Hypogea 2015

Proceedings of International Congress of Speleology in Artificial Cavities
Italy, Rome, March 11/17 - 2015

EDITORS

Mario Parise
Carla Galeazzi, Roberto Bixio, Carlo Germani

SOCIETA' SPELEOLOGICA ITALIANA
ROMA SOTTERRANEA

ANCIENT AND MEDIEVAL UNDERGROUND HYDRO-TECHNICAL STRUCTURES OF ARMENIA

Smbat R. Davtyan
Armenian Speleological Centre, NGO; Totovents 10/1, Apt 21, Yerevan, Armenia; srdavtyan@mail.ru

Abstract
In the Armenian Highlands artificial and rock-carved hydro-technical structures have been used to supply drinking water, for drainage and irrigation, as water reservoirs, and many other purposes. In general, artificial structures have been carved out in volcanic rocks, such as basalt and tuff , although they have also been constructed in limestone and sandstone deposits. Moreover, although many of these were constructed thousands of years ago, they are still active today. For example, there are numerous Urartian canals, which are still in use in Armenia. During the Medieval period, the number of artificial and rock-carved hydro-technical structures increased significantly and new forms, such as watermills, wells, and drainage systems, of rock-carved systems were created. Historical accounts and scientific investigations have brought to light the existence of a wide variety of underground hydro-technical systems; many of these will be discussed in this study.
Keywords: hydro-technical structures, underground structures, rock-carved structures, Armenia.

Riassunto
Negli Altopiani armeni sono state usate molte strutture idrauliche, artificiali e scavate nella roccia, per vari scopi: fornitura di acqua potabile, drenaggio e irrigazione, riserva d'acqua, e altro. In generale, le strutture artificiali sono state scavate in rocce vulcaniche, come basalto e tufo, ma se ne trovano anche in depositi calcarei e arenarie. Inoltre, anche se molte di queste strutture risalgono a migliaia di anni fa, sono ancora funzionanti. Per esempio, in Armenia sono ancora in uso molti canali urartei. Durante il Medioevo, il numero delle strutture idrauliche artificiali scavate nella roccia crebbe in maniera notevole, e furono inventate nuove forme di sistemi idraulici scavati nella roccia, come mulini, pozzi e sistemi di drenaggio. I resoconti storici e le ricerche scientifiche hanno portato alla luce l'esistenza di una gran varietà di sistemi idraulici sotterranei; molti di questi saranno discussi in questo studio.
Parole chiave: *strutture idriche, strutture sotterranee, strutture scavate nella roccia.*

In Armenia, among many rock-carved structures the most notable are the hydro-technical constructions. In general, these can be subdivided into the following categories:
1 - Irrigation canals;
2 - Watermills;
3 - Qanats;
4 - Reservoirs or basins for drinking water;
5 - Water catchments;
6 - Water supply systems;
7 - Drainage systems.
Many of these have very interesting designs and are considered to be monuments attesting to unique engineering achievements and are an important aspect of the Armenian cultural heritage.
The first hydro-technical tunnels in Armenia were constructed during the Urartian period, 9th-6th centuries BC. These ranged from ten to several hundred meters in length. Today, there are three surviving Urartian hydro-technical canals: Umeshin, Dalma (Fig. 1), and Mamur, which in turn consists of several water tunnels. All three canals are located within the boundaries of the modern day Yerevan; these supplied irrigation water drawn from the Hrazdan River to the orchards in the Ararat plain. The tunnel segment of the Umeshin canal (23.6 km in length and a volume of 4.0 m^3/sec), which according to cuneiform inscriptions was built under the Urartian king Rusa II (665-645 BC), reaches 78 m in length. The tunnel was carved into andesite-basalt flows. The Umeshin canal is active even today. The Dalma canal (8.5 km in length and volume of 0.8 m^3/sec) of the same period, which was in use until 2010, has two tunnel segments – respectively, 27 m and 718 m in length. These are also carved into andesite-basalts. The third Urartian canal that has preserved, the Mamur canal (15 km in length and volume of 0.6 m^3/sec) is still active, though its tunnel, which was nearly 200 m long, is no longer in use.
Several water canals constructed during the Medieval period also have tunnel segments. These are located in the city of Ashtarak, in the villages Aknates and Khndzoresk, as well as in Tigranakert (Mountainous Karabakh).
In Armenia rock-carved watermills are rare and only four have been discovered thus far. Three of these are located in Karmrashen (Aragatsotn province) and one in Yelpin (Vayoc Dzor province). The watermills in Karmrashen have been dated to the 17th-18th c. AD, and the Yelpin watermill to the 13th-14th c. AD. These are carved in tuff and have the following structure: the water channel starts at the river and in order to insure flow of water it was built at a slight slop. In the underground chamber of the watermill, the water channel connects to a series of pressure pipes, which are carved into the rock at a 45 degree angle and become progressively narrow. From here the water is directed at the wheel paddles, thus turning it. The mill itself is placed within a rock-carved chamber, which was nearly

