korys (see above, i) seems to indicate. Of very little value is the 18th-century chronicle of Oman, in which Sarḥān b. Saʿid Ezkewi ascribes the local construction of *aflāj* to Solomon and claims the use of *aflāj* during the time of Darius (see Boucharlat, 2007, p. 163, n. 1). Nor is it today any longer possible to accept the thesis of the Urartian origin of the kārēz technique. The idea was first advanced by F. F. C. Lehmann-Haupt (1926, pp. 111-14), who had widely traveled in the Lake Van region. A few decades later J. Læssøe tried to further to develop this thesis. Læssøe made a dubious interpretation of an Akkadian source for the eighth campaign of Sargon II of Assyria against Urartu in 714 BCE, and he took Akk. *ḫirītu* to mean kārēz. He based his claims on the importance of the ancient hydraulic facilities known in the Lake Van region and because of the mining skill attributed to the Urartians; thus construction of evacuation channels by them seemed plausible. The thesis was accepted by Goblot (1979, pp. 62-63, 67-69) and subsequently widely disseminated in the scientific literature. But M. Salvini (pp. 149-50, figs. 4-6) has successfully rejected the idea by showing that the hydraulic facilities described by Sargon were only surface channels. Thus the

oldest and incontestable reference to kārēz is made by Polybius (X.28). Although the passage is not without errors and guesswork (Briant, 2001a), Polybius clearly describes subterranean water channels (Gr. *hyponomoi*) on the southern piedmont of the Alborz, in the region of Hekatompylos between Semnān and Dāmḡān. It is not until the 11th century CE that the Persian Moḥammad b. al-Ḥasan al-Karaji writes an Arabic treatise about the excavation of underground water channels.

The archeological data are of no greater help. At present, there is not any archeological evidence for the construction of kārēz in Iran and Central Asia before the Islamic period (Gentelle, p. 243; Kohl, p. 195; Christensen, p. 129; Boucharlat, 2001, pp. 177-78). The finds of potsherds from the Parthian or Sasanian periods in the underground channels of Gonābād are still not sufficiently well documented to constitute acceptable evidence (Labbaf Ḵāneki; Boucharlat, 2001, p. 179). Moreover, unsupported assertions about kārēz in Iran and Central Asia continue to circulate widely in the scientific literature (e.g., Biscione, p. 13; Lisitsyna; MacLachlan, 2000, p. 183, even claims an age of 7,000 years for the technique!).

At present Oman is the only country for which the problem has been studied, thanks to the results of recent archeological excavations (Boucharlat, 2001, pp. 159-72; 2003), and the examined sites provide evidence just for underflow channels (see iv (1), above) dating to Iron Age II (1100-600 BCE). The oldest and accepted archeological evidence for kārēz has been found in Egypt's Libyan desert and dates back to the Persian occupation. In the early 1970s A. Fakhry (1974, p. 34) suggested that in the Baḥariya oasis the plan of a tomb from the 26th Dynasty (664-525 BCE) might indicate its original construction in relation to a preexisting underground water channel. Consequently Fakhry proposed to date the irrigation technique to a period before Cambyses' conquest of Egypt in 525 BCE, but it has been impossible to confirm this early date, as his study was posthumously published and the text does not precisely identify the location of the tomb. Although Fakhry's date has been accepted by I. Kobori (1973, p. 60) and F. Bliss (1983, p. 130), it most likely results from an error and should be abandoned (Planhol, 1992, p. 135). At ʿAyn Manāwir in the Karga (Ḵāreja) oasis, however, archeologists have excavated numerous underground water channels in the existing rock. These channels have been indisputably dated to the Persian 27th Dynasty (525-404 BCE), and their multiplication after the conquest of Cambyses seems directly related to a systematic plan for rapid agricultural settlement (Wuttmann). The complete novelty of this irrigation

technique in Egypt affirms that kārēz had been already perfectly mastered in the Iranian lands when the Achaemenid empire was established. The expansion of farming on the Iranian plateau had only been possible because the *kārēz* assured a permanent water supply. The underground water channels were the essential element of the irrigated agricultural system which allowed for both the permanent cultivation of forage for large herds of cattle and for a powerful cavalry, the foundation of the Achaemenids' military strength (Planhol, 2006, 2010). Still, it remains impossible to specify the point in time when this essential innovation originated on the Iranian plateau: immediately after the arrival of the Iranian peoples, or did it perhaps even predate their settlement on the Iranian plateau?

