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KĀRIZ III. ECONOMIC AND SOCIAL CONTEXTS

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(1) *Water supply*. The *absolute discharge* is measured in cubic meter per hour (m^3/hr) and varies from kārēz to kārēz, as it depends on the local conditions of supply to the water table and a channel's length. In a study of 2,000 channels in Iran, Beaumont (1989, p. 23) has calculated that the discharge is always lower than 300 m^3/hr. While two-thirds of the channels discharge less than 60 m^3/hr, for 45 percent of the channels the discharge is less than 30 m^3/hr (Beaumont, 1971, p. 47). The latter water flow allows for irrigating 10-20 hectares of land. For Iran an average discharge of 54 m^3/hr has been calculated, and the highest known discharge is given by a kārēz at Šāhrud, which yields around 3,200 m^3/hr (Goblot, 1979, p. 41). In addition to its absolute discharge, the productivity of a channel must be assessed in its relation to the region's water resources. A channel's *specific discharge* measures the liters of water per second per kilometer (l/sec/km; cf. Balland, 1992b, p. 106). In Iran the specific discharge is about 3 l/sec/km, but about 8 l/sec/km is its average in Afghanistan. The particular efficacy of the Afghan kārēz seems to reflect that the Afghan channels are generally shorter (see ii (2), above), while the area supplying the water is larger. In all other regions, from Turfan to the Sahara, the specific discharge remains in the lower range

of 2-3 l/sec/km (Balland, 1992b, p. 107, fig. 4).

The major significance of the kārēz lies in its continuous discharge throughout the year. In contrast, irrigation systems that rely on surface water runoff can completely cease to discharge water during the dry season. The *continuous* discharge, however, needs be distinguished from a *constant* discharge. Significant seasonal variations can be observed in the discharge of the subterranean aquifers, although these variations are much smaller than those of the rivers. In a study of 24 kārēz in the region of Mashad in 1964-65, the maximum discharge occurred from February to May, and the lowest discharge was measured in September and October. The same phenomenon has been noted in Afghanistan. A study of 7 kārēz in the region of Kabul calculated an average of a 29-percent decrease for the discharge between July and September 1963 (Wagner, p. 108). These variations basically mirror the regular pattern of temperatures, although with a slight time lag, as the heat increases evaporation and thus decreases the supply of water to the water tables. But variations in precipitation and local conditions of available runoff water are also important, since they can cause significant differences from one year to another (Beaumont, 1971; Balland, 1992a, p. 103). In general, the seasonal variability reflects the permeability of the surrounding rock and the thickness of the aquifer. The kārēz that drains a shallow, local water table of small volume covered by a very permeable detrital material shows the greater seasonal variability, and it may even temporarily ceases its discharge. For Afghanistan S. Radojivic described both the occasional drying up, as in the case of the kārēz of Ḡolām Ḵān at Sehgāna in Katawāz (1978a, p. 51), and the recurrent drying up for 4-6 months every year, which has been observed for the kārēz at Pol-e Sangi, about 11 km northeast of Kabul (1978b, p. 2). Farmers are of course aware of these variations, since a constant discharge increases the value of the arable land (Taraki, p. 622). Consequently, they distinguish between a kārēz with constant discharge (Pers. *ḡarq-āb*, *āb-ḡari*, cf. McLachlan, p.77; Pashto *kārēz pāḵə* in Afghanistan, cf. Balland, 1992a, p. 103, n. 5) and one whose discharge is fluctuating according to rainfall (Pers. *hāvā-bin*, *pošt-āb* in Iran; Pashto *kārēz wahri* in Afghanistan, cf. Balland, 1992a, p. 103, n. 6). In southern Afghanistan N. E. McClymonds studied the impact of the extreme drought of 1970 and 1971 (Balland, 1992a, p. 105). In the region of Kajakay the average discharge of 73 kārēz fell 60 percent in comparison with their discharge in 1950, the year for which measurements were available. Because of improvement or repair works, 9 kārēz had nevertheless experienced a modest increase of their discharge, 6 percent on average, while in 3 kārēz the discharge remained unchanged. But in the other 61 kārēz the discharge dropped on average 72 percent, and 4 channels had even dried up completely, so that the dependent villages had been deserted. The number of kārēz supplying more than 50 l/sec had fallen from 15 to 1. Since the closest meteorological stations of Laškargāh and Kandahar measured in 1971 a rainfall deficit of 47 and 70 percent, respectively, overexploitation of the water tables could be ruled out, and this fall had to be attributed to the disastrous rainfall situation in 1970 and 1971.

