INNOVATION IN HYDRAULIC INSTALLATIONS: THE CASE OF UGARIT

Lorenzo Indino - Sapienza University of Rome

The study focuses on identifying the diverse and numerous water systems in the ancient city of Ugarit during the second half of the 2nd millennium BC (Late Bronze Age I-II/1600-1200 BC), in order to produce a typological subdivision that highlights innovations in the hydraulic technology.

Keywords: Northern Levant; water management; hydraulic innovations; wells; dam

1. Introduction

This paper focuses on the hydraulic technology in order to develop a typology of water systems, to underline possible innovations in water collection and management, and to track an administrative control in the direction and construction of them.[1] Due to the presence of over a hundred wells, the ancient city of Ugarit, modern Ras Shamra, emerges as a favourable case study.

A detailed analysis of the hydraulic systems hereunder is offered. The dataset allows the identification of different installations in Ugarit, as basins, canals, dams, pits, pools and wells. For each of these, building materials, construction techniques, and measures are described.[2]

The exact location of the infrastructures (i.e. inside or outside the buildings) and their nature (i.e. private or religious) are then taken into account. In fact, the collection of data will make it possible to carry out a synchronic and diachronic analysis of the types and construction techniques of these systems in the 2nd millennium BC and to relate them to other sites in the eastern Mediterranean.

2. Water management in the old city of Ugarit, modern Ras Shamra

2.1. *Surface and underground hydrography*

The ancient city of Ugarit, modern Ras Shamra, is in north-western Syria, in the province of Latakia (35.601889°N, 35.785041°E). Two seasonal torrential beds, *widyān*, respectively the Nahr Shbayyeb and the Nahr ed-Delbeh, surrounded the tell on the north and south side. These originate on the western slopes of the Bahlouliyé plateau, a northern extension of the Jabal Ansariyé, that gently descends from north-east to south-east, draining small catchment areas. The regime of the streams follows that of rainfall, abundant during the rainy season and scarce in spring when the last rains and the inflow of water from the underlying aquifer allow a low flow trend, and then dry up in summer.[3]

The contribution from the aquifer is due to the sponginess of the marly rock and marine sandstones that surround the geological landscape of the area. The porosity of the lithic material allows the runoff of meteoric water to deposit subsoil while the groundwater bed,

---

1 The article is part of B.4.3. research line of the project PRIN2017 People of the Middle Sea.

2 Metric details, as thickness, length, height and diameter, have been collected for each water installation. If there are no measurements in the excavation reports, these have been obtained through the autopsy analysis of the plants.

3 Calvet - Geyer 1995, 169; Blanchet - Sanlaville - Traboulsi 1997, 188; Yon 2006, 9, 12; Geyer 2017, 395-397, fig 1.

ISSN 0393-0300; 2724-587X
e-ISSN 2532-5159
doi: 10.53131/VO2724-587X2024_27

made up of impermeable Paleogenic marls,[4] avoids evaporation, consequently increasing the concentration of water by 3-4 m.

Surface hydrology is therefore unstable and little exploited; on the contrary the underground is abundant and branched. Meteoric water is collected and transported inside the water table which, in addition to constituting a permanent reserve, presents an altimetric trend degrading towards the West. The water table is found at a high level in the western side of the tell, between 12 to 15 m,[5] while in the eastern side between 6 to 10 m.[6]

Recent studies[7] have shown how the pluviometric variability does not decisively affect the flow of water inside the wells. in fact, during the dry season of the 2010, the level of the water table, measured inside the well 055, was around 10.7 m a.s.l, while in the wettest seasons, relating to the years 2007-2008, the level was always around 10-10.5 m a.s.l. Where the impermeable marl layer reaches the surface, it feeds various sources that flow at the foot of the tell, like Ayn el-Borj to the north and Mqatè to the south,[8] and the numerous wells[9] discovered throughout the city; while a well-thought-out system of dams[10] retained water to be used in the vast and fertile fields of the Bahlouliyé plateau surrounding the city. The source of Ayn el-Borj, located on the south-east of the site, flows from a limestone fissure[11] and has no particular systems, except for a modern bathtub; on the contrary, the source Mqatè, located about 100 m north-east of Ras Shamra, is near to a stone quarry that has provided much of the construction material for the buildings of Ugarit.[12]

2.2. *Hydraulic infrastructure*

The hydraulic infrastructure of the city can be divided in 4 types: wells (46), pits (29), basins (16) and channels (15); in addition, there are one pool and one dam.[13]

