The karez of the Sauran region of Central Asia

R. Sala, J. M. Deom and D. Clarke

ABSTRACT

A large number of lines of water collection wells were identified by aerial surveys in the arid region near the ancient city of Sauran on the Middle Syr Darya (South Kazakhstan, Central Asia). They are locally called karez, which in Persian means 'water uplift'. Initially these were assumed to be qanat, a water collection and distribution system that is widespread in the Middle East, North Africa and Central Asia. Recent surveys discovered more than 100 km of such lines in the Sauran area. The most surprising discovery was that there was no evidence of galleries that might have collapsed due to poor construction or maintenance. The excavations of a series of these wells are described and a new model for water transport and delivery is proposed that takes advantage of the local hydrogeology. The study has historical significance for the reconstruction of water and land use in the Turkestan oasis during the last 2000 years; and the rediscovery of this forgotten technique could have economic significance for modern land reclamation in desert zones.

Key words | archaeology, Central Asia, irrigation, karez, qanat, water resources

INTRODUCTION

Groundwater systems consisting of series of aligned wells interconnected by underground galleries have been constructed on desert sloping piedmonts for more than 2000 years (Cressey 1958; English 1968; Lightfoot 2000). In the Middle East they are called ‘qanat’ and in areas of Central Asia and Tarim they are called ‘karez’ (Baillant 1992; Briant 2001; Sala 2003). These remarkable water transporting systems are still in use in many of these regions today including Iran, Turkenistan, Afghanistan, Western China and Kazakhstan. The principle of operation is well understood in that the underground gallery intercepts a water table and permits the transportation of water significant distances, sometimes may tens of kilometres, in a cool environment that minimises water losses due to evaporation or seepage. Vertical ‘well’ shafts are constructed, typically spaced between 20–100 m apart to provide access for construction and maintenance of the system (Figure 1).

BACKGROUND TO THE ‘QANAT’ AND ‘KAREZ’ OF THE TURKESTAN OASIS

Turkestan is situated in Kazakhstan in Central Asia (Figure 2) on the route of the great Silk Road. The city contains the site of the Mausoleum of Khodja Akhmed Yassaui which is considered to be a ‘second Mecca’ in the Muslim world. The history of the region is described by Barthold (1992) and Baipakov (1998) describes some of the main cities.

Lewis (1965) described the development of irrigation systems in the area, but the earliest mention of the existence of water galleries in the Turkestan region is given in the historical accounts of Wasifi (quoted by Akishev & Baipakov 1973; see Annex 1) and by the ethnographic accounts of Dingelshstedt (1889). The XVI century Tadjik writer Makhmud Zainaddin Wasifi, in a passage of ‘Amazing Events’ (Annexe 1), says that in 1510 AD the Muslim sheikh Mir-Arab, religious leader in Bukhara under the Shaybanids, offered to the town of Sauran, in the Turkestan oasis, 2 karez lines and a ‘charbag’
(walled garden) “similar to nothing that people travelling all around the world had ever seen neither on land neither on sea” (Boldirev 1957).

Wasifi’s account inspired the first archaeological researches into the karez of the Turkestan oasis. Groshev (1985) detected three karez lines north and west of the ruins of the medieval town of Sauran (Figure 3). The lines were several kilometres long and consisted of wells typically spaced 10 m apart (Figure 4). Each well was 1–3 m in diameter and 4–6 m deep. Groshev interpreted the three karez lines as the ones quoted by Wasifi.

Russian Colonel N. Dingelshstedt surveyed some of the irrigation systems of the Turkestan region. He reported that the karez had been built “more than 250 years ago” and that some of them have been continuously maintained and “are still in active use” (Dingelshstedt 1889). He reported the presence of 18 active karez systems scattered in several valleys; and, following verbal reports by the local population, he quotes the presence of 80 abandoned karez lines in the Sauran region. Like Wasifi, he was astonished by the marvellous features of the karez system and comments: “It is rare to meet such an excellent and convenient system for agriculture. In the area of Turkestan karez are partially functioning till today”. Dingelshstedt identified the coexistence of different ways for encouraging the transport and water resurgence using aligned wells. He reported that wells had a depth between 0.35 and 3.50 m and he found some wells systems connected by water galleries. However, contemporary verbal accounts collected from local farmers reporting that “there are no galleries, the water was flowing by itself from one well to another”.

