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OSL dating of the Miam Qanat (KĀRIZ) system in NE Iran

M. Fattahi [a, b, *]

[a] Institute of Geophysics, University of Tehran, Kargar Shomali, Tehran, Iran
[b] School of Geography, University of Oxford, South Parks Road, Oxford, OX1 3QY, UK

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ABSTRACT

This article presents the first direct absolute dating method of a Qanat system obtained through optically stimulated luminescence (OSL) dating of grains in spoil heaps, using feldspar single-grain, feldspar multi-grain and quartz multi-grain samples. This novel and highly promising approach to improving our understanding of the chronology of Qanats is more important than the final age results.

Hitherto, dating of Qanats has been based on indirect evidence from historical reports or archaeological investigations of nearby settlements. This study demonstrate the ability of OSL to date this type of subterranean irrigation feature, which is important in the study of both the archaeology of human settlement and palaeoenvironmental change in arid regions. This method can also be used for dating wells and handmade ditches and canals.

Our results show that advanced irrigation technologies existed at Miam in what is now north-east Iran much earlier than previously thought. Dating the now disused Qanat at 3.6–4.3 ka makes it the oldest known. Single-grain dating of sand-sized feldspar that overlie construction spoil show that the Miam Qanat was maintained until at least 1.6 ka. The early development of Qanat irrigation indicates that the causes of widespread societal collapse in eastern Iran in the Bronze Age might not have been driven purely by climatic pressures.

1. Introduction

The Qanat (also referred to as karez in Iran and other names in other countries) is a sustainable system of underground irrigation channels which use gravity to tap water from the water table in highlands and continuously distribute it through gently sloping tunnels often several kilometres long, to ground surface outlets at the lower end, where it is needed for irrigation and domestic use (Fig. 1.). Along the length of the Qanat tunnel a series of vertical shafts were used at intervals of 10–140 m to remove excavated material and provide air circulation, lighting and access for maintenance. Thus the Qanat can be traced on aerial photos by a line of circular craters. This unique, green and environmentally friendly technology created cultural and natural ecosystems that ideally addressed the specific needs of each community (Salih, 2006).

Qanats provided water for human settlements for centuries, particularly in arid and semi-arid regions in more than 34 countries (Salih, 2006; International center on Qanats and Historic Hydraulic structure (ICQHS) web site; personal communication with Lightfoot, Dale). Today, remote rural areas of low population density in Iran and other arid countries still depend on water from Qanats. In Iran alone 40,000 to 50,000 Qanats were dug, some of which are still in operation (Garbrecht, 1983; ICQhs in its web site; personal communication Lightfoot, Dale).

This paper is the extension of the work of Fattahi et al. (2011) which presented the innovative advances aimed at improving our understanding of the chronology of this important underground irrigation system. It gives details about the importance of dating Qanats, and the dating method. It will explain why quartz single aliquot OSL procedures produced earlier dates for spoilheaps associated with Miam Qanat than expected, and how the single grain IRSL dating method can overcome this problem.

1.1. The importance of dating Qanats

Direct dating of Qanats is important for both macro and micro scale studies. These include finding the origin place of Qanats, their place in relationships between settlements, as well as landscape evolution, palaeoclimate and slip rates showing Qanat displacement by earthquake faults:

* Institute of Geophysics, University of Tehran, Kargar Shomali, Tehran, Iran.
E-mail addresses: mfattahi@ut.ac.ir, morteza.fattahi@ouce.ox.ac.uk.

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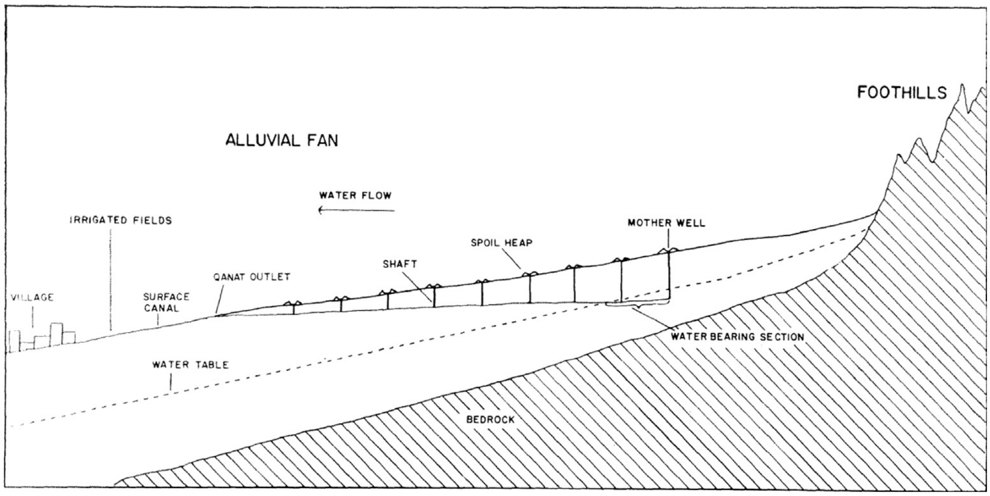

Fig. 1. Schematic cross-section through a Qanat system. From Beaumont, 1971. The main gallery taps elevated ground waters beneath highlands and allows water to flow underground to low-lying agricultural regions, thus minimising loss through evaporation. The gallery is excavated from the low-lying regions towards a 'mother well'. Vertical access shafts are dug at regular intervals of 20–100 m to provide air circulation, lighting and access for maintenance. Spoil from the excavation of the Qanat, and from subsequent periods of maintenance, is piled around the vertical access shafts to provide a barrier to prevent surface flood waters from entering the underground water supply (see also Wulff, 1968).

