



HAL
open science

Prehistoric salt production: Technological approach in ceramic studies

Olivier Weller, V. Ard

► **To cite this version:**

Olivier Weller, V. Ard. Prehistoric salt production: Technological approach in ceramic studies. *Journal of Archaeological Science: Reports*, 2024, 53, pp.104379. 10.1016/j.jasrep.2024.104379 . hal-04412448

HAL Id: hal-04412448

<https://hal.science/hal-04412448>

Submitted on 23 Jan 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



Prehistoric salt production: Technological approach in ceramic studies

O. Weller^{a,*}, V. Ard^b

^a CNRS UMR 8215 Trajectoires University Paris 1 Panthéon-Sorbonne, Centre Malher, 9 rue Malher, F-75004 Paris, France

^b CNRS UMR 5608 TRACES University Toulouse 2 - le Mirail Maison de la Recherche, 5, allée Antonio-Machado F-31058 Toulouse cedex 9

ARTICLE INFO

Keywords:

Salt production
Briquetage
Ceramic mould
Neolithic
Western France
Bulgaria

ABSTRACT

Numerous studies have been made on salt production in the European Iron Age, especially through broken low-fired clay artefacts known as “*briquetage*”. The vessels used in stoves are called salt moulds or salt containers. They serve both as crystallizer and mould for the salt obtained from concentrated brine. For the origin of salt production, archaeological evidences in Europe indicate that salt exploitation was intensified from the 5th millennium BC by using salt moulds in ceramic material. In this paper, we will present two studies conducted on “*chaîne opératoire*” of salt moulds making from two production sites, one in North-Eastern Bulgaria (*Solnitstata*, Provadia, c. 4700–4450 BCE), the other in West-Central France causewayed enclosures (c. 3400–2900 BCE). In both cases, the contexts in which these salt exploitations arose testify to an increase in social tensions.

By focusing on the technical choices adopted in the manufacture and the use of these particular pots, we will see that for a same function several technical solutions are possible. However, we will attempt to define a general framework of technical choices and patterns observed in these pots which are often fragmented and rarely identified as salt moulds on archaeological sites except on production sites. This pottery is also excellent evidence for the development of specialised salt extraction throughout Europe since the late prehistoric period.

1. Introduction

Numerous studies have been made on salt production in the European Iron Age (Nenquin, 1961; De Brisay and Evans, 1975; Daire, 1994,2003; Lane and Morris eds., 2001; Weller ed., 2002; Harding, 2013; Brigand and Weller eds., 2015; Alessandri et al., 2021), primarily through focus upon the fired clay artefacts employed in production known as ‘*briquetage*’ (concentrations of broken low-fired clay artefacts from containers, hearths and ovens). The vessels used in stoves are called salt moulds or salt containers which both to crystallize salt produced from concentrated brine and for the creation of salt cakes.

Several ceramic innovations were related to this production technique, which was particularly dynamic at the end of the Iron Age. This included the production of moulds by folding (Gouletquer, 1970), the use of aerators in the ceramic paste (Weller and Desfossés, 2002) or reusable composite moulds (Lemaire, 2002). Substantial amounts of waste have resulted particularly from many salt production sites. One particularly intense area of production was in the Seille valley, North-Eastern France, which contains, according to recent estimates, c.4 million m³ of *briquetage* (Olivier and Kovacik, 2006). The common occurrence of large quantities of this material, well-preserved at many

sites, resulting from the voluntary fragmentation of moulds as part of the salt production process, has meant that this material has been well-studied in Europe. This area in particular therefore represents a ‘hot-bed’ of innovation within a proto-industrial production process.

In contrary, relatively little attention has been paid to the origins of salt cake production which began during the fifth millennium BCE in Central and Eastern Europe (Weller, 2015). With the exception of the older salt production sites without specific ceramics (Sordoillet et al., 2018), this evidence for salt exploitation is generally discussed on the basis of a specific morphology of Neolithic pots (pointed base, tulipiform or “flower pot” shape, representing crude pottery) without detailed functional and contextual studies. The analysis of production contexts, combined with a technological approach to the study of these often abundant but fragmented ceramic salt forms, allows us to explore more details and develop a more accurate understanding of the characteristics of this Neolithic activity, which had important socio-economic implications.

In this paper, we aim to present a brief assessment of our technological approach to the study of ceramics involved in salt production, with the addition of some more general considerations about salt production. This will include a summary of the results of two Neolithic

* Corresponding author.

E-mail addresses: olivier.weller@cnrs.fr (O. Weller), vincent.ard@cnrs.fr (V. Ard).