It is indisputable, however, that the initial geographical expansion of the kārēz technique corresponds to Iranian cultural influence, so fully displayed in the provinces of the Achaemenid empire. The case of Egypt has just been mentioned. In the Fertile Crescent, underground water channels are numerous throughout Syria from Urfa (Edessa)—where the term *kāhriz* is used—and the environs of Aleppo to the Jabal al-Doruz. Tradition ascribes their introduction to the Persians, and their frequency seems to imply an organized, intentional transfer of the technique (Goblot, 1979, pp. 127-32), rather than a sporadic and anonymous diffusion. In comparison with Egypt, the greater geographical proximity of Syria to the Iranian plateau makes such a transfer more likely. Farther south, in Palestine, the presence of kārēz seems also to be attested during the Persian period (Ron, 1989, p. 219). But only two underground channels are known in Asia Minor, near Kayseri and Ankara, and while the one at Ankara is described locally as Byzantine (*Rumi*), its use during the Saljuq period (1081-1307) seems to be attested (Goblot, 1979, pp. 126-27). As it appears hardly plausible that Iranian specialists had accompanied the Turkish invaders to build the first Anatolian kārēz at the end of the 11th century CE, the introduction of this technique to Asia Minor can probably be dated to Achaemenid rule between the 6th and 4th centuries BCE. The small number of kārēz can be explained by the long-established use of an agricultural system of rainfall cultivation which yielded very little to irrigation. Moreover there was a major and very stable frontier that impeded the transfer of techniques between the Irano-Armenian area and the Anatolian plateau (Planhol, 1992, pp. 136-37). But the question remains open for Cyprus. Goblot (1979, pp. 133-34) suggested that the construction of the island's underground channels dated to the end of the 16th century CE. He argued that they were an Ottoman imitation of the kārēz in neighboring Syria,

since they are not mentioned in the numerous documents from earlier periods, especially in Byzantine and Crusader sources (Oberhummer, 1903, pp. 226-34). But Goblot's argument *ex silentio* is insufficient, as it does not exclude the much earlier introduction of kārēz technique during the Achaemenid period (Planhol, 1992, p. 137).

With regard to the Arabian peninsula J. C. Wilkinson (1977, 1983) has analyzed the case of Oman, where he sought to distinguish the methods, effects, and origin of two phases of channel development. A first and most important phase was dated to the Achaemenid period, when the underground channels spread widely over the western slopes of the mountains. A second phase during the Sasanian period was confined mainly to the coastal plain, although nonetheless accompanied by technical complements and even innovations, such as cement-lined channels—this is a Roman technique, and the channels might have been built by Romans taken prisoners of war by Shapur II (r. 309-79)—and inverted siphons for the routing of channels under rivers. But Wilkinson's distinction appears highly theoretical. While the use of underflow channels in Oman certainly dates back to the end of the 2nd millennium BCE, the date of the introduction of genuine kārēz technique continues to remain unclear. Most recently R. Boucharlat (2001, p. 180) has suggested that kārēz were probably not introduced before the beginning of the Christian era and perhaps even as late as the period of the first Ibadi Imamate in the 8th century CE. Nonetheless, the eastern side of the Arabian peninsula was so long under the political influence of Iran that it appears logical to assume that in the 5th century BCE the Achaemenids contributed a technique which they had already fully mastered.

It is against this background that the use of underground water channels in western and southern Arabia must be considered (for the data, although presented without a comprehensive discussion and not without disorder, see Goblot, 1979, pp. 105-8; cf. Braun, 1974, pp. 20-21). In general, they are a much rarer phenomenon, although they are nevertheless known in the Hejaz, in Yemen, and in Hadramaut. In these regions the Achaemenid invasions and conquests had been too brief to allow serious consideration of a concerted program of settlement and intentional influence. Consequently, terminology becomes particularly important, because the channels are frequently designated by terms derived from the New Persian word *kāriz* (see above, i). Goblot speculated that in the region of Jedda an Iranian specialist or a local craftsman who had recently traveled to the Iranian plateau might have