Since every house has at least one well, the city did not need cistern, which is not actually found in Ugarit.[14]

The water infrastructures are made up by local limestone or sandstone. Hydric elements are organized firstly according to geographical criteria, from west to east, and secondarily by types.[15]

2.3. *The wells*

4 Sanlaville 1979, 10; Calvet - Geyer 1987, 131; 1995, 170-171.
5 Schaeffer 1962, 29.
6 Calvet 1989, 311.
7 Matoïan - Geyer 2013, 67.
8 Calvet 1989, 310-312.
9 Geyer 2012, 14.
10 Calvet 1990a, 487-499; Calvet - Geyer 1992, 69-78; Matoïan *et al.* 2013.
11 Calvet - Geyer 1987, 131.
12 Calvet 1989, 312-313.
13 This count includes only those systems where it was possible to obtain data, such as diameter and depth, through the study of excavation reports and autopsy analysis of the plants.
14 Callot 1994, 163.
15 After the identification, hydric elements are labelled with the abbreviated designation “hyd” followed by numbers. The designation corresponds to the records of the PRIN database.

The wells are the most widespread means of supply and storage in the city. It is possible to identify six types of wells, based on the shape of the coping (fig. 1). They are identified with Roman numeral: circular monolithic coping (I), rectangular monolithic coping (II), square monolithic coping (III), trapezoidal monolithic coping (IV), parallelepipedal monolithic coping (V) and without coping (VI). The sub-types (fig. 2) are identified by lowercase letters: simple (a), with small holes (b), with tubular bulges (c), with hollow (d) and flat stones (e).

The Type Ia had circular monolithic coping;[16] the Type Ib had circular monolithic coping with small holes;[17] the Type Ic had circular monolithic coping with tubular bulges;[18] the Type Id had circular monolithic coping with hollow[19] and the Type Ie had flat stones or rubble.[20]

As for the last type, based on the comparison with other partially preserved copings, it can be assumed that the wells of this type also originally had a coping but their shape remains uncertain.

Also, the Types II and III has two sub-types: Type IIa, rectangular monolithic coping,[21] Type IIb, rectangular monolithic coping with small holes;[22] Type IIIa, squared monolithic coping;[23] Type IIIb, squared monolithic coping with small holes.[24]

It's interesting to note that the wells of the houses were always placed in very precise positions: the wells of Type I are found in the corners of the rooms, especially near the doors. They are rarely in the centre of the room. The Type II is located near the wall and in the corners, often associated with a basin. The Types III-VI have no particular position, but they are found near the walls, in the corners and in the central part of the rooms. The wells located in outbuildings and connected to secondary entrances suggest that they were reserved for personnel and craft or agricultural activities.

Four public wells of the Types I, III and VI are attested[25]. All of them have a cylindrical section, and sometimes, a series of notches on the walls, arranged at regular intervals, allowed maintenance.[26] The wells are divided into 4 parts: on the surface a monolithic coping crowns

[16] Hyd_023 (Schaeffer 1962, pl. 1); Hyd_025 (Calvet 1981, 39-42; Yon 2006, 51-54); Hyd_029 (Schaeffer 1962, 17); Hyd_054 (it is the well 3049 in: Matoïan - Geyer 2013, 48); Hyd_058 (Schaeffer 1938, fig. 6); Hyd_061 (Callot 1994, 14, 160, fig. 3); Hyd_062 (Callot 1994, 18, 159, 203-208, fig. 19); Hyd_096 (Callot 1994, 97, 161, figs. 210, 244); Hyd_101 (Schaeffer 1938, fig. 2; Yon 2006, fig. 71); Hyd_104 (Schaeffer 1938, fig. 2; Yon 2006, fig. 71); Hyd_105 (Schaeffer 1938, fig. 2); Hyd_106 (Schaeffer 1938, fig. 2); Hyd_108 (Calvet - Geyer 1987, 134, fig. 2).

[17] Hyd_005 (Schaeffer 1954, 20; 1962, 13; Yon 2006, 38); Hyd_055 (it is the well 3051 in: Matoïan - Geyer 2013, 48-62); Hyd_086 (Callot 1994, 57, 161).

[18] Hyd_015 (Schaeffer 1962, 31, 50; Calvet 1981, 46-47); Hyd_016 (Schaeffer 1962, fig. 33b).