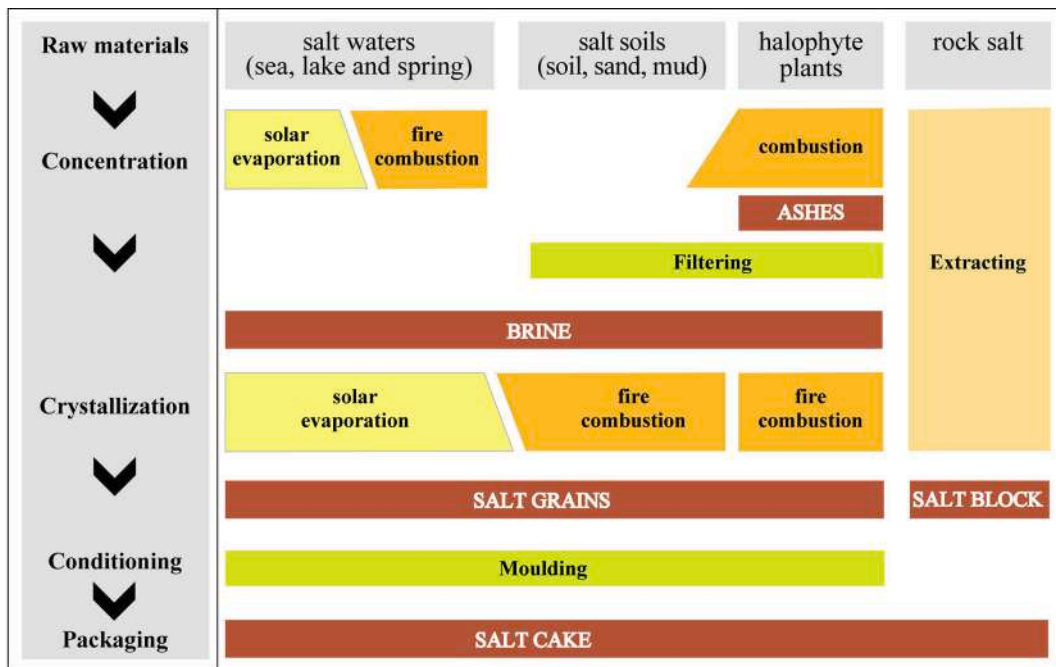


Fig. 1. General principles of salt production (Conception O. Weller).

ceramic studies; one in South-Eastern Europe in Provadia (Bulgaria) and the second in Western France. Based upon these studies and our cumulative experience of technological studies of prehistoric ceramic and the salt industry, it is concluded that there is no room for doubt: the Neolithic pottery we have studied corresponds to what European archaeologists have been calling *briquetage*. This specific production is universally attributed to salt industries. These two examples testify to an intensive production that went beyond the purely domestic framework and was integrated into regional or even supra-regional exchange networks, which in the case of central-western France also included other productions such as decorated pottery and lithic raw materials (Ard and Weller, 2014). The appearance of the first Neolithic moulds means that salt in the form of salt cakes became a standardised item, dividable, transportable and storable, or, briefly said, a socialised good, an identity marker, capable of enabling long-distance exchange networks.

2. Salt Moulds: Characteristics and study methods

2.1. General considerations about salt production

We believe that the search for salt for exploitation has enabled and encouraged behaviours ranging from simple gathering to a more complex industry. This exploitation aims to separate salt from its natural origins such as waters, soils, plants or rocks.

The basic process employed to obtain these salt cakes has involved the carrying out of four main operations which are categorised as 'strategic moments' by ethnologists (Fig. 1). This has included:

- obtaining a slightly salty raw material, which may be either solid or liquid;
- transforming this raw material into a sufficiently concentrated brine, able to be evaporated with relatively low energy expenditure (a process known as gradation);
- crystallizing the salt in crystals which are as light and thin as possible, which requires a relatively fast evaporation;
- reducing, by whatever operation possible, the spaces between these little crystals in order to get a hardened and coherent block of salt.

Therefore, what is the archaeological evidence allowing us to identify and define salt exploitation? The principal evidence is in the remains of fired clay from ceramics, *briquetages*, and heating structures such as stoves.

2.2. Archaeological evidence

The use of fired clay containers to bake and mould salt exists in many temperate or tropical zones in the World. In Fig. 2, we can observe the shape variability of salt moulds across Europe, as well as Japanese examples dating from the Bronze and Iron Ages. In all cases, these particular single-use ceramics have the same general characteristics:

- clay is from a local origin;
- the inclusions are numerous and sometimes of significant volume;
- the inclusions tend to be sandy in nature and may also include added organic temper;
- the container shape is open;
- the vessel is created by forming using coiling or modelling, or even by moulding or folding. All of which are quick;
- the marks left by fingers, as well as organic matter or even textile prints are frequent;
- the external walls have no regularity but the internal smoothing is sometimes very meticulous;
- the fragmentation is considerable since it has been broken on purpose. There is only one use for these forms, to remove the salt cake.

In the Neolithic period, the archaeological evidence in Europe indicates that salt-working intensified from the middle of the 5th millennium BCE using mould-making (Weller, 2015). Whatever its precise chemical composition and the techniques, this salt artefact can be used as a pre-monetary wealth, able to be used as an ordinary food for men or cattle, used for trade and barter, offer as a gift or hoarded. That is why one can call it an "ingot" (Gouletquer & Weller, 2015). Use of fire is crucial to producing salt, this enables the brine to evaporate, concentrate, and then for salt to crystallize, which can then be formed into hard and transportable cakes. This requires specialist knowledge and

