The Qraya Salt Experiment

PROOFS

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Abstract

Qraya is a small site on the middle Euphrates in Western Syria: excavations carried out between 1977 and 1984 gave abundant evidence for late fourth millennium occupation. The diminutive size of the site and the lack of monumental architecture indicates that this was not an urban site; and yet, some of the vessels, in particular the so-called beveled rim bowls, were found in very large quantities, such as are normally associated with large scale activities typical of early urbanism. An experiment was carried out in 1989 to test the hypothesis that these vessels could be used in the production of salt destined for the large contemporary cities in the north (where salt was lacking). At Qraya, salt could be procured in raw form in the nearby playas of Bouara, and could be processed easily with the abundant water from the Euphrates river. The experiment was successful, and it is presented here in full detail. The whole inventory of artifacts found at the site can be explained in function of the process entailed in the production of salt. The beveled rim bowls, in particular, can be seen to have served as ideal vessels for both the production and the conservation of salt. Importantly, this speaks to a unusual trade model, one that was initiated by the cities in the north specifically to exploit a distant natural resource (the salt from the playa), by processing it and shipping it to the cities in the north.

Keywords

Introduction

The project: chronicle and authorship

The Qraya experiment in salt production was initially suggested by Beatrice Hopkinson, following a presentation at UCLA of Buccellati's excavations at the site of Qraya, in eastern Syria. She remarked that some of the vessels, which she had seen first in the slides and then in the actual sherds, was remarkably similar to that used in salt producing sites in Europe, with which she was intimately familiar. She suggested that it may be worthwhile to make a test to verify the plausibility that these vessels may indeed have been used to produce salt cakes. Taking her up on this suggestion, Buccellati organized a study trip to Syria to test the hypothesis.

The trip took place in the early fall of 1989. Buccellati and Hopkinson spent several days at the field house of the Terqa Expedition in Darnaj, across the Euphrates river from Ashara (Figure 1). The house had been built by Buccellati during the years in which he served as Director of the Joint Expedition to Terqa, and had been turned over to Olivier Rouault when he took over the excavations at Terqa. Some of the material originally excavated in Qraya was stored in the house and was thus readily available for the experiment.

The starting point of the experiment was the procurement of raw salt from the salt playas of Bouara, to the east of the Euphrates. The experiment lasted for a few days and was carried out on the edge of the courtyard facing the house, which fronted the Euphrates river. At the end of the experiment, the material was taken to the expedition house of the Mozan/Urkesh Archaeological Project, in northeastern Syria, where Buccellati served then as Co-Director of the project.

In addition to visiting the Bouara salt playas, Buccellati and Hopkinson visited also the salt mines near Der ez-Zor and the salt playas of Palmyra and the Jabbul.

While Buccellati was responsible for the logistic organization of the trip, Hopkinson was entirely responsible for the intellectual scope of the project and for the coordination of the various phases of the experiment. Hence this report reflects essentially her thinking. She had also prepared the first draft of the text that is published here, but it was impossible to coordinate the final writing with her. The final redaction of the text is thus the work of Buccellati.

A short description of the experiment was published in Buccellati 1990 "Experiments." The possibility that Qraya might have served specifically the purpose of providing northern cities with salt was presented at length in Buccellati 1990 "Dawn," and briefly mentioned in Buccellati and Kelly-Buccellati 2007 "Qurayya." This proposal has been noted (e. g., Bernbeck 1993 *Steppe*; ....), but has not been otherwise tested nor has it found general consensus. Goulder (2010 "Administrators' Bread" p. 357) refers to the proposal (but only on the basis of Buccellati 1999 "Urbanism" without considering the more detailed account in Buccellati 1990 "Dawn") and reports having done "a brief experiment with wet salt precipitated from brine," as a result of which "the salt dried out well as the water soaked into the bowl, but then had to be scraped out with difficulty, with the damp BRB [Beveled Rim Bowls] again breaking when picked up": clearly, this result is contradicted by our own Qraya experiment as reported below.

General historical and archaeological setting

The development of urban civilization in Syro-Mesopotamia (Figures 2 and 3), in the fourth millennium B. C., caused a radical re-alignment of social structures (Buccellati 2013 *Origini* ch. 5). In particular, a much larger demographic base resulted in the need to stock increased quantities of food supplies, the management of which required new expertise and favored the centralization of power in the hands of a small elite. Large storage facilities for dry food stuff give evidence of this. It is to be expected that salt would have played a role for the preservation of more perishable items like meat and fish. Sources of salt were as limited in antiquity as they are today, and thus any supply of this resource would have had to originate there.

A number of concomitant reasons suggest that the site of Qraya would have served to provide the northern cities of Syro-Mesopotamia, such as Tell Brak, ancient Nagar, with salt coming from the closest point of origin, in the area known today as Bouara. Qraya is the only site near Bouara which was inhabited in the fourth millennium, and it is located directly on the Euphrates river (Figure 4), which was the necessary presupposition not only for the processing of salt, but also for fishing, which would have yielded a by-product that could also be shipped north on the road along the Euphrates and the Khabur rivers.