[19] Hyd_083 (Callot 1994, 54, 161, figs. 126, 127, 136).

[20] Hyd_008 (Callot 1983, 744); Hyd_009 (Pitard 1994, fig. 27); Hyd_040 (it is the well 2070 in: Yon *et al.* 1990, 23); Hyd_053 (it is the well 205 in: Mallet - Matoïan 2001, 91); Hyd_057 (Schaeffer 1938, fig. 6); Hyd_072 (Callot 1994, 38, 159, 203-208); Hyd_074 (Callot 1994, 38, 159, 203-208); Hyd_084 (Callot 1994, 52, 162); Hyd_087 (Callot 1994, 70, 161); Hyd_100 (Schaeffer 1938, fig. 2).

[21] Hyd_013 (Schaeffer 1960, pl. 1); Hyd_037 (Yon 2006, 73); Hyd_038 (Yon 2006, 73); Hyd_068 (Callot 1983, 31-35, 53, 65; 1994, 161, 203-208); Hyd_089 (Callot 1994, 72, 162).

[22] Hyd_079 (Callot 1994, 53-54, 161).

[23] Hyd_021 (Calvet 1981, 45); Hyd_022 (Schaeffer 1960, pl. 1); Hyd_031 (Calvet 1981, 39); Hyd_090 (Callot 1994, 82, 161).

[24] Hyd_051 (it is the well 1071 in: Calvet - Geyer 1987, 134).

[25] Hyd_069 (Callot 1994, 36, 161, 203-208); Hyd_090; Hyd_096; Hyd_108.

[26] Callot 1994, 160.

the opening; the first cylindrical section and the wall are built of irregular rubble; the second section is in a layer of sand and sandstone slabs, and the last one section is dug in the marl.[27]

2.4. *The "bridge-dam"*

The dam (fig. 3)[28] was built in the 13th century BC and is located a few hundred meters south of the tell, on the Nahr ed-Delbeh. It consists of a central pillar and two anchor blocks located on the banks. Only the left bank, the southern one, has been preserved. Thus, the two passes could be closed by beams or planks inserted in notches cut in the blocks of the pillar and anchor blocks. The structure, 11 m long and 9.50 m wide, also served as a bridge,[29] ensuring good circulation towards the city, and allowed the crossing of the watercourse, but it created above all a precious reserve of water. Similar installations are attested at Mycenae[30] and Tiryns.[31] and dated to the 1st millennium BC.

3. Innovations in hydraulic Technology

3.1. *The use of wells*

The first characteristic that can be noted in Ugarit water installations is the presence of coping for 89% of wells. These elements suggest the presence of a wooden superstructure with a well-conceived system of pulleys that made it possible to capture the water even in the lowest points of the wells and easier to pull large quantities of water.[32] Some houses had the kitchen upstairs[33] and the pulley system allowed water to be taken directly from the kitchen, making easier this operation.[34]

The oldest known wells in the Levant,[35] during the Pre-Pottery Neolithic (8500-4500 BC), did not have the coping, as at 'Atlit Yam,[36] Sha'ar HaGolan;[37] in Cyprus at Kissonerga-Mylouthkia[38] and Shillourokambos;[39] in the central Jordan Valley at Tell Tsaf[40] date to the Chalcolithic period (4500-3400 BC).

---

27 Callot 1994, 159-160.
28 Hyd_046 (Calvet 1990a, 487-499; Calvet - Geyer 1992, 69-78; Yon 2006, 89-90; Bessac 2010; Geyer - Calvet 2013, 1-43).
29 Yon 2006, 90; Geyer - Calvet 2013, 43.
30 Hope Simpson - Hagel 2006, 179-181; Orgeolet 2019, 17-18.
31 Tölle-Kastenbein 1990, 114-117; Orgeolet 2019, 17.
32 Callot 1994, 161.
33 Callot 1994, 167.
34 Callot 1994, 162.
35 Garfinkel 2014, 1456-1457.
36 Galili *et al.* 2017, 97. Along the Israel coast, near Mount Carmel.
37 Garfinkel - Vered - Bar-Yosef 2006. In the upper Jordan Valley.
38 Peltenburg *et al.* 2000. On the western end of the island.
39 Guilaine - Briois 2001, 41. On the southern part of the island.
40 Garfinkel 2014, 1457.