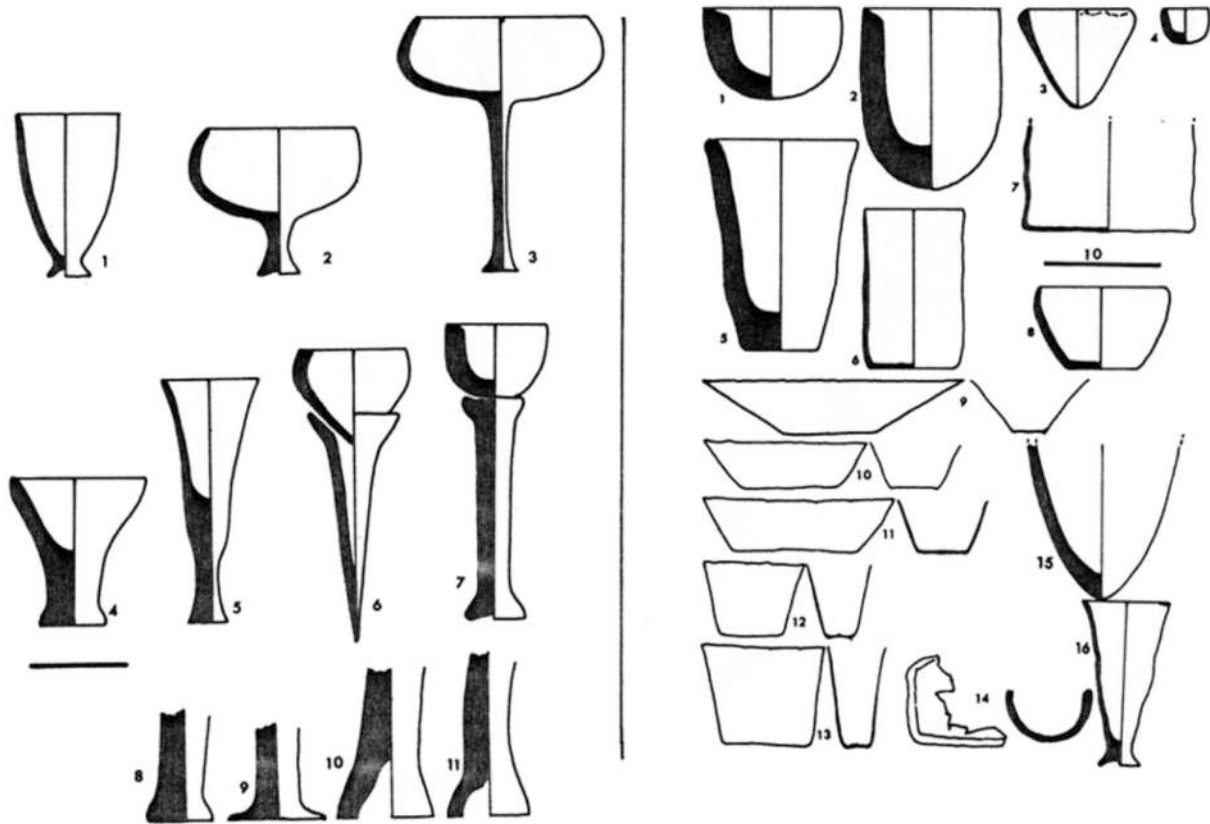


Fig. 2. Some examples of briquetage (support and mould) in European and Japanese Protohistory (after Gouletquer, 1974, Fig. 3 et 4). Left: 1–3 Japan (after Kondo); 4–7 Saale valley (after Riehm); 8–11 French Atlantic Coast. Right: 1–3 Saale valley (after Matthias); 4, 6, 7, 9–14 French Atlantic Coast; 5 Bad Nauheim (after Riehm); 8 Kimmeridge-Dorset (after Calkin); 15–16 Little Poland (Krakow, after Jodlowski).

expertise, primarily on the chemical changes in material state, temperature control (less than 100 degrees inside for slow, small crystalline crystallization) and on moulding with mass crystallization (Weller, 2004). This is probably the reason why briquetage appears in the earliest metal working societies in Central and Eastern Europe (Lengyel, Cucuteni or Vinča cultures), where copper objects were also moulded (Weller, 2015).

2.3. Technological approach to the creation and use of salt moulds

After the general considerations made above, we now want to focus on two specific ceramic studies of Neolithic salt moulds at both ends of Europe: one in Bulgaria and the other in West-Central France. These studies combine technological and chemical analysis (Weller, 2004; Ard & Weller, 2012). This paper focuses only upon the technological analysis and observations recorded (not the results of our chemical analysis which confirm the function of salt moulds for the two studied sites). Using a specific preparation (pressed disc with 5 g of powder and no glass disc), the general protocol consists to quantify the chlorine by X-ray fluorescence spectrometry over an extended measurement time and to compare the concentrations in soil, domestic vessels and pottery vessels suspected as being used to produce salt. In both cases, the chlorine content in the salt moulds was 2 to 20 times higher than in domestic contexts. These levels are even higher due to lower rainwater infiltration (Ard & Weller, 2012).

Our technological approach is based on the concept of ‘*chaîne opératoire*’; the manufacturing process for transforming raw materials

into a finished product (Leroi-Gourhan, 1988). Some previous studies have also applied this concept to the study of Iron Age salt containers (Morris, 1985; Weller, 2000; Rouzeau, 2002). Numerous ethno-archaeological studies have already demonstrated that the different steps of this *chaîne opératoire* are conditioned by cultural or functional factors (e.g. Arnold, 1985; Bowser, 2000; Gosselain, 2000; Gelbert, 2003). It is possible to reconstruct the main steps of this manufacturing process by macroscopic observation of the features relating to the shaping and finishing of the vessel, before defining fabrics by microscopic analysis (Roux and Courty, 2005; Roux, 2010). Our comparative analysis of two Neolithic sites reveals common attributes related to their function as salt moulds.

3. An Eastern Perspective: *Solnitsata*, *prodavia* (Bulgaria)

3.1. Context

The site of *Provadia-Solnitsata* (Bulgaria), 35 km west from Varna, represents one of the most important discoveries for the prehistory of salt exploitation in Europe (Gaydarska, 2003; Николов et al., 2009, 2021; Nikolov et al., 2008, 2010). Near a brine spring associated with an underground salt diapir (about 12 to 20 m deep), a salt workshop, a settlement and a cemetery were discovered, corresponding to a homogeneous Chalcolithic complex. The study of the salt workshop was conducted in 2009 and 2010 by one of us and the first technological ceramic study has partially been published (Weller, 2012).