Fig. 1: rock-carved water tunnel of Dalma.
Fig. 1: tunnel scavato nella roccia a Dalma.

perpendicular to the pressure pipes. The water was removed through a water canal carved into the floor of the chamber and was most likely covered either by rock slabs or wooden planks.

Qanats were more widely spread in Armenia. Many of these are still in use today. Individual segments have preserved in Gumri, Vagharshapat, Meghri, Yerevan, etc. These often serve as catchments for underground waters located under alluvial and colluvial deposits; using gravitational forces the water is pushed to the surface and used for irrigation. These are comprised of series of well-like vertical shafts, connected by gently sloping horizontal tunnels. The tunnels have an arched cross-section. While some qanats stretch for a few dozen kilometers, most are noticeably shorter, only 1-1.5 km in length and 0.6-1.2 km in width. These are built without any supporting structures, though in some places where the tunnels are built in soft or loose soils, they are secured with slabs and the shaft walls are lines with rocks.

The total length of the Gumri qanats, which were built during the 19th century by fountain builders belonging to a specific gild ("laghumjiner"), reaches 30 km. In the qanats the flow of water reached 300-320 l/sec. In Gumri these were destroyed in the 1040's during various building and construction activities; today the majority of qanats are gone and the remaining few are damaged and neglected. There are however, the rare few which still flow with fresh spring water.

The qanats in Vagharshapat were built between the 17th-18th centuries in order to supply irrigation water to the field in the vicinity of the settlement, drinking water to the monastery, as well as to dry the walls of the monastery. The Catholicos Pilipos Aghbakeci (1632-1655 AD) commissioned the construction of "Sari qanqan" qanat, which originated in the territory of the monastery, continued to the church of St. Gayane and from there extended into the nearby fields.

Similarly, between 1655 and 1970 Catholicos Hakob Jughayeci (1655-1688 AD), commissioned the construction of a large qanat, which started at the Qasagh River and supplied water to the church of Echmiadzin, where it joined the qanat built under Pilipos Aghbakeci. In 1768 Chatholicos Simeon Yerevanci (1763-1780 AD) added several other qanats on the territory of the church, which he connected to "Sari Qanqan" qanat.

Presently, fragments of Vaghashapat qanats can be found on the territory of St. Gayane church and Mother Church at Echmiadzin. In 1845 a small stone building (Fig. 2) was built over the well of the qanat of St. Gayane (Fig. 3), which until the early 2000's supplied water via water pumps to the church. Although the well is no longer in use, the presence of water attests to the fact that the qanat is still functioning.

Four wells have been preserved on the territory of the Mother Church at Echmiadzin. One of these is located inside the monastery, north of the altar (Fig. 4). The well is always filled with water.

In the Armenian Highlands, qanats were common even in mountainous regions and to this day fragments of these can be found on the Ishkhanasar and Tsghuk massifs, in the upper reaches of Vorotan River, and in alpine pastoral campsites. Their presence or direction of flow can be determined from masonry of collapsed remains. The springs which fed the qanats are active even today and the connection between the springs and the qanats is not damaged.

Today several settlements of the Meghri region, such as Karchevan, Shvanidzor, and Nrnadzor, still use these ancient qanats for irrigating their orchards and fields. Until the 1960's the region had 12 functioning

Fig. 2: stone structure built over the well of St. Gayane Church.
Fig. 2: struttura in pietra costruita sopra il pozzo della chiesa di San Gayane.