introduced the kārēz technique. But these scattered islands of Persian terminology in southern and western Arabia, in the midst of quite varied designations from the general Arabic vocabulary for irrigation, cannot be arranged in any chronological sequence. In this Arabic-language environment the linguistic isolates surely testify to a direct introduction of the technique by speakers of Persian or people who had come from Iran. But at what time should it be placed? The question of possible Iranian cultural influence on western Arabia during the Achaemenid period remains completely unexplored, and it might seem reckless to go back so far in the absence of any initial data. Yet such influence is evident during the Islamic period, and texts report the creation of underground water channels at Mecca in the time of Harun al-Rašid (r. 786-809; cf. Mez, pp. 391-92). These facilities were most probably constructed in the context of the Arab-Iranian technical symbiosis during the ʿAbbasid period, when cultural contacts between Iran and the Hejaz were furthered by the Hajj and when the aristocratic social structures conducive to the building of underground water channels were present.

In Afghanistan, the southeast of the Iranian lands, there is a major contrast between the areas north and south of the great mountain barrier of the Hindu Kush: kārēz are rare in the north but very numerous in the south. Balland (1992b; cf. the imperfect accounts of Jentsch and Goblot, 1979, pp. 91-93) was the first to explain this situation, on the basis of new quantitative evidence, as an original dissymmetry, rejecting conclusively the possibility of regression, in particular as consequence of the Turco-Mongolian invasions that ravaged the Bactrian piedmont. North of the Hindu Kush, the underground channel technique only filled in the gaps in a countryside already widely developed since the 3rd millennium BCE through the use of canals which diverted fluvial waters. To the south, the land was farmed little before the introduction of the kārēz technique, which allowed for a veritable conquest of the interfluves and expanded very widely. This expansion clearly must be assigned to the Achaemenid period and has not progressed further since that time. The present limit of the underground channels in Pakistani Baluchistan (Scholz, 1972; Goblot, 1979, pp. 93-97, unaware of Scholz) essentially still represents the outermost border of the Achaemenid empire. The settlement and dominance of the Baluch in the 2nd millennium CE has generally led to a modern and present-day tendency of regression and decline, because the Baluch are people of nomadic and semi-nomadic origins and have remained profoundly ignorant of kārez technique for which they must still bring in specialists from Afghanistan.

(4) *Agricultural uses outside the Iranian lands.* While in this entry the diffusion of kārēz technique for agricultural use beyond the widest expansion of the Achaemenid empire cannot be traced in detail, the broad outlines will be given to clarify the stages of cultural and political Iranian influence as far as possible (for more details see Goblot, 1979, pp. 113-25, 134-79).

In Africa underground water channels are known throughout the Maghreb and in the northern part of the Sahara, including Fezzan in Libya. From there, very locally, the technique passed to Sicily (Goblot, 1979, p. 134) and much more widely into the Iberian peninsula, where one instance has been reported as far north as 42° north latitude in the Ebro basin (Humbert). The Spaniards in turn brought the technique to the Americas, Mexico, and northern Chile. As for the pre-Columbian underground channels of Nazca in Peru, they are only much more rudimentary underflow channels (Planhol and Rognon, p. 107; Braun, pp. 27-28; Planhol, 1992, p. 133).

Throughout western Africa, beyond Egypt and the oases of the Libyan desert, during the Islamic period, the spectacular renewal of eastern, particularly Iranian, influence during the ʿAbbasid caliphate initiated a great developmental phase dates. Numerous traditions in the Saharan oases report the excavation of channels by more or less legendary persons, who are identified in the sources as Barmakids and whose Persian and ʿAbbasid origins are not in doubt. The very complex diffusion phenomena are still poorly elucidated, but they involved travels of “technicians” or “engineers,” perhaps with reverse influences from Andalusia to Africa (for the very complicated case of the origin of the channels of Marrakesh at the end of the 11th century CE, see Planhol, 1992, pp. 190-92). But the earlier existence of underground water channels since the Roman-Byzantine period, in particular throughout the northeastern Atlas region, on the Constantinian high plains and in Fezzan, is equally well attested by archaeology, epigraphy, and written sources. This earlier cultural stratum was perhaps linked to the Phoenicians, the intermediaries with the Orient (Planhol, 1992, pp. 138-39). Their influence, radiating out from Carthage, was considerable in the Berber world to the west, reaching perhaps as far as Touat (Echallier). The development of underground water channels in Fezzan should therefore probably be dated to the second half of the 1st millennium BCE, when the prosperity of the Garmantes was based on control of the trans-Saharan commercial routes (Wilson, pp. 223-24).

