Roots of invasive plant species such as Tarza and Taghanimt, which can grow to more than 10 m, easily penetrate the main seguia that connects the output of the qanat to the kasria. Inhabitants of the oasis have found that the only way to remove these plants and keep them from clogging the flow of water through the seguia is to burn them.

BOUALEM REMINI AND BACHIR ACHOUR

The qanat of the Greatest Western Erg

BUILDING ON THE ANCIENT FUNCTIONAL PRINCIPLES OF QANAT DESIGN, THE AUTHORS PROPOSE A NEW TYPE OF QANAT THAT WOULD DRAW GROUNDWATER FROM THE GREATEST WESTERN ERG.

Qanats, systems of underground tunnels for delivering groundwater, have been used to provide water to arid environments for hundreds of years. Qanats in the Greatest Western Erg capture the groundwater present in the erg, which is often referred to as a sand sea. The most widely known qanat in Algeria collects water from the Intercalary Continental Aquifer. Located in the regions of Gourara and Touat, this is a "classic" qanat, consisting of a slightly inclined underground tunnel that drains water from the aquifer and carries it to the surface.

In 2007, 2008, and 2010 in the oases located on the southwestern periphery of the Greatest Western Erg, the authors recorded the presence of about 100 qanats in service in the oases of Ouled Said. These qanats, whose galleries have been lost among the vast sand dunes of the Greatest Western Erg, continue to provide an appreciable flow of water to palm groves and gardens in the Timimoun, a small oasis town in the Adrar Province in Algeria. However, qanats are often threatened by silting. In the Aghlad oasis, only one qanat of the six initially excavated remains in operation; the other five are sandy and have been abandoned by their owners.

Even though some uncertainty remains regarding the origin of the qanat, several authors agree that this hydraulic system was born in the northwest region of Iran more than 3,000 years ago (Hussain et al, 2008; Kazemi, 2004). It is known by various names, depending on the geographic region in which it is located—qanat in Iran (Hussain et al, 2008; Goblot, 1979;

Goblot, 1963), khettara in Morocco (Lightfoot, 1996), karez in Pakistan (Daanish & Muhammed, 2007), falaj in the Sultanate of Oman (Al Sulaiman et al, 2007), and foggaras in Africa. The qanat is a hand-dug horizontal underground tunnel intersected with air shafts spaced approximately 10–15 m apart. Spoil from the shaft is deposited around its opening in order to help protect it from silt intrusion. The irrigation of thousands of palms in southwestern Algeria has been ensured for more than 10 centuries by systems of qanats. Currently, there are only about 880 qanats in service, drawing a flow of 3 m^3/s. The number of functioning qanats is expected to decline over the next few years. The majority are already in very poor shape and present technical, environmental, and social problems.

The authors have developed a type of qanat that has the same functional principle as that of the classic qanat, except that water is drawn from a different source. Unlike the classic qanat, which carries water from the Intercalary Continental Aquifer, the Erg qanat collects the groundwater of the Greatest Western Erg. To understand the Erg's varying characteristics and their functions, investigations and interviews were conducted with the owners of the oases in the Timimoun qanat.

INVESTIGATIONS YIELD INFORMATION ABOUT THE ERG QANAT

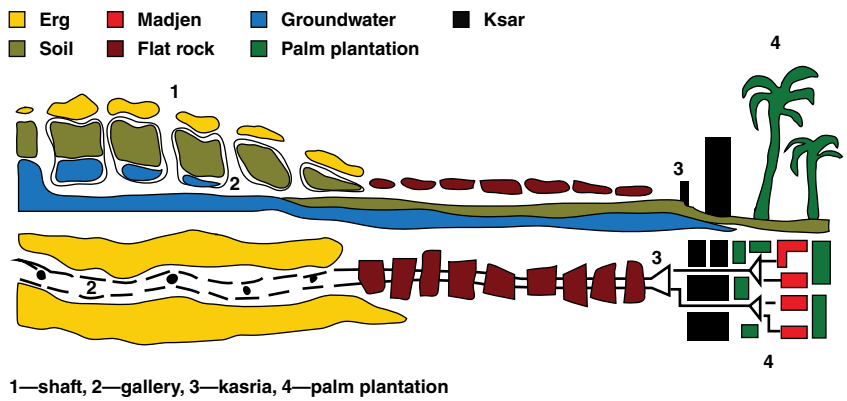
Investigations were conducted in 2007, 2008, and 2010 in the oasis town of Timimoun, located approximately 1,000 km southwest of Algiers (Figure 1). The authors conducted interviews at the Ouled Said, Kali, Outakou, and Aghlad oases. In addition to these interviews, the authors spoke with the owners of various qanats and the local population.

Functioning of the Erg qanat. The Erg qanat is composed of a gallery (low slope) equipped with a multitude of air shafts and collects the groundwater that forms below the Greatest Western Erg. This water flows slowly under the Erg in the old river coming from the Saharan Atlas. Unlike a classical qanat, the Erg qanat is equipped with a canal of several hundred metres, that connects the output of the gallery in the Erg. The kasria (outlet) is located at the entrance of the palm plantation (Figure 2).