In the 2nd millennium BC, the wells are not always equipped with coping, like at Aredhiou Vouppes,[41] Hala Sultan Tekke,[42] Alassa-Paliotaverna,[43] Enkomi,[44] Kourion-Bamboula,[45] Kouklia,[46] Palaikastro.[47]

The presence of monolithic coping is attested[48] in Minet el-Beïda,[49] that properly is Ugarit harbour, at Enkomi,[50] and at Hala Sultan Tekke.[51] However, the coped wells at Hala Sultan Tekke and Enkomi were close to a cult area and may have been different. Therefore, at Ugarit the presence of a consistent percentage of coping and other features like small holes, tubular bulges and hollow in the coping, attests the great attention in water management and architectural complexity. It can be noted the precise location was perfectly planned from the beginning of the works, so that their walls were integrated with the foundations of the houses. This made the walls of the wells much more resistant. Moreover, the presence of coping with the small holes on the surface suggested that these chambers were intended to anchor the lower part of two posts, the upper part of which was fixed to the beams of a third pillar or ceiling. Between the two pillar there was a pulley or cylinder that could turn on itself and around which the rope was wrapped. It is possible hypothesize that this system allowed the collection of water also from the upper floor.[52] This ingenious system of pulleys facilitated, thus, the collection of water from high depths with minimal effort.

3.2. *The dam*

The case of the Ugarit dam appears to be innovative in the construction technology of hydraulic infrastructures with regard to the processing of the raw material, i.e. stone, and its installation.

The building material consisted of carved rectangular blocks of ramleh. The observation of the technical characteristics of the curved stones indicates an advanced lithic technology that was attested also within the city, as in the defensive system, in the "*tomb aux casemates*" and in the "*Quartier Résidentiel*".[53] This rock is soft enough to be worked with bronze tools.[54] Thus, most of the facings of the first course of the central pier was left raw. The second course is faced using a tool with one or two cutting edges, arranged perpendicular to its handle.[55]

The second element of innovation is the use of wooden dovetails to join the blocks carefully cut. These joints, between 25 to 34 cm long, and an average width of 10.5 cm, were

41 Steel 2016, 520-523.
42 Åstrom 1998, 55-77, 108-109, 133.
43 Christou 1996, 1066.
44 Dikaios 1969, 177, 194, pl. 294.
45 Weinberg 1983, 32, 56.
46 Halstead 1977, 270.
47 Tomlinson 1994-1995, 69.
48 The presence of coping in the upper part of the well is attested also at Ebla/Tell Mardikh on the wells P.9125, P.9130, P.9516 e P.9761 (Ascalone - Peyronel - Spreafico 2014, 249-250, 256, 258, 261-262, figs. 5-7, 9-10, 22-24), but without specific layout as small holes like at Ugarit.
49 Schaeffer 1935, 169.
50 The wells 1, 9 and 23; Dikaios 1969, 56, 174, 182.
51 The well F.1750; Åstrom 1998, 57-64, 133.
52 Callot 1994, 162.
53 Bessac 2010, 32-33; Geyer - Calvet 2013, 30-31, 39-40.
54 Bessac 2013, 465-466; Matoïan *et al.* 2013, 30.
55 Matoïan *et al.* 2013, 29-31.

dug on the waiting beds, directly above the internal upright joints, to accommodate *tenons*.[56] The absence of trace of oxidation or lead sealing in these cavities suggests that the *tenons* were made of wood.[57] These held the lower blocks in place during the laying of the stones for the next course. In addition, the dovetails allowed to keep the stones firmly together, a particularly sought-after solution to face the river current during the full months of the wadi. The use of wood instead of metal allowed to adjust the distance of the stone blocks during the installation, and it was against the frequent earthquakes[58] to which the area was subject. These construction techniques will be reused in the Hellenistic[59] and Achaemenid[60] periods but with the use of more efficient metal *tenons*.