A set of vessels that is typical for this early urban culture, the beveled rim bowls (Figures 5 and 6), present morphological traits that are similar to those of the ceramics from Bronze Age Europe known as *briquetage*, used in producing salt. The experiment reported below showed that indeed these vessels were ideally suited for the production of refined salt cakes, and they were part of a larger assemblage, each element of which was just as ideally suited for the complex production process that would have provided the northern cities with the salt supply they needed.

Figure 1. The authors at the Terqa Expedition house in Darnaj.
Here is where the Qraya artifacts were stored and the experiment was conducted.

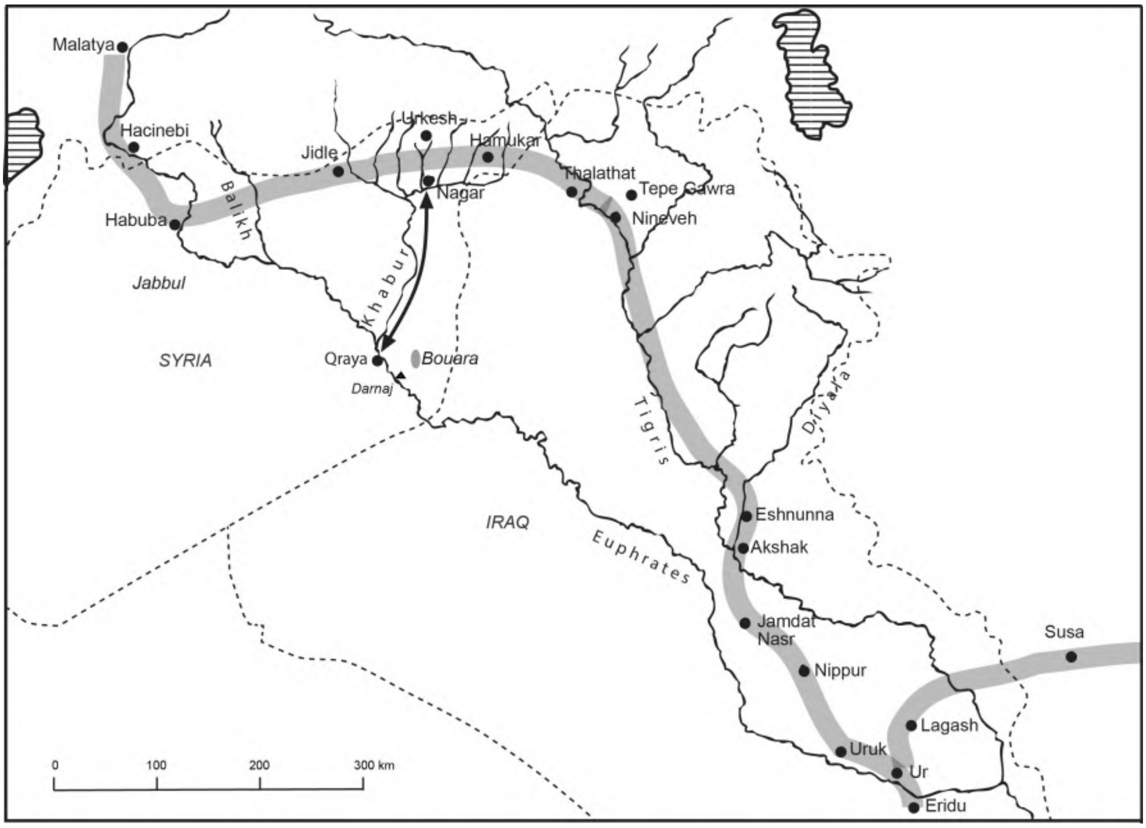

Figure 2. Syro-Mesopotamia with the major urban centers of the fourth millennium
It is assumed that the Tigris was the main North-South artery of communication between urban centers. The small site of Qraya, which exhibits urban traits but is not a city, is assumed to have been created by the Northern cities for the specific purpose of exploiting the Bouara salt deposits, and of exporting both salt and cured fish from the Euphrates to the Northern cities.