Characteristics and features of the Erg qanat. During the three investigations conducted in the oases of the Timimoun region, the following unique features were identified:

FIGURE 1 Map of the study area

FIGURE 2 Cross section of the Erg qanat



1—shaft, 2—gallery, 3—kasria, 4—palm plantation

• To decrease the speed of the water flow arriving at the main kasria, the gallery below the erg was constructed in a zigzag line.

• To minimize the amount of sand that could infiltrate the Greatest Western Erg, the wells, seguias, and kasrias are covered by flat rocks.

• To facilitate flow measurement, the kasria of the classical qanat is equipped with a surge of flows. The kasria of the Erg qanat is elongated and does not possess a surge.

• In the absence of drilling in the Erg (because it is difficult to apply this technology in the Erg), the flow of the Erg qanat is stationary in time.

• The water of the Erg qanat is less salty and is of good quality.

• The Erg qanat is limited to the oases of Ouled Said (Timimoun).

• There are 100 qanats of this type, fewer than 80 of which are functional.

• It is impossible to identify the length of the gallery and the number of wells.

• It is impossible to localize the "mother shaft" (i.e., the main water source of the Erg qanat).

• The Erg qanat contains three types of kasria (outlet) designs: sawtooth, circular, and rectangular.

• The Erg qanat has six types of madjens: circular, rounded, L-shaped, zigzag, rectangular, and elongated. The madjens (ponds) of the Erg qanat occupy a large part of a garden. The peripheries of madjens are surrounded by palm trees whose roots are constantly fed through the infiltration of water.

Degradation of the Erg qanat. Two significant natural elements create problems for the population and cause degradation of the Erg qanat—invasive sand and wild plants.

Silting of the qanat of Erg. The presence of the Greatest Western Erg creates significant problems for the Erg qanat. After every sandstorm, all systems of the qanat (i.e., gallery, seguia, well, kasria, and madjen) become filled with silt. Unfortunately, keeping silt out of these elements is a daily chore that is performed by simple methods. Farmers use traditional methods to reduce the effects of silting, such as cutting rock into flat slabs that are fitted over the elements of the qanat (seguia, kasria, well, and madjen). Then clay is mixed with water to seal the gaps between the flat rocks to prevent the sand from penetrating the openings. Despite these practices, farmers must still periodically flush and clean sand from the elements of the qanat. Once cleanup is completed, the farmers again cover all elements of the qanat with carved rocks and clay. Combatting silt is a daily battle between the farmer and the sand.

Invasion of the qanat by wild plants. Two wild plants, locally called Tarza and Taghanimt, constantly invade the Erg qanat. Their roots, which are more than 10 m long, create serious blockage problems in the seguias and kasrias. The roots penetrate easily into the main seguia, which connects the output of the qanat to the kasria. Both plants multiply rapidly until they close off a section of the covered seguia.

Farmers in the Kali, Aghlad, and Ouled Said oases struggle daily against the propagation of these two plants. The only way to stop the invasion of these plants is to burn them.

Silting and invasion of these destructive plants create a continual problem of clogging in the Erg qanat. Maintenance remains the only way to save this hydraulic heritage. The population of the Ksar of Kali sets an example for the Timimoun region. This group maintains cultural traditions by organizing touiza (volunteers). Their efforts resulted in rehabilitation of the Iflambara qanat in 2002 and the qanat of Aghlad Ksar in 2004.

CONCLUSION

The qanat of Erg is still relatively unknown, and few studies have been conducted on this hydraulic heritage. This qanat continues to provide water to the oases despite the fact that its gallery is lost below the immense sand dunes of the Greatest Western Erg. Thus there is no information on the situation and location of the tunnel and mother shaft of this qanat. Without access to the Erg, this type of qanat cannot be maintained.

The ksouriens, the people of this region, are constantly confronted by the difficulties of the climatic nature of the region. The invasion

Terminology

Erg: a sand sea generally located in the bottom of a large basin; includes areas of actively shifting dunes, fossilized dunes, or sand sheets

Greatest Western Erg: located in the Sahara Desert between Algeria and Libya; considered one of the most difficult of all Saharan areas

Kasria: an outlet in a horizontal tunnel of a qanat; the Erg qanat has three types of kasria—sawtooth, circular, and rectangular

Madjens: a "pond" at an oasis; the Erg qanat contains six types of madjens—circular, rounded, L-shaped, zigzag, rectangular, and elongated

Qanat: a hand-dug underground horizontal tunnel system built to deliver groundwater by gravity in arid regions; developed in Iran 3,000 years ago; punctuated by vertical shafts to provide air supply, allow for removal of sand, and keep the tunnels from becoming too long; known by various names in other regions—foggaras (Africa), khettara (Morroco), karez (Pakistan), falaj (Oman); environmentally sound because they cannot cause significant aquifer drawdown

Seguia: aboveground canal carrying water from the qanat

of sand and wild plants on the galleries and the seguias of the Erg qanat are the daily challenges faced by the ksouriens. The removal of sand and curing of the qanat by simple means is a periodic operation. As far as controlling plants in this environment, specificially the Terza and Taghanimt that block the qanat with their long roots, ksouriens have found that fire is the only solution to stop their proliferation.

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