Another innovative element is the removable nature of the beams. In fact, only the pillars were permanent, while the boards, that were used to block the canal, were subject to regular maintenance and were replaced every year. Such a device is well adapted to the resources of the environment: the hinterland of Ras Shamra, particularly wooded, could provide beams of excellent quality for all the architecture of the region and for the dam. Its removable nature fits very well with the water resources of the wadi. In fact, the flood could have been very violent, and it was preferable to let it pass so as not to cause flooding. On the other hand, before and during low tide, the flow, partly stored in a reservoir, irrigated nearby fields.[61]

4. Conclusion

In the 2nd millennium BC the inhabitants of the Northern Levant benefited from favourable environment and natural conditions (§ 2.1.), and tried to control essential elements, such as water, for their survival. Therefore, they tried to elaborate methods for water conservation and developed innovative techniques (§ 3.) which mainly aimed at retaining water so that, under certain climatic conditions, it could never run out; so, the aim was to build plants that were perfectly efficient in all circumstances. The validity is demonstrated using dovetails for the junction of the stone blocks which allowed an excellent seal of the running water of the neighbouring Nahr ed-Delbé and made it possible to exploit the dam also as a passageway when the river was in flood. At the same time, the creation of lithic coping of various types with small holes on the surface suggests the presence of an ingenious system of pulleys which facilitated the collection of water even at high depth. The copings are only in some cases found in the eastern Mediterranean (§ 3.1.), but in none are found small holes that suggest the presence of wooden superstructures to facilitate the collection of water. This comparative study has allowed to identify a sharing of hydraulic knowledge, in a sort of regional hydraulic *koinè*, favoured by a wide availability of resources and technological experimentation in which Ugarit is at the forefront.

56 Calvet - Geyer 1992, 72; Matoïan *et al.* 2013, 15-16; Yon 2006, 90.
57 Bessac 2010, 32-33; Matoïan *et al.* 2013, 16.
58 Like in the 2400 BC, 2100 BC, 1750 BC, and 1250 BC; Schaeffer 1968, 760-762.
59 Bessac 2010, 33.
60 Nylander 1970, 63-66.
61 Calvet - Geyer 1992, 127.

References

Ascalone, E. - Peyronel, L. - Spreafico, G.

2014 Family Daily Life at Tell Mardikh-Ebla (Syria) during the Middle Bronze Age: a Functional Analysis of Three Houses in the Southern Lower Town (Area B East): M. Lionel (éd.), *La famille dans le Proche-Orient ancien: réalités, symbolismes, et images. Proceedings of the 55th Rencontre Assyriologique Internationale at Paris 6-9 July 2009* (Rencontre Assyriologique International), Eisenbrauns 2009, pp. 243-266.

Åstrom, P.

1998 *Hala Sultan Tekke* 10. *The wells* (Studies in Mediterranean Archaeology 45), Jonsered 1998.

Bessac, J.-Cl.

2010 Étude des techniques de taille dans l'architecture d'Ougarit; Le pont-barrage sur le Nahr ed-Delbé: M. Al-Maqdissi - Y. Calvet - V. Matoïan (éd.), *Rapport préliminaire sur les activités de la mission syro-française de Ras Shamra - Ougarit en 2007 et 2008 (67e et 68e campagnes)* (Syria 87), Paris 2010, pp. 32-33.

2013 La construction en pierre à Ougarit: V. Matoïan - M. Al-Maqdissi - J. Haydar - K. Al-Bahloul - C. Benech - J-C. Bessac - E. Bordreuil - O. Callot - Y. Calvet - A. Carbillet - E. Dardaillon - B. Geyer - J-P. Goiran - R. Hawley - L. Herveux - N. Marriner - F. Onnis - D. Pardee - F. Rejiba - C. Roche-Hawley - C. Sauvage (éd.), *Rapport préliminaire sur les activités de la mission archéologique syro-française de Ras Shamra - Ougarit en 2009 et 2010 (69e et 70e campagnes)* (Syria 90), Paris 2013, pp. 465-466.

Blanchet, G. - Sanlaville, P. - Traboulsi, M.

1997 Le Moyen-Orient de 20 000 ans BP à 6 000 ans BP. Essai de reconstitution paléoclimatique: *Paléorient* 23.2 (1997), pp. 187-196.

Callot, O.

1983 *Ras Shamra - Ougarit I. Une maison à Ougarit* (Mémoire 28), Paris 1983.

1994 *Ras Shamra - Ougarit X. La tranchée «Ville sud». Études d'architecture domestique*, Paris 1994.

Calvet, Y.

1981 *Installations hydrauliques d'Ugarit, L'homme et l'eau en Méditerranée et au Proche Orient I* (Travaux de la Maison de l'Orient 2), Lyon 1981.

1989 La maîtrise de l'eau à Ougarit: *Comptes rendus de l'Académie des Inscriptions et Belles-Lettres* 133.2 (1989), pp. 308-326.