Lastly, many kārēz are destined to dry up eventually because their water tables are overexploited. Such long-term variations are irreversible without radical modification in human attitudes. For example, an ill-considered multiplication of channels will deplete the water table, which in turn causes the water level to drop permanently.

(2) *Geographical characteristics.* Preferred sites for the construction of kārēz are those that have sufficiently and regularly supplied water tables and are located below abundantly watered mountainous terrain, where the channels can emerge into plains with good cultivable soil. Piedmont areas thus seem to be the best, especially since the nature of the surface materials (regolith) is generally quite favorable for water infiltration. Within these areas the alluvial cones are especially favorable, watered as they are not only by runoff on the main slopes but also by drainage of fluvial basins located at various distances within the mountains (Goblot, 1979, pp. 28-29). The kārēz tend to be built in networks where fluvial basins are quite numerous. On the Iranian plateau there are numerous areas that fulfill these conditions particularly well, and kārēz were important fort Iran’s development. In general, in the Iranian regions (Figure 3) where the most *kārēz* are grouped in networks (Beaumont, 1971, pp. 41-42), the annual precipitation does not exceed 100-200 mm, so that these regions are unsuitable for rainwater cultivation.

Tehran at the foot of the Alborz mountains is an exceptionally well-suited site: a row of converging piedmonts, covered with Pliocene detrital soil, at the foot of a mountain with a height of more than 4,000 m (Figure 4).

Another very dense kārēz network can be found on the plain of Varāmin (Beaumont, 1971, p. 42).

But in the subarid piedmonts for which kārēz are particularly well suited, the underground water channels do not occupy the whole area, inasmuch as diversion canals, starting from the mountain slopes, are an effective means for harnessing more or less permanent water runoffs for irrigation (Figure 5). These may be found serving narrow strips of land along rivers and streams, in alternation with the karez that dominate the broad areas between rivers and streams (Figure 5B), as in southern Afghanistan, at the eastern end of the Zamindāwar district along the Helmand river and its tributaries (Balland, 1992b, p. 110). The region of Kajakay receives about 200 mm of annual precipitation, and its fluvial irrigation is strictly limited to the very narrow low alluvial plain of the Helmand River. The extensive alluvial slope which rises above it some tens of meters away on the right bank has a dense network of around 80 kārēz in two tiered groups, so that the more abundant kārēz are located uphill, while the lower, less productive ones recover the water lost through seepage. On the regional scale, over the whole Zamindāwar, the surface area irrigated by kārēz (30,000 hectares) markedly exceeds that of the fluvial oases (17,500 hectares).

In large oases the arrangement, which differs from the preceding one only in details, is based on the opposition between center and periphery. The kārēz is located on the margins, which extend in both directions, uphill and downhill, from the oasis, so that it is possible to cultivate high plains beyond the reach of fluvial diversion canals and to capture water lost through seepage, taking over from the canals which have been exhausted in these areas due to the withdrawals of successive users. This type is very widespread on the whole Iranian plateau, from the piedmont of Tehran (Beaumont, 1968, p. 173; 1974, p. 422) to Kābolestān (Gentelle, 1977, p. 251). It is also found in the southeast of Afghanistan, as in the Ḵōst basin, at the foot of an eastern branch of the Solaymān mountains (Wald, 1969, p. 29) and on the eastern piedmont of the Hazārajāt (see HAZĀRA i. HISTORICAL GEOGRAPHY). Between Qalāt and Ḡazni, along the great longitudinal valleys of the Ḡazni Rōd and the Tarnak, about 1,000 kārēz irrigate around 16,000 hectares (that is a sixth of the total in Afghan territory) versus 60,000 hectares supplied by the diversion canals in the same region (Balland, 1992b, p. 112).