Origin of Qanat: This system is called different names in different regions: Qanat (Iran); **Kahriz**/karez (Iran, Iraq, Afghanistan, Pakistan, Azerbaijan and Turkmenistan); Kanerjing (China); Qanat Romoni (Jordan and Syria); Ain (Saudi Arabia); khettara (Morocco); galleria (Spain); falaj (United Arab Emirates and Oman); Kahn (Baloch); Foggara (Algeria); Fughara, Khettara and Iffeli (North Africa); Galerias (Canary Islands); Mambo (Japan); Inguttati (Sicily) and other terms such as Ghundat, Kona, Kunut, Kanat, Khad, Koniat, Khriga, Fokkara, etc (e.g., Lightfoot, 2000; Mays, 2010; ICQHS web site).

The widespread distribution of this ancient hydraulic technology known by many different local names makes it difficult to establish the origin of Qanats. The timing and location of their initial development is a matter of ongoing debate, largely because of the difficulties in dating them. The existing constraints on establishing the age of Qanats derive from their reliance hitherto on historical reports or archaeological investigations and evidence in nearby habitation sites, rather than on direct dating of the irrigation systems themselves (e.g., Lightfoot, 2000). As a result, different times are given for the earliest Qanats. It has been suggested that the start of Qanat construction was in Persia more than 2500 (English, 1968; Beaumont, 1971; Ahmadi et al., 2010) or 2800 (Salih, 2006) or 3000 (Wulff, 1968; Lightfoot, 2000; Stiros, 2006; Mays, 2010; Javan et al., 2006) years ago. Different articles have also referred to particular Qanats as the oldest. For example, the Bam area has been claimed as containing the oldest Qanats in Iran and perhaps in the world (Salih, 2006). Similarly, it has been suggested that the water supply system of Chagazanbil temple (east-south of Shoosh) is the oldest hydraulic structure in Iran, dating back to 3300 years ago. Qanats existed in the city of Uhlu lying on the western north of Uroomiye lake in 714 BC (Garbrecht, 1983; Semsar Yazdi and Askarzadeh, 2007).

The question remains whether the data support a "one cradle of development" model (Fig. 2) or tilt in favour of multiple centres of development.

Settlement – landscape evolution – paleoclimate: Dating Qanats improves our understanding of the chronological relation between local settlement, landscape evolution and land use with paleoclimate and palaeo environmental data. As aridity increased, people had to dig the tunnels deeper and consequently spoils were transferred on top of the wells. By dating these spoilheaps we can find out about the periods of aridity.

The importance of the desert interior of eastern Iran in the Bronze-Age world is increasingly recognised (e.g., Encyclopedia Irania, 2014 and references there in). Archaeological investigations over the last few decades have revealed the widespread existence of urban centres, with advanced industries in metals, ceramics, and textiles (Encyclopedia Irania, 2014), and trading links that extended to the ancient cultures of Mesopotamia and the Indus valley (McIntosh, 2011). The civilisations of eastern Iran were at their zenith in the 3rd Millennium B.C., but by ~2000 B.C. the cities of the eastern Iranian desert had collapsed (Lawler, 2011). The causes of large-scale collapse and gradual abandonment of complex societies across eastern Iran by ~2000 B.C. are debated (Lawler, 2011). These include violent invasion and mass migration (Encyclopedia Irania, 2014), evidence of continuity of occupation (Jarrige, 1983), gradual decline of urban centres after 1850 B.C. (Tosi, 1986); and shifting hydrological conditions (Encyclopedia Irania, 2014). However, increasing aridity and periods of prolonged drought in the mid- and late-Holocene have been cited as the cause of collapse in a number of agricultural civilisations from Mesopotamia, North Africa, and the Indus valley (e.g., deMenocal, 2001; Staubwasser and Weiss, 2006). Although there are no detailed palaeoclimate records from the interior of eastern Iran, it seems probable that the region showed a similar increase in aridity through the mid-Holocene, as also suggested from early Holocene ages of lake and basin deposits at several sites around the east (Walker and Fattahi, 2011). Whether such changes in the climate played a significant role, or whether the decline was due to economic pressures such as shifts in trade routes, is unknown. One of the major lines of evidence for the influence of an increasingly arid climate on complex farming societies in eastern Iran is the apparent change in the irrigation techniques utilised before and after the societal collapse (e.g. Fouache et al., 2008). Early Bronze-Age societies appear to have used surface canals, implying the presence of a stable water supply year-round. The later resurgence of complex agricultural societies has, however, been attributed to the development of Qanats for irrigation and domestic use because, being underground, they are less vulnerable to dry periods.