At 200 m from the tell settlement, a production area of more than 0.5



Fig. 3. Chalcolithic tell and salt production centre at Solnitsata-Provadia, Bulgaria (Photos O. Weller).

ha consists of several overlapping and intersecting open-air fire installations in pits. In the centre is a very large pit, 10 m wide and 1.75 m deep, which has produced an impressive quantity of very homogeneous pottery (Fig. 3). The ceramics contained within the pit represented 80 per cent of the total pit fill. The lower level presented some traces of fire, even if no certain stove or hearth was identified. The upper level appeared to strongly represent an area of waste discard, with many sherds and ashes. With three new AMS dates, the chronological span of production is confirmed (4700–4450 BCE; Fig. 4)¹. This clearly states that the salt production is to be located before, but also during the “phenomenon” of the Varna cemetery, located 35 km to the east, even with dates for Varna 1 below 4560 BCE (Higham et al., 2018).

While the impressive quantity of ceramics in this pit (consisting of a deposit measuring c.17 m³ containing between 600 and 1100 containers) is quite typical of sites using moulds for salt production, it is the homogeneity and the large size of the moulds that is so remarkable here (see below, Fig. 7). Therefore, based upon this significance, following the excavation we undertook the first technological study of this massive ceramic assemblage, in order to reconstruct the *chaîne opératoire* both of mould manufacture and also of salt production.

¹ The 5 radiocarbon dates were made on charcoal previously observed with a binocular and determined for 2 of them by Alexa Dufraisse of the MNHN Museum (St 1–3 is a bark fragment and St 1–2 is a fragment of a short-lived *Maloideae*).

3.2. Technological study of salt moulds

The origin of the clay employed in the salt mounds has of yet, not been identified but it is most probably a source of local clay, abundant in the site area. The main temper used by the Neolithic potters was grog. It was abundantly used and identified within the ceramics, often coarse, between 5 and 6 mm in size and a maximum size of 10 mm. There are also small mineral inclusions in lower quantities. The high proportion of temper in the ceramic paste enables rapid drying, safe firing due to the additional porosity and, above all, improves heat circulation during use.

The bases of the moulds are made from two compressed discs which are both built with spiral coils (Fig. 5). This guarantees watertight and stronger resistance, especially if the coils are wound in opposite directions. The sub-concave bases also have magnificent mat impressions which have recently been studied in detail (Andonova and Nikolov, 2021). These woven mat impressions, absent from other categories of pottery at Provadia, are due to the high pressure on the clay discs, which increases the impermeability of the bases, and to the heavy weight of the complete pots during drying (without displacement).

The vessel wall is constructed by superimposition of collars or rings of clay (10 to 15 cm high), one on top of the other, which offered a rapid means of building large vessels (Fig. 5). The coils are joined by internal overlapping or with U-joints (basic), without stretching. As a result, the vessel is not completely watertight. The top edge is just straightened by fingers (no tool traces), and the rim is often folded outwards.

The external surfaces (Fig. 6) are sometimes difficult to identify and study in detail because of the coating and also because of the white film (carbonate/ash crystallization) covering many sherds, especially in the upper part of the pit. For all sizes of moulds, the finger traces and coarse scraping were designed to regularize and homogenize the paste, and probably to facilitate the fixation of the future thick coat. The direction of this operation corresponds to a movement of the hand from the bottom up and from right to left, in the direction of the potter.

Observations of the internal surfaces (Fig. 6) often revealed the application of a slip which was then probably polished with a small stone (flat, shiny features) or better, with a ribbing tool, perhaps over a long time. This operation made the container much more watertight.

Finally, all the ceramics were fired in an oxidizing atmosphere at a temperature probably around 800 °C.

The first distinct feature particular of Provadia salt moulds is the presence of a thick clay coat, which contains small chopped plants (1 to 2 cm), and also sometimes has the addition of many seeds, and is applied to all external wall and base surfaces (Fig. 6). If it is still preserved and still adheres to the external surface, this clay coat is dried but not fired. Preliminary analysis suggests that the temperature was less than 100–150 °C. This raises the question as to the function of this ‘clay coat’, a feature we have never observed on briquetage elsewhere. Two scenarios are possible:

- this very porous coat served to maintain a uniform and relatively low temperature inside the container during the long salt crystallization. Thus it acted as a distributor of heat, as well as preventing leakage of brine;
- this wet and cold coat is applied to the exterior of the moulds at the end of salt crystallization to provoke an event similar to a thermal shock in order to facilitate release of the salt cakes.

Currently, this technical choice is unexplained. Laboratory analyses and experimental research could clearly help us understand this issue.

The general shape is open and tapered (Fig. 7). The fragmentation rate is high, and no complete mould was discovered. Few profiles have so far been reconstructed, but refitting, particularly difficult here, is still in progress. The vessels are all roughly similar in shape but we can distinguish three size modules. The largest one has single, double or even triple vertical conical lugs to facilitate handling and transport.

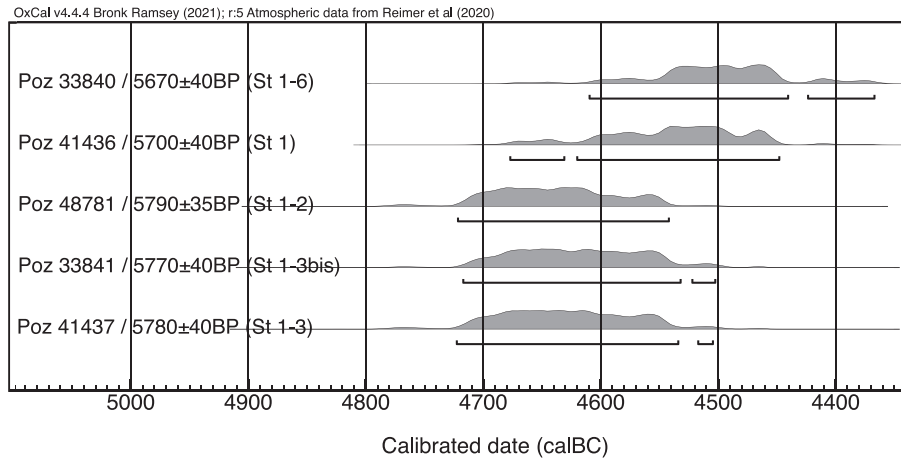


Fig. 4. AMS dates from the large salt pit of Solnitsata-Provadia (Bulgaria).