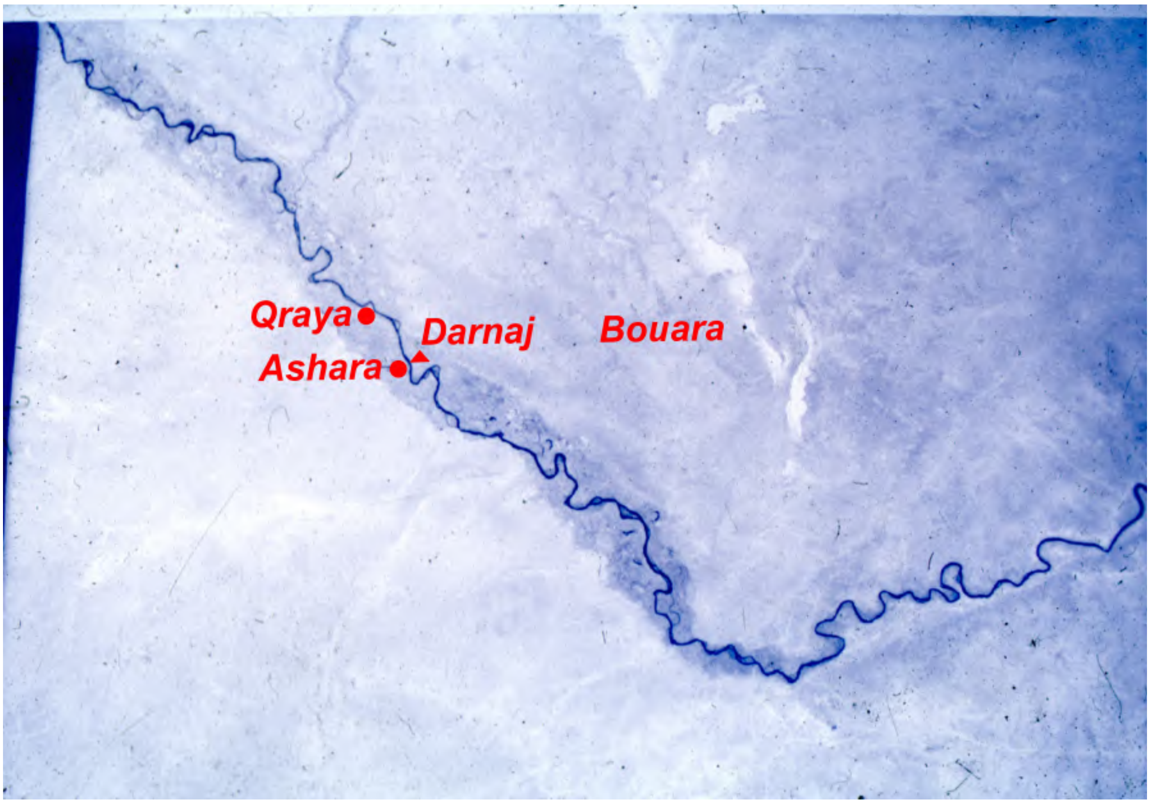

Figure 3. A satellite image of the middle Euphrates, with the location of relevant sites.
Qraya and Ashara (ancient Terqa) and Darnaj on the banks of the Euphrates, and the Bouara playas (white area) in the steppe.

Figure 4. An aerial view of Qraya, on the Euphrates.

Figure 5. A group of beveled rim bowls from Qraya.
The unevenness in size, as well as their presence in large quantitites in a non-urban site like Qraya, argues against their serving as standards of measure for doling out rations.

Figure 6. A beveled rim bowl from Qraya.
The bevel along the rim comes from the fact that the vessel was made in a mold, which increased the speed with which they could be produced.

The beveled rim bowls
The major hypotheses for the use and function of the Beveled Rim Bowls suggest that they were used as grain measures (Nissen 1970 "Grabung"; Johnson 1975 "Locational"; Nissen 1988 *History;* 2001 "Networks"), as bread molds (Schmidt 1982 "Verwendung"; Millard 1988 "Bowls"; Potts 2001 "Bakeries"; Goulder 2010 "Administrators' Bread"), for tax payments (Nicholas 1987 "Function"; for a similar use of salt as tax revenue in the 11^{th} century A. D. see Hopkinson 1995 *Domesday*). There are difficulties with these interpretations, such as the existence of considerable variations in the actual size of the bowls (Beale 1978 "Bowls"). But it is more than likely that, on given occasions, these bowls would have been used for all these purposes and more, as well as the one suggested here for salt production. One thing, however, distinguishes the salt hypothesis from the other ones: it seems clear that salt production could *only* have been effected through the use of these bowls. Such exclusivity does not apply in the case of the other proposals: a single standard vessel could have been used to measure quantities as they were being issued; bread could certainly be baked on flat surfaces; tax payments were in fact made with other means.

Porosity is a special characteristic of these vessels. A Sorptomatic 1990 Analysis Test was conducted on a sherd from a Qraya beveled rim bowl by Dr. Robert Jacobs at the Surface Analysis Facility, Research Laboratory at Oxford, in 2008, for this study. This BET analysis measures the voids that penetrate from the inner to the outer wall of the vessel, and he found on a microscopic level that this sherd was "*significantly porous,* with 36% open pores and an additional 6% or less, of closed pores," making it ideal for rapidly absorbing liquid. At the macroscopic level, the pores varied in size up to about 80 Angstroms, which is at least four times the size necessary to adsorb Mg2 impurities that remain in solution after sodium chloride has crystallized, as described above in the draining and drying of salt. In addition, Dr. Walter Franke prepared thin sections in 2008, at the Hydrogeology Laboratory at the Freie Universitåt, Berlin, on the same sherd. It was found to contain uneven inclusions of both large and small grains of quartz, feldspar, limestone, and volcanic fragments – inclusions that are found in the Euphrates river clay used at Qraya (Lease and Abdel-Rahman 2008 "Euphrates").

Bouara and salt sites in Syria
Three important Syrian salt sites were visited before proceeding with the Qraya experiments: Sabkhat al-Jabbul in the Aleppo governorate; Palmyra in the Homs governorate; and the Sabkhat al-Bouara in the Der ez-Zor governorate.