To the east, in lower Central Asia, in Farḡāna and Ḵokand (Qūqon), where the underground water channels bear essentially Persian names (Goblot, 1979, pp.

174-75), the introduction of the kārēz technique cannot be dated, although the Iranian cultural influence is beyond doubt. The diffusion of the underground water channels in the Chinese cultural area and the Far East remains a major problem, still not completely resolved (see especially the Chinese research in *PICKI*; cf. Maillard, pp. 9-12; Goblot, pp. 175-79; Planhol, 1992, pp. 133-34). The channels are present in significant numbers in Kashgar, Yarkand (see online), and Khotan (see online), oases south of the Taklamakan desert. In Kashgar the kārēz date back at least to the 10th century CE (Huang, p. 18). Channels are also found further beyond, particularly at Turfan and, 300 kilometers to the east, at Komul (Hami). The kārēz technique penetrated as far as Korea and Japan. In the prefectures of Mie and Gifu, in central Japan, underground water channels are found in an area where running waters cannot be used to irrigate the rice fields. In the case of Gifu, the import of the technique from Korea is not in doubt (Okazaki). The Japanese term *mambo* is derived from Korean *man-nun-poo* (ibid., p. 276), and the channel construction is dated to the beginning of the 17th century CE. While the problem of Korean kārēz does not seem to have been approached in a thorough manner, the Chinese origin of the isolated Japanese pocket seems clear. The diffusion of the kārēz technique in China remains much more difficult to explain and has been complicated in recent discussions at the 1993 kārēz conference (*PICKI*), held in Urumqi in 1993.

In the 19th century, the first Western travelers and observers reported unanimously that most underground water channels at Turfan were of very recent construction. After the establishment of the Chinese protectorate over Xinjiang in 1750, the new Chinese rulers strongly supported the expansion of farming, so that channel construction must have peaked about 1780. At the end of the 19th century, all traditions collected by European travelers report that in the late 18th century the technique was introduced by men coming from Persia and Transcaucasia (Huntington, p. 310). Most of these men had Muslim, though not specifically Persian, names (Planhol, 1992, p. 133), but the channels are locally known as *kariz*.

Chinese researchers (Huang; Liu; Sunao) working with administrative Chinese sources have reached the same conclusion, although the theory of the recent Iranian origin has not always been openly affirmed. During the Tang (618-907 CE) and Ming (1368-1644) dynasties the Chinese sources mention for Turfan only open-air irrigation channels (Huang). While there is some plausibility that the Turfan underground channels date back to around 1780 (Liu, p. 60),

their construction might have only started with certainty in 1805 or 1807 (Huang). The underground channels of Komul were definitely built in 1906.

However, this discussion is further complicated by an account by Sima Qian (ca. 145-ca. 86 BCE) in his epic history *Shi ji* for ca. 120 BCE, in the reign of the Han Dynasty emperor Wu Ti (r. 156-87 BCE; Goblot, p. 178; cf. Pelliot, 1920; Needham, pp. 333-35). The book describes how in central China underground channels, aided by a series of shafts, were employed for the irrigation of the plain of Guanzhong (Shanxi), and it thus irresistably calls to mind the kārēz technique. The Chinese historian Wang Guowai (Pelliot, 1929, pp. 123-24) interpreted this account to prove that the kārēz technique had been practiced in China proper since the Han dynasty (206 BCE-220 CE), spreading west during the Chinese conquest (Liu, pp. 55-57). Although a direct Iranian influence on Guanzhong during the Han period seems very unlikely, the kārēz technique was certainly in use much earlier in the Iranian world. Moreover, several Chinese scholars (e.g., Liu) have categorically refused to accept that the Guanzhong channel, which seems to have carried water from a river and not water captured from the water table, was a genuine kārēz. Yet others have argued that there is a specifically Chinese vocabulary relating to the underground water channels (Fan, p. 45) and that the Chinese term *karjing* "well," "bad well" (Cai and Jing, pp. 30-31) does not derive from *kārēz* and has been known since the early Qin dynasty (221-207 BCE). On the one hand, markedly younger dates, which fall into the Ming dynasty (1368-1644 CE), have been suggested for at least some of the channels at Turfan, if not for the whole network: 1570 for the existence of a "Yiar karez" (Fan, p. 45), or 1588, 1593, and 1622 (Ha, p. 88). On the other hand, representations of a series of shafts in drawings and rock engravings found at various archeological sites in Chinese Turkestan have been interpreted as plans for underground channel networks dating back to 2300 BCE (Liang; Wang, pp. 95-96), or even 6000-4000 BCE (Alim) in the middle of the Neolithic period (!!).