1990a Un barrage antique à Ras Shamra: B. Geyer (éd.), *Techniques et les pratiques hydro-agricoles traditionnelles en domaine irrigué. Approche pluridisciplinaire des modes de culture avant la motorisation en Syrie, Damas, juin 1987* (Bibliothèque Archéologique et Historique 136), Paris 1990, pp. 487-499.

1990b Les bassins du palais royal: *Syria* 67 (1990), pp. 31-42.

Calvet, Y. - Geyer, B.

1987 L'eau dans l'habitat: M. Yon (éd.), *Ras Shamra - Ougarit III. Le centre de la ville. 38e-44e campagnes (1978-1984)* (Mémoire 72), Paris 1987, pp. 129-156.

1992 *Barrages antiques de Syrie* (Collection de la Maison de l'Orient Méditerranéen 21), Lyon 1992.

1995 Environnement et ressources en eau dans la région d'Ougarit: M. Yon - M. Sznycer - P. Bordreuil (éd.), *Ras Shamra - Ougarit XI. Le pays d'Ougarit autour de 1200 av. J.-C. Actes du colloque international Paris, 28 Juin - 1er juillet 1993*, Paris 1995, pp. 169-182.

CHRISTOU, D.
1996 Chronique de fouilles et découvertes archéologiques à Chypre en 1995: *Bulletin de Correspondance Hellénique* 120 (1996), pp. 1049-1100.
DIKAIOS, P.
1969 *Enkomi. Excavations 1948-1958. The Architectural Remains. The Tombs*, Mainz 1969.
GALILI, E. - BENJAMIN, J. - HERSHKOVITZ, I. - WEINSTEIN-EVRON, M. - ZOHAR, I. - ESHED, V. - CVIKEL, D. - MELAMED, J. - KAHANOV, Y. - BERGERON, J. - RUGGLES, C. - RONEN, A. - KOLSKA HORWITZ, L.
2017 Atlit-Yam: A Unique 9000 Year Old Prehistoric Village Submerged off the Carmel Coast, Israel - The SPLASHCOS Field School (2011): N. BAILEY - J. HARFF - D. SAKELLARIOU (eds.), *Under the Sea: Archaeology and Palaeolandscapes of the Continental Shelf* (Coastal Research Library 20), Springer 2017, pp. 85-102.
GARFINKEL, Y.
2014 The Levant in the Pottery Neolithic and Chalcolithic Periods: C. RENFREW - P. BANN (eds.), *West and Central Asia and Europe* (Cambridge World Prehistory 3), Cambridge 2014, pp. 1439-1461.
GARFINKEL, Y. - VERED, A. - BAR-YOSEF, O.
2006 The domestication of water: the Neolithic well at Sha‘ar Hagolan, Jordan Valley, Israel: *Antiquity* 80 (2006), pp. 686-696.
GEYER, B.
2012 Ressources en eau et aménagements hydrauliques en Ougarit : état de la recherché: V. MATOÏAN - M. AL-MAQDISSI - Y. CALVET (éd.), *Études ougaritiques* II (Ras Shamra - Ougarit XX), Paris 2012, pp. 11-18.
2017 Climat et variabilité dans la region de Ras Shamra - Ougarit: V. MATOIAN (éd.), *Archéologie, patrimoine et archives. Les fouilles anciennes à Ras Shamra et à Minet el-Beida I* (Ras Shamra - Ougarit XXV), Leuven 2017, pp. 393-401.
GEYER, B. - CALVET, Y.
2013 Le «Pont-Barrage» du Nahr ed-Delbé (Ras Shamra - Ougarit, Syrie): V. MATOÏAN - M. AL-MAQDISSI (éd.), *Études ougaritiques III* (Ras Shamra - Ougarit XXI), Paris 2013, pp. 1-45.
GUILAINE, J. - BRIOIS, F.
2001 Parekklisha Shillourokambos: An Early Neolithic site in Cyprus: S. SWINY (ed.), *The Earliest Prehistory of Cyprus: From Colonization to Exploitation* (American Schools of Prehistoric Research), Boston 2001, pp. 37-54.
HALSTEAD, P.
1977 A Preliminary report on the Faunal Remains From Late Bronze Age Kouklia, Paphos: *Report of the Department of Antiquities Cyprus* (1977), pp. 261-275.
HOPE SIMPSON, R. - HAGEL, D.K.
2006 *Myceneans fortifications, Highways, Dams and Canals* (Studies in Mediterranean archaeology 133), Sävedalen 2006.
MALLET, J. - MATOÏAN, V.
2001 Une Maison au sud du Temple aux Rhytons (fouilles 1979-1990): M. YON - D. ARNAUD (éd.), *Études ougaritiques I. Travaux 1985-1995* (Ras Shamra - Ougarit XIV), Paris 2001, pp. 83-190.
MATOÏAN, V. - GEYER, B.
2013 Premières observations rèalisèes sur le puits 3150 du chantier « Grand-Rue » (Ras Shamra - Ougarit): V. MATOÏAN - M. AL-MAQDISSI (éd.), *Études ougaritiques* III (Ras Shamra - Ougarit XXI), Paris 2013, pp. 47-71.
MATOÏAN, V. - MARRINER, N. - LECONTE, M. - CHAMBRADE, M.-L. - ONNIS, F. - GOIRAN, J.-P.
2013 Le «Pont-Barrage» du Nahr ed-Delbé (Ras Shamra - Ougarit, Syrie): V. MATOÏAN - M. AL-MAQDISSI (éd.), *Études ougaritiques* III (Ras Shamra - Ougarit XXI), Paris 2013, pp. 1-45.