Al-Jabbul is the largest natural lake in Syria, located in a closed basin covering about 100 square kilometers. During the Pleistocene the basin overflowed and formed a tributary of the Euphrates. The lake is now relatively stable, flooding in the spring and shrinking in the summer and autumn, making it necessary to pump brine into an adjacent pond where the salt is crystallized by solar evaporation, producing large hard crystals of crude salt. When we arrived at the end of October, it was the end of the dry season in this semi-arid region, and it was raining. Crystallized salt had been heaped into large mounds for draining and was being hurriedly bagged by women for transport.

In Palmyra (ancient Tadmor**,** a historically renowned salt site) there is a salt patch that was, at the time, harvested privately under license from the government. The site where salt ponds are laid out was wind-swept (ideal for crystallizing salt), and floating around were delicate branches with lace-like agglomerations of salt formed by whirlwinds that testified to the ecology and salinity of the site. Long narrow groups of ponds were laid out in no particular order, facing different directions. They were about 8-12ft long and 4ft wide, making it easy to gather the salt from each side of the pond. The salt had already been gathered into small heaps to drain in some ponds, while in others it was in various stages of crystallizing. The grain was smaller than that we had seen at Jabbul, presumably because of wind conditions moving the crystals around while they were forming. The walls of the pond were about 1m high by 15-20cm thick, formed simply by heaping up soil to enclose the area and contain the brine for evaporation. A narrow ditch fed the ponds, presumably by seepage from a spring that was not visible, and there were reservoirs. Heaping solar-evaporated salt is common practice world-wide, its main purpose being to drain the magnesium, boron and other soluble salts present, to improve the quality of the salt.

The third salt site we visited was Bouara, a vast inhospitable salt-encrusted flood plain, a desert plain that stretches out into the distance as far as the eye can see. We arrived there in October when the crude salt had mostly been gathered for the season and was awaiting transport. Because of the intense heat and high rate of evaporation, large grains of crystallized salt could be seen in the shallow waters of the lake that had a reddish-pink hue, similar to that seen in solar evaporating ponds that use seawater. As the concentrations of red halophytic bacteria (*artemia salina*) develop in the ponds, the brine increases in density and becomes red just before the salt begins to crystallize, and we concluded this is what we were seeing. To judge from the organization and loading equipment being used at Bouara to transport salt, the yield must be high. Large bags of salt were lined up in very long narrow strips across the desert, stacked six bags wide and six high, each bag probably weighing about one hundred pounds, awaiting the men to transfer them manually from the stack to the truck**.** In the forefront, a line of trucks stood by ready to be loaded. In yet another area, a mechanized loader was standing by, and on the 60km journey along the Ottoman Salt Way to Qraya, we drove past a line of fully loaded salt trucks. A bag of this salt was kindly given us by the Manager for use in our experiments at Darnaj, where our experiments took place.

A hydro-geological map clearly defines the mineral character of the salt sites (Paver 1947 "Water Supply"; Burdon et al. 1954 "Groundwater," p. 385), illustrating the regional importance of these sites for producing salt. Although the mineral composition of the groundwater is not given precisely, it is sufficiently descriptive to determine the problems that might be encountered in refining the salt and can also be useful in assessing the function of the archaeological artifacts. Thus, in the elongated strip along the borders of Syria with Iraq, the saline waters of Bouara were found to contain "water with much NaCl" where the yield of salt is high. Adjacent to this strip is a vast area that is also saline, but here the mineral composition was found to be high in $MgSO_4$ (magnesium sulfate) and C_aSO_4 (calcium sulfate), where it would not be economic to exploit for salt. The two great rivers, the Tigris and Euphrates, are also saline, with a mineral composition that again differs, containing "much NaCl and $MgSO_4$," where the yield and quality of salt would be less. Although the crude salt from Bouara had to be refined with water from the Euphrates, the magnesium sulfate it contained was easily removed by draining and drying in the process we describe below, while the salt saturation with NaCl would be increased.

The site of Qraya

Qraya is the name of a small village that sits atop a tell on a spur of land which juts out into the Euphrates (Fig. 3). It is some 5km north of the town of Ashara, ancient Terqa.

Excavations took place from 1977-79, under the direction of ~~Giorgio and Marilyn Kelly Buccellati~~, and then again in 1981 with Daniel Shimabuku as field director, and in 1984 with Steven Reimer as field director. They revealed an ancient settlement that was occupied sometime during the Ubaid and extensively in the Late Uruk period; was abandoned near the beginning of the 3rd millennium; and was reoccupied a millennium later in the Old Babylonian period (Reimer 1984 "Summary"; 1989 "Qraya"; Simpson 1988 *Soundings*, p. 44). Although the evidence shows specific characteristics of an early urban site of the Uruk period, it was clearly not a city, because it is small in size and it lacks monumental architecture (Buccellati 1999 "Question").