Fig. 5. Base and wall. Forming and manufacturing traces (Photos O. Weller, F. Giligny and S. Oboukhoff).

3.3. Estimation of the quantities produced

In this closed assemblage, we also tried to estimate the production quantities. The three forms of salt moulds represent quite different volumes (from 1 to 80 L), and it was possible to make an approximate estimation of these pots from all bases and lugs (Fig. 7). Although this is only an approximate figure, we estimate the number of salt moulds produced and used to be 300–600 large molds, 200–400 medium molds,

and 50–100 small moulds. The volume ranges from 60 to 80, 30–40, and 1–1.2 L. The theoretical density of salt is 2.12 (2120 kg/m³), but this corresponds to the mineral in rock form. In the case of recrystallized salt, this density is lower and we have chosen an apparent density of 1.60, which is between the theoretical one and the 1.13 corresponding to that of a stock of road salt. Based on this average density of salt, we conclude that salt cakes weighing between 1,6 and 128 kg were produced (approximately three classes of about 2, 55 and 110 kg). Even if these

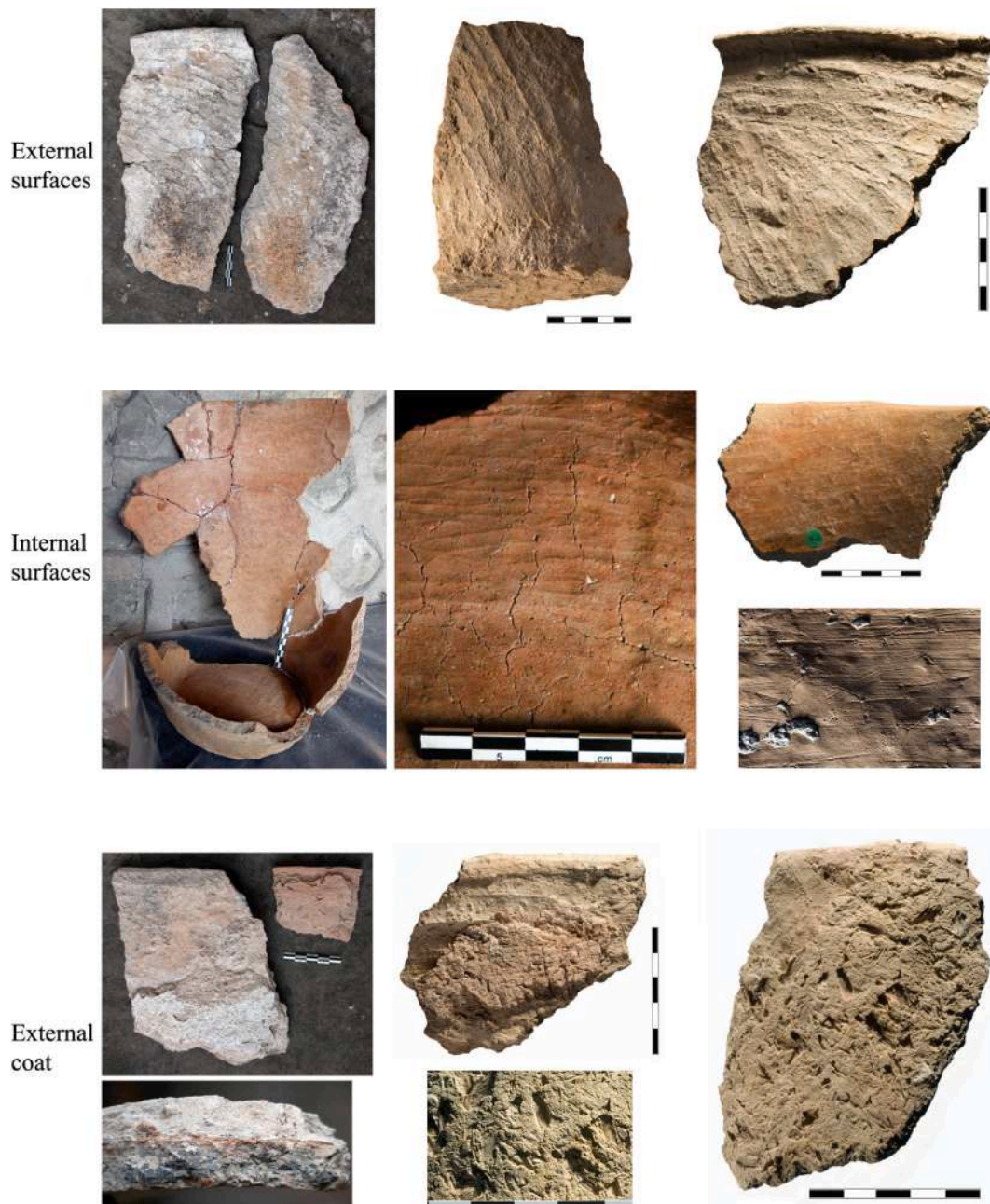


Fig. 6. Surface treatment and external coat (Photos O. Weller and S. Oboukhoff).

estimations are not completely accurate, this is the first time that impressive 100 kg salt cakes have been observed in prehistoric Europe.