Most Chinese scholars (Xinjiang Water Conservancy; Zhang; Liang; Ha; Wang; Chu) accepted the thesis that underground water channels originated either in central China or in the loess hills of the Yellow River basin. They explained the technique's later implementation in the west as following the Chinese expansion or as representing an independent local invention in Chinese Turkestan. While the current state of knowledge does not allow for totally excluding this thesis of an autonomous development in China, the identification of underground water channel networks in the rock figures is

nevertheless very far from convincing. Unless there are new archeological discoveries, an Iranian origin seems to be by far the most plausible hypothesis. The general laws of diffusion provide an additional major argument against an independent Far Eastern origin of the kārēz technique. Only scattered, isolated sites are known in the Chinese area, where they clearly mark the farthest reaches of the technique's dissemination. Their distribution suggests that the Iranian technique was diluted within another civilization, without being widely adopted. Moreover, China's entire semi-arid interior was magnificently favorable for using the kārēz technique. It seems therefore probable to expect much more archeological evidence and a more dynamic development, should this irrigation technique be an original Chinese discovery (Planhol, 1992, p. 134). In fact, the Iranian origin of the kārēz technique has recently received strong support at an international conference about water management, held in 2006 in Urumqi (*WESDASZ*), because Eric Trombert proved in his presentation that the Guanzhong channel does not have any of the characteristics of a kārēz. Trombert supported his technical analysis with written evidence from unpublished manuscripts, which originated during the Tang period and document that between the 7th and the 10th centuries CE the irrigation of Xinjiang was restricted to open-air channels.

(5) *Physical constraints of kārēz diffusion*. The overall geographical dissemination from its original Iranian center remains a general problem of research on the kārēz technique, as applied to agricultural use. In the arid zones of the Old World their diffusion was very asymmetrical. Underground water channels are unknown in the southern Sahara, where they were not used beyond Ahnet, the Ahaggar, and Fezzan. Already in the 1940s they had perceptibly retreated in comparison to their farthest historical advance (Despois, pp. 55-61). But to the north they have widely encroached upon the Mediterranean subtropical zones in Spain (Humbert). The same contrast can be observed in Asia. On the Indian subcontinent only scattered, altogether isolated sites are found beyond the boundary of the Indus in the Deccan, around Ahmadnagar in the state of Maharashtra (Balland, 1992a, p. 3), although the topographical and hydrological conditions in numerous areas along the Ganges plain would have been particularly favorable for employing the kārēz technique. Another remarkable lacuna can be observed in continental highland Asia. Whereas the kārēz technique was used in Transcaucasia and lower Central Asia, which are areas with winter rains, it was not used in the areas of continental highland Asia with summer rains, where irrigation channels could have certainly contributed to an expansion of

farming. These data taken together suggest that the relation between rainy seasons and growing seasons is a determining factor for the use of underground water channels. A major advantage of the karēz technique is a relatively constant outflow in every season. Such an independence from the variations in rainfall and river flow, which drastically limit irrigation using surface waters (see iii (1), above), is of capital importance in all subtropical zones with winter rains, where the dry season coincides with the growing season. But the constant outflow is much less advantageous in the tropical zone and in continental highland Asia with summer rains, even if regions have a marked dry season, because their growing season coincides with the rainy season. In sum, the worldwide distribution of underground water channels reflects very elementary natural constraints (Planhol, 1992, p. 142), as well as the political influence of the Achaemenid and the Sasanian empires and the technological impact of the Islamic civilization during the first centuries after the Hijra in the 7th CE.