A very large number of beveled rim bowls, intact and broken, was found, part of it discarded in a disposal pit about two meters in diameter and a meter and a half deep The rest of the inventory included spouted jars, trays and platters, bowls with a pouring lip, clay ladles, jar stoppers. There were also round clay grills which served as shelves on top of shallow open ovens. The nature of this assemblage is significant because it includes all the elements that are needed in the process of salt production as it was tested in our experiment.

The experiment

Overview

The goal of the experiment was to re-enact what we assumed to be the "chaîne opératoire" that produced refined salt cakes from the crude salt layers at the Bouara playas. The material used in the experiment that was identical to that presumed to have been used in antiquity included (1) the crude salt, (2) the water from the Euphrates, and (3) the original beveled rim bowls: these were available in sufficient quantities so that their use in the experiment was felt to be acceptable. The other elements approximated those found in the assemblage, including the source of fire.

The goal was to test the quality of the refined salt produced and, therefore, the suitability of the beveled rim bowls and of the entire assemblage to obtain such results. (For a video presentation of the project see http://ethnosalro.uaic.ro/2016/03/interviews-with-prof-giorgio-buccellati-ucla/.)

Figure 7. Stage 1: Procurement. The Bouara salt playa.
From the right: Buccellati, the manager, and Marwan Dabbagh, who took care of the logistics of the trip.

Figure 8. Stage 1: Procurement. The Bouara salt playa.
Hopkinson on the right, with the manager of the playa

Stage 1: Procurement
We traveled by car to the Bouara playas, which are at some 60km from Qraya, on an unpaved but well-marked track. The logistic arrangements were done by Mr. Marwan Dabbagh, who accompanied us (Fig. 7), as well as a representative of the military, given the fact that we were going to an unmarked portion of the Syria-Iraq border. For its entire length, the track crosses a steppe landscape, with no settlements (Bernbeck 1993 *Steppe* p. 57 f.). The playa is clearly visible in the satellite image (Fig. 2) because of its intense white color.

The salt can easily be gathered because of the presence of water that dissolves the salt. It is mixed with soil, which gives it a dark red color (Fig. 8). We collected the salt in a cloth that was placed in baskets (Fig. 9), which may have been the container of choice in antiquity as well. The distance between Bouara and Qraya could easily have been covered on donkeys in antiquity.

Figure 9. Stage 1: Procurement. Raw salt in a basket.

Stage 2: Purifying
Back at Darnaj (the expedition house of the Terqa project, on the banks of the Euphrates, where we were housed), we purified the crude salt through a double step. We first placed the crude salt in a bowl filled with water, which dissolved the solid block of crude salt. We then placed the resulting liquid in a jar (Fig. 10), thus obtaining a purified brine that was fully concentrated with salt. When the salt dissolved, a red flocculant floated to the surface of the brine, and heavier particles of red earthy matter settled to the bottom, leaving clear brine in between (Fig. 11).

Figure 10. Stage 2: Purifying. The water solution in two modern containers
The shallow bowl would presumably have been a larger vessel, like a basin (see Fig. 12). The surface of the liquid and the transparent jar show the sedimentation of the impurities at the top.

Figure 11. Stage 2: Purifying. The water solution in two modern containers
The transparent jar shows the double sedimentation at the top and the bottom. The green jar imitates the shape of the ancient jar (Fig. 13) in that the spout is place on the shoulder of the vessel, so that the central portion of the liquid (without impurities) would be poured out.

This double procedure, for which we used metal and plastic containers, reflects the use of the ceramic vessels we find in the ancient assemblage. The large deep bowls or basins (Fig. 12) would have been ideal for the initial step of liquefying, as it were, the salt blocks, while the spouted jars (Fig. 13) would have served for the purification of the crude salt. This makes clear how perfectly suited the spouted jar shape would have been for this kind of double sedimentation, to the top and the bottom: the position of the spout is perfect for the clear brine to be poured out of the container. The two plastic vessels we used are obviously completely different from the originals, but in this case, it is the shape more than the ware of the ceramics that matters.

The purification process brought to mind the comment of the manager at Bouara, who said something to the effect that this had been "a bad year because of the wind." He was indicating that when the wind blows red earth from the surrounding area onto the salt flat, as it did in that particular year, it affects the degree of pollution, hence causing a bad year in terms of the yield of salt. And it was this need to separate out the earthy impurities from the brine for which the spouted jars in the assemblage were useful. They allowed the surface flocculant to be poured off first (perhaps into one of the lipped bowls, or a jar), in order to use the clear brine below for boiling, being careful not to let the remaining sediment at the bottom mix with the clear brine. It was a meticulous process carried out by practiced salt-makers who thus were able to produce a much better quality of salt that would be more valuable in the market place.

Figure 12. Stage 2: Purifying. The ancient deep bowl or basin from Qraya, with a small cup for pouring.

Figure 13. Stage 2: Purifying. Two ancient spouted jars from Qraya.

Stage 3: Boiling

The clear brine was then boiled in shallow bowls or high-rimmed platters. We placed it in a metal pan (Fig. 14), of roughly the same size as the ancient one (a sherd of which is shown in the picture). We placed this in turn on a clay grill (Fig. 15), which approximates those found in the excavations. The fire came from a butane gas tank.