We are thus dealing with potentially quite large volumes. The total salt produced was estimated between 45 and 90 tons for the large pit. However, if we take into account the long useful life of the pits², which according to radiocarbon dating is between 150 and 300 years, we estimate an annual production of about 300 kg of salt. This estimation would appear low and far below the theoretical nutritional requirement for salt for such an apparently large local population which inhabited this region during the Hamangia Culture. The function of shaped salt as a transportable, storable and socially recognisable artefact therefore

² This large pit with several holes is *a priori* the only one in the vicinity of the Chalcolithic site. However, we cannot be entirely sure that there were other structures of this kind within the present-day industrial salt complex of Provadia.

remains the central question if we want to understand salt production in the socio-economic context of the middle of the 5th millennium BCE, as well as its relationship to the development of the Varna copper production centre and the emergence of the spectacular Varna I cemetery, less than 40 km East of Provadia (Slavchev, 2010; Weller, 2012; Manolakis, 2020; Николов et al., 2021; Gaydarska and Chapman, 2022).

4. A Western perspective: Causewayed enclosures of West-Central France

4.1. Context

At the other end of Europe, ditches of causewayed enclosures and pits located around marshes of West-Central France, particularly in the Marais poitevin (Fig. 8), offer a second example of salt moulds. About thirty sites dated to the Late Neolithic (c. 3400–2900 BCE), mostly

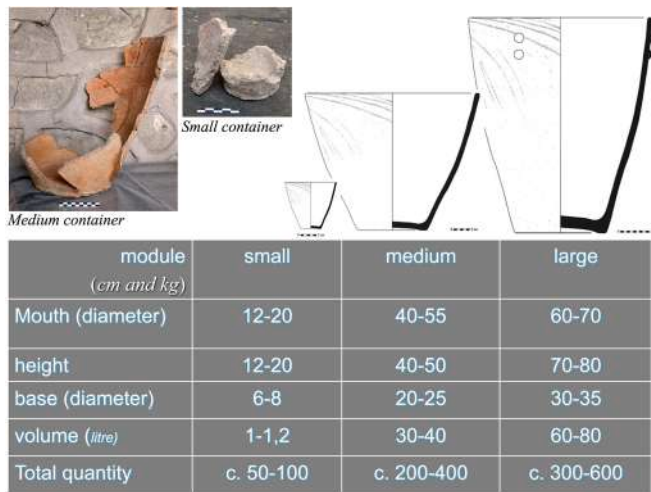


Fig. 7. Shape, dimension and quantity for the 3 types of salt moulds (Photos O. Weller).

enclosures, have yielded sherds of these moulds, known as pots called 'type *Champ-Durand*' (Ard and Weller, 2012). Fragments were found in about thirty enclosures (Ard and Weller, 2014). In the causewayed enclosures on the edge of the Marais poitevin, fragments of salt moulds can constitute more than 20 % of the ceramic assemblage (Ard, 2014).

These original ceramics, with coarse surfaces and a tapered shape, were discovered for the first time in the ditches of Champ-Durand enclosure (Nieul-sur-l'Autise, Vendée) during the excavations conducted by Roger Joussaume between 1975 and 1988 (Joussaume, 1981,2012).

The large number of these ceramics and their technological and morphological homogeneity resulted in a long debate about their function. In the 80 s, after the discovery of similar vessels in the ditches of the La Mastine enclosure (Nuaillé d'Aunis, Charente-Maritime) and in four other enclosures around the Marais Poitevin, Serge Cassen proposed the hypothesis of salt moulds from the model of the Metal Ages

salt production (Cassen and Scarre, 1992).

Fifteen years ago, chemical analysis by X-ray fluorescence undertaken by Olivier Weller during his PhD on samples of Champ-Durand, revealed a much higher concentration of chlorine in these ceramics than in domestic ceramics from the same site. These results confirm the hypothesis of salt moulds. Further analysis of several sites conducted in 2011 produced similar results (Ard and Weller, 2012).

In these enclosures located around marshes, surrounded by the highest areas of sea in the Neolithic period, salt moulds are found as heaps of sherds (Fig. 9). These large quantities of sherds in production sites, correspond to deliberate mould fragmentation in order to extract salt cakes. These significant quantities of vessels (more than 2000 vessels in the excavated part of Champ-Durand for example) provide great assemblages for technological studies, as well as for other contemporary ceramic traditions of West-Central France (Ard, 2013, 2014).

4.2. Technological study of salt moulds

The paste (fabric) of these pots contains abundant sandy inclusions (quartz, mica and feldspar) from local sources, and in the case of Champ-Durand (Huet and Ard, 2012) consists of shell and limestone tempers and sometimes organic temper like in the site of La Sauzaie (Soubise, Charente-Maritime).

The methods used to manufacture these vessels is very similar in all studied sites (Fig. 9). The base of the mould is manufactured by modelling a clay mass with discontinuous digital pressure. The clay disk obtained is thicker in its central part than in its periphery. Small cupules corresponding to fingerprints are observable in the internal and external surfaces. In order to consolidate the junction between the base and the wall of the vase, a coil is sometimes added in the last stage of manufacture by turning over the vase.

Contrary to earlier observations, it appears that these moulds from Western salt marshes are made using the coiling technique, like other ceramic productions, and not by modelling. Several features of this technique are visible within vessels, including the junctions between coils (Fig. 9). Large vertical fingerprints indicate that, in very plastic paste, the wall is thinned by stretching the clay from the bottom up. So, rims of these moulds always present a thin lip. A small technical feature