**GEOARCHAEOLOGICAL FIELDWORK IN THE TURKESTAN-SAURAN REGION**

A geoarchaeological study of the Turkestan oasis was carried out between 2002–2004 by members of the Laboratory of Geoarchaeology of the Academy of Sciences of Kazakhstan. The study took place in the region north of the medieval town of Sauran (43°31’ N, 67°46’ E), 45 km northwest of modern day Turkestan. Previous research and existing topographic maps identified three large tobe (raised townships) at Karatobe (II-XIII AD), Sauran (XII-XVIII AD) and Mirtobe (XIV-XVI AD). Existing maps and aerial surveys proved to be particularly useful in assisting in the detection of a few karez lines in five valleys near Turkestan. Hundreds of other lines in the basins of the rivers Tastaksai, Aksai and Maidantal rivers near Sauran were detected from low level aerial surveys. These were surrounded by ancient fields and farms and were fed with water supplied by the karez lines and small canals (Figure 4).

An extended aerial and surface survey found an astonishing archaeological complex. Seven other mid-size townships (tobe) were discovered together with 104 isolated dwellings including Neolithic, Bronze Age, Early...
Iron Age and Medieval villages. Medieval agricultural fields, farms and canals were also mapped. In total, 261 lines of karez with about 10,000 wells were found, comprising over 124 km of water delivery systems. These figures are a preliminary estimate and as additional surveys are made, it is expected that these figures will rise.

More than 20 of the Karez lines were examined from the surface and through the access wells. In each case, no evidence of a gallery connecting the wells or remnants of collapsed galleries was found. This was confirmed by excavation of several of the wells near Sauran to 4 m below the existing bed. A lack of galleries joining the wells was found in all locations surveyed, including sites where river erosion of the river Maidantal cut through a karez (Figure 5). This supports the work reported by Groshev (1985, 1996) who excavated several of the wells (and bulldozed nine more) without finding any trace of underground galleries. Like Wasifi, Groshev interpreted the karez of Sauran as an “exotic rarity imported by an enlightened religious leader” during the Late Middle Ages.

GEOGRAPHICAL AND HYDROGEOLOGICAL FEATURES OF THE TASTAKSAI-AKSAI-MAIDANTAL (TAM) REGION

The study area is a zone 20 × 20 km located on the alluvial plain between the southern slopes of the Karatau mountains and the right bank of the middle course of the Syr Darya river (Figure 6). It is a typical desert landscape characterised by light brown desert soils and shrub vegetation with undulating relief. The area slopes gently south-south-west between 320 and 200 m asl with an average incline of 0.4%. It is crossed by three seasonal streams flowing north-south towards the river Syr Darya and converging in the area of the two largest ancient towns of the region, Karatobe and Sauran. The streams are the Tastaksai to the west; the Maidantal 10–12 km to the east; and the Aksai draining the central zone. The Aksai forms the smallest and shortest valley, being less than 25 km long but it is deeper and tends to accumulate water from the other two rivers in its lower courses.

Geology and hydrogeology

The geological structure of the region comprises of four main units. The upper layer (1 in Figure 7) comprises sandy
clay and occasional beds of pebble deposits. It is impervious or at least semi-permeable. The second layer (2) is of late Quaternary origin and is composed of sand and pebbles. The third layer (3) is made of impervious grey clay formed during the Eocene period. The fourth layer (4) is sand typically 130 m thick deposited during the late Carboniferous period, and forms the deep confined aquifer of the Karatau basin which provides artesian flow in the valley floor of the River Syr Darya with typical flows of 50 litres per second (B).

Modern groundwater levels in the TAM region average 4 m below ground level (bgl), varying from 3 m bgl near the mountains and deepening to 8 m bgl in the Sauran region and rising to 2.4 to 4 m bgl near the river Syr Darya. Soviet period irrigation schemes have been developed by constructing small dams to impound the flows of the rivers and this interception of water has probably lowered the water levels in the former karez regions further downstream. Mineralisation by hydrocarbonate, sulphate and chloride anions increases progressively from north to south, ranging from 0.5 g l$^{-1}$ at the upper piedmonts to 1–1.4 g l$^{-1}$ near Sauran and rising over 12 g l$^{-1}$ in proximity to the river Syr Darya.