Fig. 3: the well adjoining the qanat at St. Gayane Church.
Fig. 3: il pozzo sul qanat della chiesa di San Gayane.

qanats, which had a volume of 25 l/second.
Many fortified settlements of Armenia, notably Bjni, Jraberd, and Kachaghakaberd, contain underground water reservoirs (Fig. 5), which were built to supply drinking water in times of siege. Two methods were employed to fill these reservoirs with water: 1) rain-fed or snowmelt accumulations, 2) spring waters brought in with the aid of clay pipes. In general, the underground water reservoirs were not very large; their maximum length did not exceed 7 meters and had a width of up to 5 m and height of 3.5 m. Thus, their maximum capacity was around 50 m^3.
In general, caves which contained freshwater springs often served as water catchments; in order to maximize the capacity of the springs, the walls of the cave were carved out and widened. One such example is located in the village of Sarnaghbyur (Shirak Province), which was turned into a shrine, with crosses carved out in the walls of the cave. It is likely that during the pre-Christian period the cave was a place of water worship, which was adapted and continued to serve as a sacred local during Christianity. Another water catchment was built in 1730 -1732 in Metsamor, when the natural cave was enlarged and an underground water catchment system, composed of a basin and tunnels, was carved out in order to maximize the utilization of the natural spring waters.
Only one water well has survived; it is located on the territory of the Zvartnots cathedral and is 50 m deep. The well, which supplied the entire cathedral complex with water, is now dry as the underground waters, which supplied the well, have now dropped far below the 50 meter mark.
The water supply systems**,** which supplied natural spring water to various settlements, survived in fewer numbers. One such system can be found in Kosh community of the Aragatsotn province, where a 70 m long underground system brought natural spring waters to the community.
Water drainage systems were used to remove used or unwanted water from populated areas. One such system existed in Geghardavanq, where an underground

Fig. 4: the well adjoining the qanat at the Mother Church at Echmiadzin.
Fig. 4: il pozzo sul qanat della Chiesa Madre a Echimiadzin.

drainage system was used to remove water stagnancy caused by landslide materials. In the 1970's this system was modernized and the underground system was replaced with cement structures.
In addition to the hydro-technical structures, there are also secret passages, which were used to supply water in secret to the residents of fortified citadels. Such passages existed in Ani, Kars, Erzrum, Maghasberd, the acropolis of Harich, Bjni, Amberd, Lori Berd, Kaytson and many other fortresses and castles. According to the 5th century Armenian historian Movses Khorenaci during the construction of the city of Yervandashat, King Yervand had ordered that within the fortification walls of the city, in certain places the rock was to be carved in step-like fashion all the way to the base of the mound, where the river water could be collected in reservoirs in order to supply drinking water to the residents.
The best example of such a construction is preserved in the Bjni fortress (Fig. 6), where the secret passage goes from the citadel down a windy corridor towards the bank of Hrazdan River, eventually ending inside a cave with two spring waters, one containing fresh water, and the other mineral water.

Conclusion

Hydro-technical structures have been used for different purposes, to supply drinking water, for drainage and irrigation, and many others. In general, artificial structures have been carved out within volcanic rocks,

Fig. 5: underground water reservoir of the Bjni Fortress.
Fig. 5: riserva d'acqua sotterranea nella fortezza di Bjni.

such as basalt and tuff , although they have also been found in limestone and sandstone deposits. Moreover, although many of these were constructed thousands of years ago they are active today. For example, there are numerous Urartian canals, which are still in use. During the Medieval period, the number of artificial and rock-carved hydro-technical structures increased significantly, and new forms of rock-carved systems were created (e.g. watermills, drainage systems, etc.). Historical accounts and scientific studies bring to light the existence of a wide variety of underground hydro-technical systems and structures; regrettably, many of these have been destroyed or are in ruins due to lack of care and financial resources and we have only small fragments of what once was a rich and diverse architectural and cultural heritage.

Fig. 6: underground secret passage of the Bjni Fortress.
Fig.6: passaggio segreto sotterraneo nella fortezza di Bjni.

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