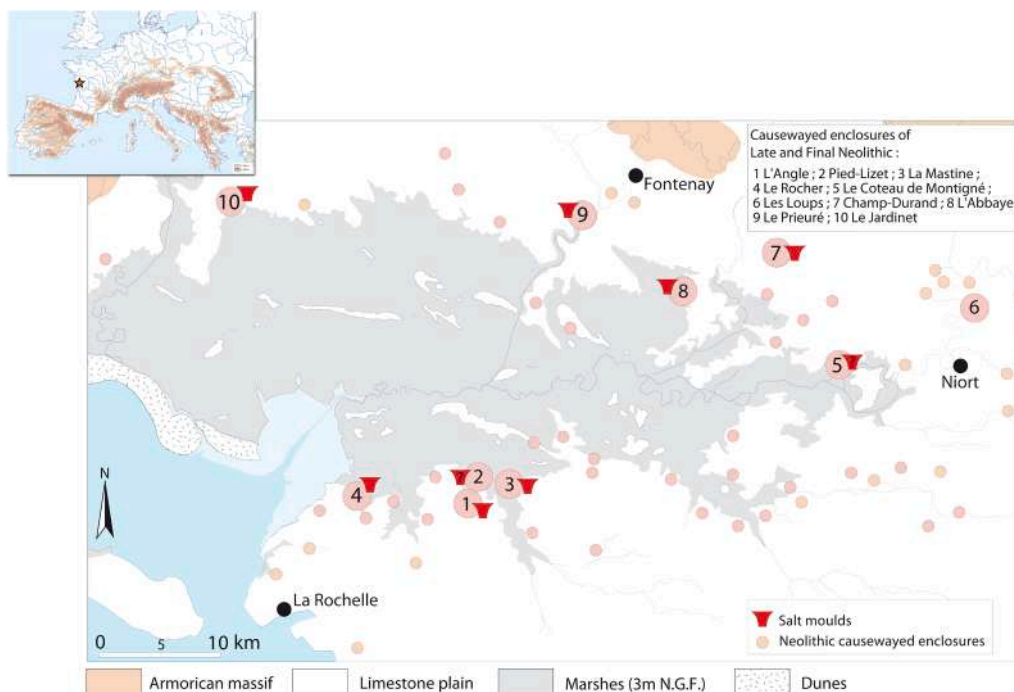


Fig. 8. Geographical distribution of causewayed enclosures in the Marais poitevin and discoveries of salt moulds (O. Weller).

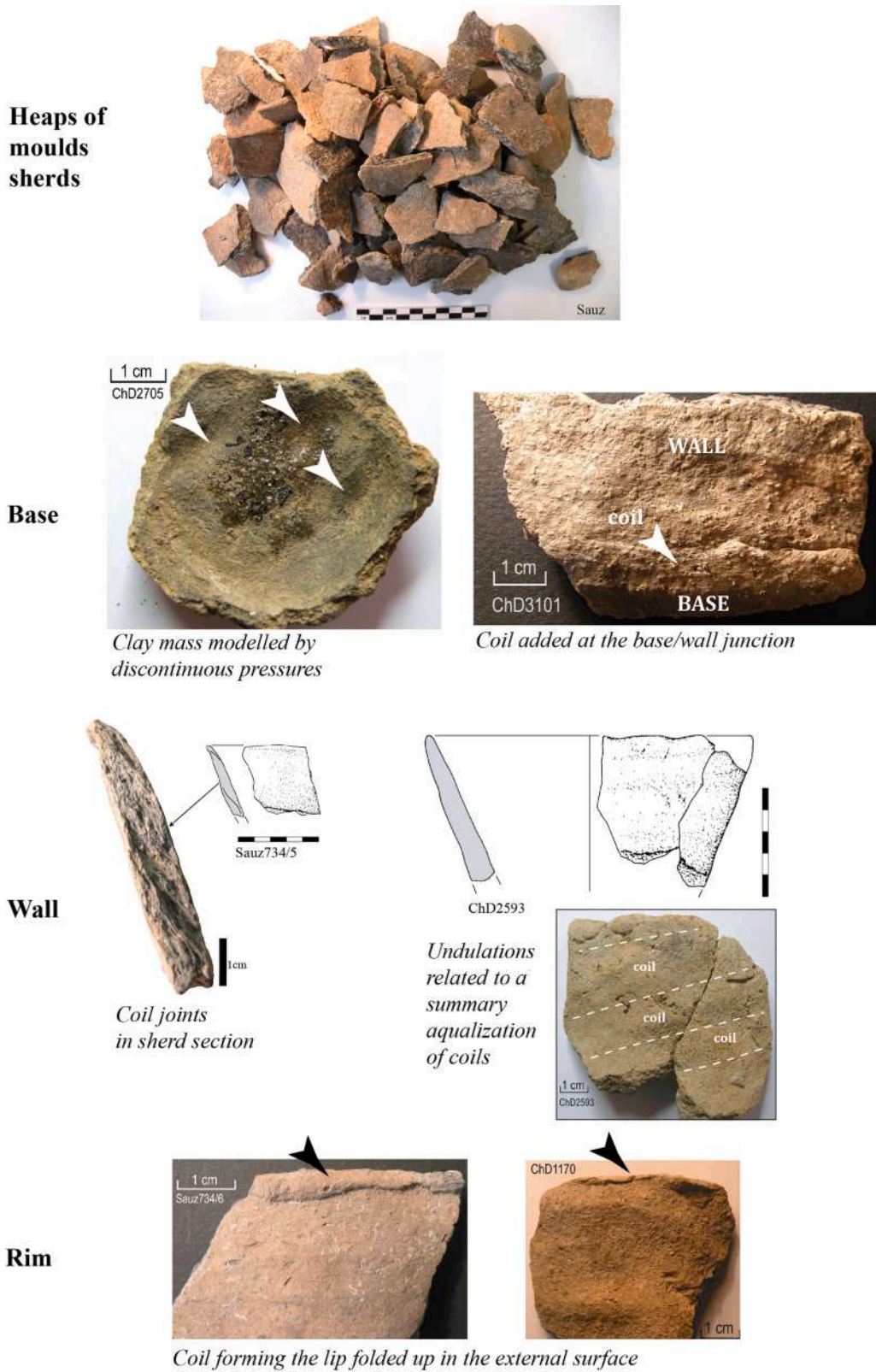


Fig. 9. Heaps of sherds and manufacture traces of salt moulds in West-Central France (Sauz: la Sauzaie at Soubise; ChD: Champ-Durand at Nieul-sur-l'Autise; drawings and photos V. Ard).

can be found on several sites: the coil forming the lip is folded up in the external surface of the rim.