Figure 14. Stages 3 and 4: Boiling and drying.
As the salt crystallizes from boiling, it is gradually scooped out and placed into the beveled rim bowls on the edge of the grill, where it dries out evenly. The sherd is from an ancient shallow bowl or platter where the boiling would have occurred.

Figure 15. Stages 3 and 4: Boiling and drying.
A modern ceramic grill similar to the ones found in the excavations at Qraya.

The thickness of the sherds of the ancient platters (Buccellati 1990 "Dawn" Plate 6c) has been somewhat perplexing as ordinarily this would detract from the heat of the fire. However, designed as they were to cap the grill, the amount of heat might be right for boiling. The platters are smooth on both the interior and exterior and were fired at a higher temperature making them suitable for boiling.

At a certain point in the boiling process, the top of the brine surface was instantly transformed into a pure white crystalline texture. We did not, unfortunately, at the time have a video camera to record this extremely sudden transfiguration of the surface of the brine.

Stage 4: Drying

As the crystals formed, they were removed with a ladle or wooden spatula and placed in the beveled rim bowls, on the edge of the grill (Fig. 14; for a picture of an ancient grill from Qraya see Buccellati 1990 "Dawn" Plate 6b). Clay ladles are present in the ancient assemblage (Buccellati 1990 "Dawn" Plate 7a), and the beveled rim bowls used were, of course, the original ones. The purpose of this final step was to allow the brine to drain and then to dry. While the process continued, small amounts of brine were continually added to the boiling pan and to the beveled rim bowls, to make the most of the fuel and the heat of the fire. The porosity of the beveled rim bowls as well as their shape make them ideally suited for this process, in terms of both draining through the walls of the vessels and desiccating evenly through the progressively wider exposure at the top away from the direct fire.

Since water from the Euphrates was used to dissolve the crude salt, minerals contained in that water would add additional sodium chloride, as well as magnesium sulfate (Epsom salt), to the crude salt from Bouara. However, the magnesium sulfate is more soluble, still in solution when transferred to the BRB, and would be absorbed by the pot as described above.

The importance of the boiling and drying stages cannot be underestimated. The special nature of the beveled rim bowls could deal with the issues related to the hygroscopic properties of salt, as well as its taste. This is accomplished by dissolving impure salt in water to produce a brine solution that is boiled to allow for the removal of impurities (brine is classified as being any salt solution that is more concentrated than seawater that contains 3.5% dissolved mineral solids, of which 2.9% is sodium chloride). This is fortuitously made possible because mineral salts precipitate out of a saline solution sequentially in the order of their solubility, allowing them be removed before they mix with each other (O'Brien et al. 2005 *Chlor-Alkali*, 7.2.2). To achieve this, the volume of brine is reduced by the boiling process until it reaches 53% of its original volume. At this point, the *least* soluble minerals like the stony calcium salts (as the salt makers liked to describe them), precipitate. Differentiated from common salt in appearance, they can be removed from the pan before sodium chloride begins to crystallize, and this occurs when the volume of brine has been reduced to 19% of its original volume. If, at this point, the wet sodium chloride crystals are *not* removed from the pan when the brine solution reaches 4% of its original volume, the NaCl will mix with the more soluble minerals - the magnesium and potassium bromides and chlorides known as the bittern, making the salt unpleasant to the taste. But if they *are* removed and transferred to a porous *briquetage* type vessel, the remaining salts still in solution will be absorbed, and will precipitate on the *outside* of the vessel, thus removing them from the salt, a quite ingenious and very simple method of refining, leaving the salt inside the pot purer.

It may be noted that, in solar evaporation, refining is handled by using a series of ponds where brine is moved from pond to pond leaving behind the less soluble mineral impurities that precipitate before sodium chloride. The more soluble impurities are more difficult to handle, as the weather mainly controls the process. In this case, crude salt gathered from the ponds is usually left in large stacks to drain, sometimes for as long as a year or more. And depending on how the salt is to be used, it is still considered crude salt that requires further refining (washing with a weak brine) if it is to be useful in one way or another.

Figure 16. Beveled rim bowls with salt cakes produced during the experiment

Conclusions

Uses

In a few hours we were able to produce a considerable quantity of pure salt cakes (Fig. 16). Clearly, great quantities of salt could be produced in antiquity, and the question arises as to the use to which they could have been put. The ancient settlement at Qraya was, we saw, very small and without any of the traits distinctive of an urban center. On the other hand, the general set-up of the remains found in the excavations, and the sheer quantity of beveled rim bowls, indicate a large scale activity hardly in keeping with the needs of a small village.

For this reason, we have suggested (Buccellati 1990 "Dawn") that the site was an outpost established specifically to provide the northern cities of the Protoliterate period with salt in the first place, and also with fish, which was plentiful in the Euphrates, but not available in the plains of the "upper country." What is significant about this is that the entire commercial network would have been initiated and then managed by the cities in the north, without any previous local expertise or even knowledge of the potential of salt production. It was not a regular trade exchange, neither symmetrical nor asymmetrical. It was rather an endogenous production activity, i. e., one started and managed by the recipients of the goods, the cities in the north.