NYLANDER, C.
1970 *Ionians in Pasargadae*, Uppsala 1970.
ORGEOLET, R.
2019 Gestion de l'eau, grands travaux et pouvoir politique dans le monde Mycénien: S. BOUFFET - O. BELVEDERE - S. VASSALLO (éd.), *Gérer l'eau en Méditerranée au premier millénaire avant J.-C.* (Archéologies Méditerranéennes), Aix Marseille 2019, pp. 13-24.
PELTENBURG, E. - COLLEDGE, S. - CROFT, P. - JACKSON, A.
2000 Agro-Pastoralist Colonization of Cyprus in the 10th Millennium BP: Initial Assessment: *Antiquity* 74 (2000), pp. 844-853.
PITARD, W.T.
1994 The "Libation Installations" of the Tombs at Ugarit: *The Biblical Archaeologist* 57.1 (1994), pp. 20-37.
SANLAVILLE, P.
1979 Étude géomorphologique de la basse-vallée du nahr el Kébir: P. SANLAVILLE (éd.), *Quaternaire et préhistoire du nahr el Kébir septentrional* (Collection de la Maison de l'Orient méditerranéen. Série géographique et préhistorique), Paris 1979, pp. 7-28.
SCHAEFFER, C.F.A.
1935 Les fouilles de Ras-Shamra, 6e campagne (printemps 1934): *Syria* 16 (1935), pp. 142-176.
1938 Les Fouilles de Ras Shamra-Ugarit. Neuvième campagne (printemps 1937). Rapport sommaire: *Syria* 19 (1938), pp. 313-334.
1954 Les fouilles de Ras Shamra-Ugarit. Quinzième, seizième et dix-septième campagnes (1951, 1952 et 1953). Rapport Sommaire: *Syria* 31 (1954), pp. 14-67.
1960 Résumé des résultats de la XXIIe campagne de fouilles à Ras Shamra-Ugarit: *Les Annales Archéologiques Syriennes* 10 (1960), pp.134-158.
1962 *Ugaritica IV. Mission de Ras Shamra, tome 15. Découvertes des XVIIIe et XIXe campagnes, 1954-1955. Fondements préhistoriques d'Ougarit et nouveaux sondages. Etudes anthropologiques. Poteries grecques et monnaies islamiques de Ras Shamra et environs*, Paris 1962.
1968 Commentaires sur les lettres et documents trouvés dans les bibliothèques priveés d'Ugarit: J. NOUGAYROL - E. LAROCHE - C.H. VIROLLEAUD - C.F.A. SCHAEFFER (éd.), *Ugaritica V, Nouveaux textes accadiens, hourrites et ugaritiques des archives et bibliothèques privées d'Ugarit, commentaires des textes historiques, Mission de Ras Shamra 16* (Bibliothèque Archéologique et Historique 80), Paris 1968, pp. 607-768.
STEEL, L.
2016 Exploring Aredhiou: New Light on the Rural Communities of the Cypriot Hinterland During the Late Bronze Age: *American Journal of Archaeology* 120.4 (2016), pp. 511-536.
TÖLLE-KASTENBEIN, R.
1990 *Antike Wasserkultur*, Münich 1990.
TOMLINSON, R.A.
1994-1995 Archaeology in Greece: *Archaeological Reports* 41 (1994-1995), pp. 1-75.
WEINBERG, S.
1983 *Bamboula at Kourion: The Architecture* (University Museum Monograph 42), Philadelphia 1983.
YON, Y.
2006 *The City of Ugarit at Tell Ras Shamra*, Winona Lake 2006.
YON, M. - GACHET, J. - LOMBARD, P. - MALLET, J.
1990 Fouilles de la 48e campagne (1988) à Ras Shamra-Ougarit: *Syria* 67 (1990), pp. 1-29.