The geological structure of the two sedimentary layers covering the upper 15–20 m of the TAM area is the most significant for the analysis of the karez. The first layer 3–8 m thick is semi-permeable, and allows some percolation...
which reduces water-logging and salinisation; and it contains strata of pebble deposits 4–6 m bgl which creates a network of subsurface horizontal waterways. The second layer, located between 5 and 15 m bgl, is water-bearing: and constitutes a semi-confined aquifer that is fed by percolation from the pre-mountain alluvial fans. Experimental digging of a new well in this material resulted in a water level rise from 5 m to 4 m bgl within 24 h of construction.

**Agricultural development in the TAM region**

Agricultural development falls into three distinctive bands that run east-west parallel with the mountain range and the river Syr Darya and are most clearly pronounced along the river Aksai. The highest zone is between 320 and 260 m above sea level (asl) and consists of the immediate piedmont plain sloping at 1%, crossed by small perennial streams that are probably fed by the deep aquifer. Evidence of agriculture dating back to the first century AD has been found, consisting of small walled towns and the use of small water diversion canals. The middle zone, between 260 and 215 m asl, is dry with surface water only existing in the form of seasonal seeps. During the Middle Ages it was an area of groundwater exploitation with a high concentration of karez and a complex of 100 villages and a large town. The lowest zone at 200 m asl, is very flat with poor drainage. Starting with the I century BC, it saw the implementation of drainage canals leading to extensive land reclamation and the building of the two large towns of Sauran and Karatobe and four mid-size towns surrounded by farms and fields.

**FEATURES OF THE T-A-M KAREZ**

In the Tastaksai-Askai-Maidantal (TAM) area 261 lines of karez have been mapped. The Karez lines have an average length of 500 m, summing to 123 km of development. The majority of the systems consist of multiple converging well lines and only 20% are single lines. The average area covered by a single karez system was 400 × 700 m, although they may be made up of several converging lines of wells covering an area as wide as 1,500 m and up to 2,500 m long. The highest concentration of karez appears in the central band of the Aksai river valley (Figure 6).

The central-upper zone was the most densely populated with 117 karez lines and 4237 wells concentrated in an area of 5 × 5 km. The central-lower band covers an area of 5 × 3.5 km, and contains 45 karez totalling 16.9 km in length.

The top of a karez line usually appears near the bank or outlet of an upland stream bed that, during wet regimes, will supply water into the head-well and assist in groundwater recharge. The head well is often enlarged and oval in shape, up to 9 × 12 m. The slope of the karez line averages 0.5% but can be as steep as 1% in the hills or as flat as 0.2%. The typical fall in water level is 2.5 m over a 500 m length of well lines.

Well depths average 3–4 m and always stop at a layer of large pebble deposits. The majority of wells in a karez are typically 15 m apart, but can be as much as 50 m or as little as 5 m apart. Well shafts are typically 0.8–1.0 m wide with a spoil ring 6 m wide and 1 m high on the surface. Significantly, the upper layers of the spoil ring always show pebble deposits, suggesting that the well construction was deliberately stopped once a pebble horizon had been encountered. The mouths of the wells can be unlined but 20% are lined with mud or baked bricks covering the upper 0.5–0.8 m. These are associated with the largest and most recent constructions in the late Medieval period.

The end of a karez line usually connects through an enlarged well with an inclined mouth that feeds into short canals and fields but in some cases the canals can be up to 2 km long. Canals running parallel with the middle and lower segments of the karez lines are found in more than 50% of cases, and these were probably built to cope with seasonal variations in ground water levels.

**A PROPOSED MODEL FOR OPERATION OF THE KAREZ**

The remarkable fact that the karez do not have artificial underground galleries suggests that they are not qanat but constitute a now-forgotten hydraulic device working on a principal that takes advantage of the widespread occurrence of a sand-pebble layer occurring 4–6 m below ground level in the confining layer. This layer was readily accessible
by hand dug wells. The areas hosting karez all exhibit the following conditions:

- The karez lines are located in a depression where groundwater recharge is favoured by the convergence of underground and ephemeral surface waters from neighbouring aquifers and streams;
- The geological sedimentary structure consists of an upper semi-impermeable layer 5–25 m thick resting on top of a permeable horizon, the latter bearing a semi-confined aquifer located at a depth reachable by hand dug wells;
- There is no artificial gallery constructed between the wells;
- The upper confining layer contains a sand-pebble strata of high permeability at 4–6 m below ground level. This layer hydrologically connects adjacent wells and acts as a ‘natural gallery’ between the wells.