A rarer pattern is characterized by a genuine interweaving, or overlapping, of the diversion canals and the kārēz, and is generally reserved for large oases. This pattern represents an ancient development (Neely, 1974, p. 28), as it is attested since the Sasanian period (224-650 CE; see online SASANIAN DYNASTY). The kārēz is located within the network of diversion canals in the center of the site, and these internal kārēz are always parallel to the nearest thalweg and capture the underflow recharged by seepage of the fluvial waters upstream. Examples can be found south of Kandahar (Balland, 1992b, figs. 4B and 5), along the valley of the Tarnak (Balland, 1992b, pp, 110-12).

The multiplication of kārēz in the piedmont sites has had profound impact on the rural landscape of the Iranian plateau, because they have shaped both agrarian patterns and settlement patterns. Their presence has led to a general division of the lands below the channel outlets into long strips parallel to the direction of water flow (Figure 6), which contrasts distinctly with the much more irregular polygonal division of fields irrigated by diversion canals (Bonine, 1989).

This general trend in land division can be frequently observed in the orientation of rural roads and even in the layout of roads within villages (Roaf, 1989).

(3) *Social implications.* Because the construction cost of these complex facilities is always very high, kārēz have important repercussions for rural society. Since substantial capital is required to excavate an underground channel, only great landowners, rich merchants, governors, and other powerful persons are normally capable of making the considerable investments required for its construction. There are no examples of kārēz being built by a community of small farmers. Conversely, this irrigation technique appears, at least at the time of its origin, to be linked to large-scale land ownership, which traditionally dominated the society of the Iranian plateau (Lambton, 1953). In the course of time, however, the great majority of kārēz have been progressively parceled out through the process of inheritance, which extends to the division of irrigation water among the heirs. Moreover, shares of water can be leased and are frequently sold independently of land ownership. Many kārēz have become endowment properties (sing. *waqf*). In the 20th century, before and after the agrarian reform of the 1960s, there was a growing tendency toward such parceling out and to an increase in the number of small owners of shares of water (Bonine, 1989).

There are two established methods for the sharing out of the water (Safi-Nežād, 1980; 1992, pp. 65-75)—measuring time or volume (Planhol and Rognon, pp. 119-20). In Iran distribution by volume is quite rare, practically limited to the piedmont of Tehran, and division by time is by far the most prevalent method. According to a timetable peculiar to each kārēz, the total outflow is successively placed at the disposal of each user. Time is measured by a water clock (clepsydra) or more rarely by a sundial, which was, for example, still in use in the Biābānak region in the 1980s. These traditional methods are increasingly abandoned in favor of battery-powered timekeeping. A frequent complication for the same user is the diurnal and nocturnal alternation of successive withdrawals of water, because nocturnal irrigation, although tiring for the farmer, is much more effective due to lower rates of evaporation. The alternation systems are sometimes extremely complex, as their organization aims at insuring a certain advantage for those with the smallest shares in order to avoid their being disadvantaged. The oases with kārēz are thus veritable hydrologic micro-societies, characterized by the emergence of a whole hierarchy of control authorities, which in Iran are generally villagers. Each kārēz is placed under the direction of a manager (*raʾis*), who is almost always the most important shareholder of water and who in turn appoints the water distributor (*mir-āb*). The latter office is very demanding but highly regarded in village society, and the office holder is always paid, usually in goods, produce, or water, although nowadays more and more often in money.