To extract the salt cake from the beveled rim bowl, one could hit the base of the upturned vessel (Fig. 17), which would neatly break the bowl in two (Fig. 18). This singular breakage pattern, along the longitudinal axis of the bowl, can be noted frequently in the sherds of the bowls found in ancient discards, and can only be attributed to an intentional act.

Figure 17. Breaking the bowl to get a complete salt cake.
Hitting the base of the upturned bowl causes it to crack open, leaving the salt cake intact. The unusual longitudinal breakage pattern is often found in the discards in the excavations.

Figure 18. Detail of the bowl cracked open.

The salt was then readily accessible for salting fish, such as the catch we photographed when a fisherman happened to pass by our working station on the edge of the river (Fig. 19). The fish, salted for preservation, could then be shipped to the northern cities.

Figure 19. A fisherman with a fresh catch.
The photo is taken at the Expedition house in Darnaj, on the eastern side of the Euphrates, where the experiment took place. The site on the opposite side of the river is Ashara, ancient Terqa.

How successful early salt makers were in preserving food with impure salt is unknown, although in antiquity the task of obtaining a better quality of salt for preserving different kinds of food was no doubt made easier by exploiting salt resources that were relatively purer, or at the very least contained fewer mineral impurities that could be recognized by color and taste. Impure salt was, and still is, frequently gathered worldwide by tribal communities, either for their own consumption, or for their animals. Only when the need arose to preserve and store larger quantities of seasonal food did the parameters for purity become more stringent. As humans moved beyond the subsistence stage, they learned the survival value of preserving and storing surplus food to guard against periods of famine. In Mesopotamia as elsewhere, fish was a major source of food, but it rots quickly and needs to be preserved in some way if it is intended for future use. The methods used in antiquity in a given area can nevertheless be reconstructed not only from the ecology of the site, and the ethnographic evidence, but also from the kind of fish available for salting. Salt containing 4.7% magnesium chloride will turn fish putrid before it is fully preserved, particularly during the first two days when fish are most susceptible to bacterial attack. But the standard of purity required varies according to the muscle and oil content of the fish that can exhibit a noticeable change if only 1% magnesium and calcium salts are present. Although 2% magnesium is not an ideal level, this amount was found acceptable by the trade because common salt is generally expected to contain this amount of impurity (F. W. van Klaveren and R. Legendre in Borgstrom 1965 Fish Vol. 3, p. 134). All fish muscle is a mixture of water, fats, sugars, salts, and solids (both soluble and insoluble), are affected by temperature, which influences the methods that can be successfully used to preserve fish (A. C. Jason in Borgstrom 1965 Fish Vol. 3, p. 15), and the type of drying process that will succeed. For example, salt herring keeps better than smoked herring, because the physical barrier to fat oxidation presented by complete submersion in brine is thought to be more effective than the chemical barrier provided by the phenolic antioxidants absorbed from wood smoke (C. L. Cutting in Borgstrom 1965 Fish Vol. 2, p. 14).

Shipping of salt

The salt itself would also be shipped, and the inference is that this would be done using the beveled rim bowls themselves. This would explain the quantity found in the northern cities, and would also allow for them to be reused in a number of different ways.

At first, the notion that beveled rim bowls would be used to ship salt cakes over the considerable distance that separates Qraya from the northern cities (more than 200km) seemed to pose a difficulty: why use such heavy containers for such relatively small quantities of salt? The answer came, unexpectedly, from a chance discovery. In addition to the beveled rim bowls, an ordinary pottery bowl had also been used in our experiment, to compare results. At the end of the experiment, all the vessels in which salt cakes had been produced were taken to the expedition house at Tell Mozan, ancient Urkesh, where Buccellati was at the time co-directing an excavation project. The vessels were stored side by side in the expedition house. Upon returning the following summer, we discovered that the state of preservation of the salt content was sharply different: the walls of the ordinary bowl had completely disintegrated, and the salt had become unusable, while those of the beveled rim bowls had remained in perfect condition and the salt remained in its pristine condition. Figs. 20-21 show the two types of bowl side by side, and Figs. 22-23 a close-up of each type. The salt in the beveled rim bowls remained in the same condition for several years. Clearly, the cost of the extra weight was necessary to ensure the quality of the product and preserve it for the long haul.

Figure 20. Stored salt a year later.
The salt in the beveled rim bowl is in perfect condition, whereas the salt cake produced in an ordinary ceramic vessel has caused the ceramics to crumble.

Figure 21. Detail of the two vessels with stored salt.

Figure 22. Detail of salt stored in the beveled rim bowl.

Figure 23. Detail of the ordinary vessel in which salt was stored.