The following principle of operation is therefore proposed for the ‘Karez’ of Sauran: The existing hydrogeology consists of a semi-confined aquifer that receives recharge in the hilly areas to the north of the Turkestan area. Attempts at constructing traditional karez or qanat in the area resulted in the upwelling of water into the wells under piezometric pressure from the confined aquifer (Figure 8). The shallow sand/pebble layer in the confining stratum then became saturated and permitted water to move downhill in the direction of the ‘intended qanat’ line.

This mechanism was probably deliberately adopted as a means of water harvesting over extended areas. The water was conveyed with low evaporative losses towards the irrigated fields on the outskirts of the large medieval towns. The existence of canals paralleling the lower reaches of the karez systems enables the combined karez-canal system to respond to seasonal and inter-annual variations in groundwater recharge and piezometric levels, permitting more free flowing water to be collected during wetter periods. Under drier conditions, the upper reaches of the canals would be empty and a lower, but probably more dependable flow would be obtained from the lower end of the karez lines. Such novel systems would have provided a flexible and dependable source of water and would have created a seemingly magical oasis on the desert floors described by Wasafi in the XVI Century.

The Sauran karez systems had been in operation for centuries but there is no certain proof of why they were abandoned. Oberhänsli et al. (2007) state that irrigation activity in the region decreased after 1300 around the time of the commencement of the Little Ice Age (Mackay et al. 2005). This is a period when annual precipitation amounts fell from 450 mm/y to 250 mm/y. This agrees with work on the nearby Oasis of Otrar 60 km to the east of Sauran.
where the extension of irrigation canals slowed and declined after 1350 (Clarke et al. 2005). The decline of economic activity coincided with the post Mongol period, a time of economic and social upheaval, which threatened the security of these cities.

However Dingelshdtedt (1889) suggests that the Karez had been in operation in the XVI-XIX centuries. It is likely that the aquifers received considerable recharge in the post glacial period (Aubekerov et al. 1989), and the deeper aquifers still function. Possible causes for the decline in the systems include the fact that shallow aquifer recharge was less than the rate of water extraction and this depleted the available water, but this will require further field work to verify. The location of the systems 100 m above the flood plains of the Syr Darya river isolates them from the modern Soviet large scale irrigation systems and the well known over exploitation of surface waters. However if large scale groundwater extraction took place it is possible that the shallow aquifers feeding the karez might be affected.

CONCLUSIONS

The ‘Karez’ of the Sauran region represent an unusual system that exploited a combination of local hydrogeology and traditional qanat construction techniques to provide a dependable supply of irrigation water to the medieval towns in the Turkestan area. It is probable that traditional karez using galleries were employed alongside the wells described in this paper and combined into a general water system managed by the large town of Sauran. In particular the study of the forgotten technology of the karez of Sauran has most probably scientific significance for the hydro-geological and hydro-engineering sciences, and economical significance for modern land reclamation in desert zones.

ACKNOWLEDGEMENTS

The work of this project was carried out in the context of the EU funded INTAS project ‘Geo-archaeological investigations of land use and irrigation works in Kazakhstan in present and in historical times’ (INTAS 2000-0699).

We would also like to thank the BG Chair of Environmental Technology in Almaty for assistance in the establishment of this collaborative project.

REFERENCES


ANNEXE 1: THE REPORT OF TADJIK HISTORIAN MAHKMUD ZAINADDIN WASIFI

‘Mir-Arab offered to its native city (Sauran) 2 karez similar to nothing that people travelling all around the world have ever seen neither on land neither on sea, dug by the work of 200 Indian slaves. The sources of the karez were situated at the distance of 1 farsakh from Sauran. On them has been built a castle inside which were dug wells 200 gyaz deep, with 50 gyaz between the ground and the water surface and 150 gyaz of water depth inside the well. The water was lifted up by chigirs (waterwheels). The chigirs were moved by bulls. At the source of the karez was situated a water reservoir. A portion of land was irrigated. On one of the karez was built a charbag (walled garden) with gardens, vineyards and economical buildings’. ‘Amazing Events’, Makhmud Zainaddin Wasifi, XVI century AD. quoted by Barthold (1992), pp. 225–226 and Akishev & Baipakov (1973).