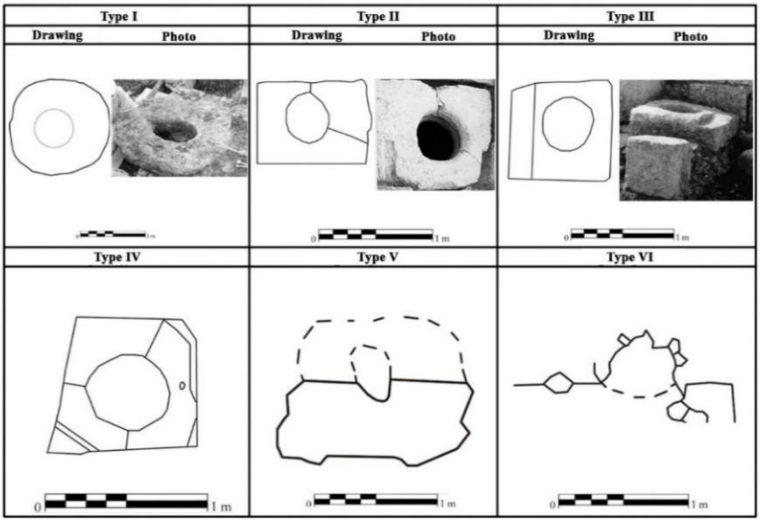

Fig. 1 - Wells of Type I: Hyd_108 (Calvet - Geyer 1995, fig. 4); Type II: Hyd_037 (Yon 2006, fig. 42b); Type III: Hyd_031 (Matoïan - Geyer 2013, fig. 8); Type IV: Hyd_065 (Callot 1983, fig. 4); Type V: Hyd_011 (Calvet 1990b, fig. 2); Type VI: Hyd_064 (Callot 1994, fig. 19).

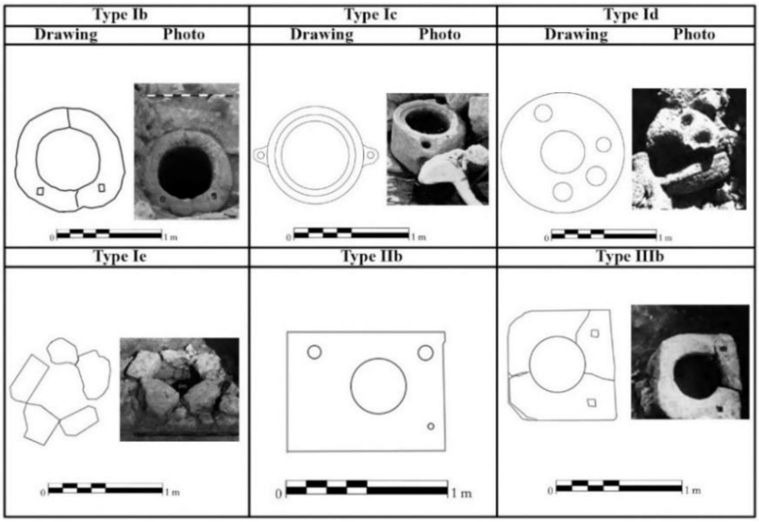

Fig. 2 - Wells of Type Ib: Hyd_055 (Matoïan - Geyer 2013, fig. 14); Type Ic: Hyd_016 (Schaeffer 1962, fig. 33b); Type Id: Hyd_083 (Callot 1994, fig. 373); Type Ie: Hyd_053 (Mallet - Matoïan 2001, fig. 6d); Type IIb: Hyd_079 (Callot 1994, fig. 126); Type IIIb: Hyd_051 (Calvet - Geyer 1987, fig. 13).

Fig. 3 - Dam Hyd_046 (Matoïan *et al*. 2013, fig. 14). View of the dam from the east. The central pylon of triangular shape with the wooden dovetails and on the left the southern pylon. On the ground the stone channel and the floor.