The phenomenon may be explained as follows. The salt stored in the beveled rim bowls kept dry, as moisture from the air was able to evaporate through the open pores of the pot, maintaining the stability and texture of the salt by keeping it dry. The salt stored in the two impervious and more highly fired pottery bowls totally disintegrated, with red particles of the pot mixing with and contaminating the salt. Less porous than the beveled rim bowls, the moisture from the air that was absorbed by the salt in the ordinary ceramic bowls was not able to evaporate and keep the salt dry, and acids in the clay pot reacted with the salt and became corrosive, attacking the clay and causing the pot to disintegrate. Soluble salts respond to both high and low changes in humidity that changes them from a solution to a solid and back, damaging the surface of the ceramic as salt crystals and liquid salt, respectively, expand and shrink within the ceramic body. And over time, the physical components of the body will crumble until completely destroyed (Little 2000 Winterthur Guide, p. 61), as was the case with the vessels stored in the Mozan expedition house.

The need to drain and thoroughly dry salt may thus have been the primary reason for developing the beveled rim bowls in the first place. This was due to the hygroscopic nature of salt and its propensity to dissolve from moisture in the air. It can absorb 0.5% of moisture at ordinary room temperature and lose as much as 25% of its bulk when being transported, or while being stored. Where salt contains the more soluble mineral impurities like the chlorides and sulfates of magnesium and potassium, that are more soluble than salt, it becomes even more susceptible to losing its granularity, partially dissolving, affecting its granular texture and becoming a homogenous lump that cannot be dispersed evenly over food that is being preserved or consumed. Fine-grained salt produced by boiling fast is required if it is to be thoroughly compacted and molded in briquetage type pottery to protect it from moisture in the air. Certainly, these highly porous salt molds were ideal for rapidly absorbing water in order to compact the salt, and when thoroughly dried, it was found that the salt compacts even further. The resulting solid cake of salt is then more stable and more resistant to dissolving from moisture in the air while in storage and during transport. And as briquetage was not flammable, the mold could be placed close to the fire for drying.

Results

The advantage of the *briquetage* process was that it produced a refined salt of a higher quality, which was more useful than raw and impure salt in a number of ways. Besides protecting the salt during transport and storage, it would have had greater value in the market place, either in terms of preserving food, or for use as currency in barter and exchange. Its very shape and color was an indicator of its quality, and the fact of being "packaged" in a beveled rim bowl would have served as a trademark of sorts.

The experiment shows convincingly, in our opinion, that the hypothesis of a complex salt production process at the dawn of history, as described here, is plausible. The following major points emerge from the argument we have developed:

The beveled rim bowls were ideally suited for producing high quality salt, while other vessels would not have worked.

1. As reconstructed by us, the beveled rim bowls were used at the end of a specific *chaîne opératoire*, which utilized a number of the items present in the whole inventory or assemblage excavated at Qraya – basins, spouted jars, high rimmed platters, ceramic ladles, ceramic grills.
2. Such a functional distribution in the use of specialized vessels at a site like Qraya, with no large scale administrative set-up, can best be explained as documenting a production center specifically designed to serve the needs of the large cities to the north.
3. The location of the site was ideally chosen for the intended process, being as it was the shortest distance from the playas of Bouara and directly on the shores of the Euphrates river, which provided all the fresh water needed for the production process.
4. The same location also made it possible to catch large quantities of fish and prepare them for shipping to the north, having been first appropriately cured with the salt that was immediately available for the purpose.
5. The overall procedure presents us with a unique type of resource exploitation, in three ways. First, instead of a pre-existing local salt production expertise, we may more likely assume that the process originated with the consumers, i.e., the cities in the north that would have installed the whole process from the outside.
6. Second, the production method evinces a sophisticated system of controls, which entails a well-honed set of skills and the awareness of properties that are not immediately apparent and require considerable training to be maintained.
7. Third, this can be seen as a type of industrial activity, in the sense that the commercial network behind it consists of a number of intermediate steps where each individual involved is not necessarily aware of the overall sequence (Buccellati 2013 *Origini*, 5.12; 6.2).
8. The specific suitability of the beveled rim bowls as quality-identifiers for shipping and storage explains the large number of these vessels found at great distances from the original place of production.
9. Finally, while the vessels employed are ideally suited for salt production, and the experiment showed that they would have so functioned, they could and would, of course, be used for a variety of

different purposes.

The conclusion to which we have arrived is thus significant for a better understanding of both the history of salt and the archaeology of early Syro-Mesopotamia.

With regard to the history of salt, we see how it played a major role at a very beginning of urban life, around 3500 B. C.: a complex technology was mastered capable of producing truly high quality salt that would rival any we can produce today. This was suited for the purposeful strategy behind gathering large quantities of perishable food, which is a hallmark of early urban society. In the case of meat, the strategy was possible if it was known that large caches of it could be preserved for future use. Sufficient salt had to be made and kept in storage to accommodate seasonally surplus food as it became available, particularly over the vast area in which the beveled rim bowls are found.

With regard to archaeology, the experiment supports the hypothesis that a particular and ubiquitous type of vessels, the beveled rim bowls, would have been produced for a very specific purpose. This purpose accommodated so many specific technical requirements and worked in such synergy with the rest of the evidence as to make it inconceivable that it might have been just accidental. It goes without saying that successive multi-tasking would have been the rule of the game; but for no other such task can we say that other vessels would have been as uniquely suited as for the task for which our experiment has shown these vessels to be perfectly suited.

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