One of the technical characteristics of these salt moulds is the surface finishing (Fig. 10). The external surfaces are smoothed in a wet paste,

usually by 'wet hand', or just quickly smoothed with fingers. The fingerprints appear as vertical, horizontal or oblique deep grooves. The internal surfaces are finely smoothed and sometimes burnished like in the assemblage of La Sauzaie.

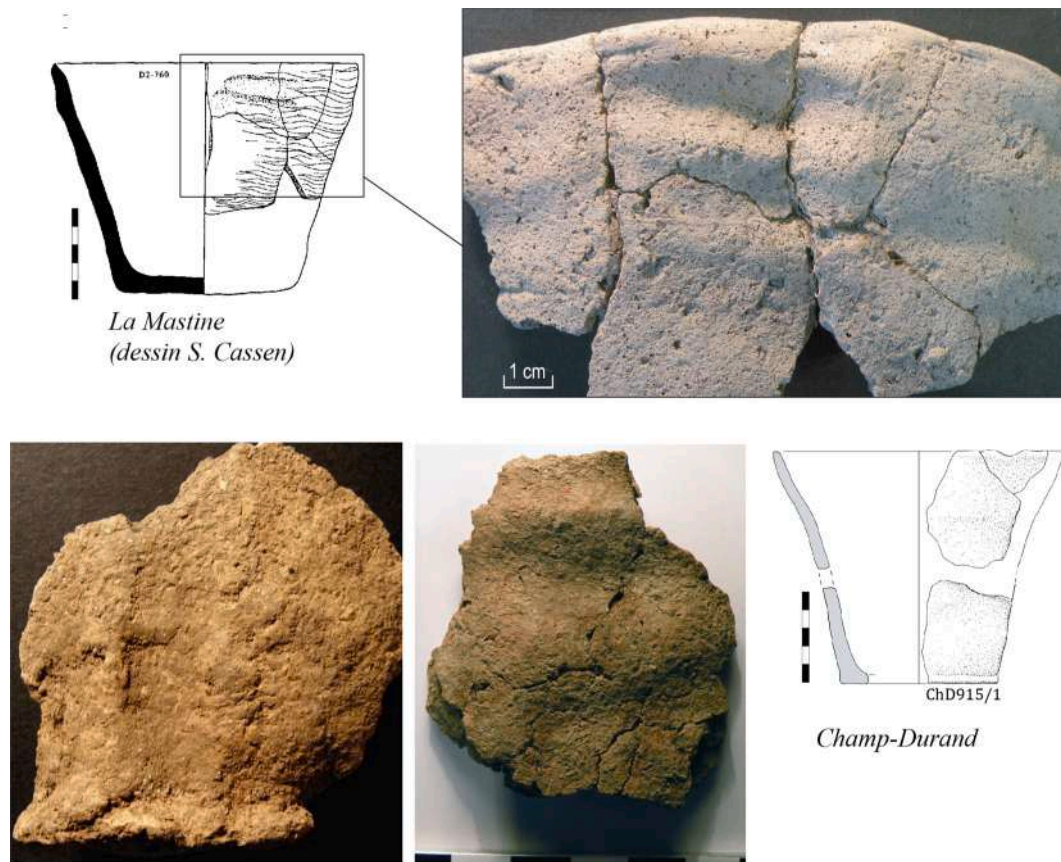


Fig. 10. Vertical and horizontal fingerprints in the external surface of salt moulds in West-Central France (drawing La Mastine after Cassen & Scarre, 1997; photos V. Ard).

Finally, the vessels were fired exclusively in an oxidizing atmosphere, which produced distinctive surface colours of yellow or orange.

In all sites, the vessels have an open and tapered shape, with very similar overall dimensions. Despite the high rate of fragmentation, by multiplying the measurements on the different parts of this vessel, it is possible to estimate the volume of the moulds at the Champ-Durand and La Mastine enclosures, at respectively 1 and 1.5 L. Taking an average density of salt of 1,6 (as previously explained, see 2.3), the salt cakes should weigh about 2 kg.

Contrary to the pit of Provadia, the causewayed enclosures of Western France are not an optimal context for the estimation of the production quantities of salt. Indeed, excavations are generally limited to superficies and the contents of ditches, and included contexts from numerous periods, many of which were often mixed, in opposition to a closed, secure assemblage.

5. A European Perspective: General attributes for Neolithic salt moulds

5.1. Technological attributes of salt moulds

In the two previous examples, we observed that for the same overall goal, function and constraints, crystallization or conditioning of salt cakes, several technical solutions had been found by Neolithic potters for making moulds.

The main result of our comparative study is to highlight common attributes for Neolithic salt moulds in two different chrono-cultural contexts. We observed eleven similar attributes:

- massive accumulation of sherds;
- high fragmentation rate;

- local clay and temper;
- high density of temper;
- fast forming (with coiling technique);
- irregular mouth and out-turned rim;
- external surface impressions (basket, mat, plant, fingerprints);
- contrasting finely finished internal surface (smoothing, slip, burnishing);
- oxidized firing;
- open shape;
- homogeneous production.

However, some differences exist between these two types of moulds, particularly the manufacturing support (mat), the external coat and the large dimensions observed only in Provadia context. These differences could be related to cultural choices, techniques of salt exploitation and/or various quantities of salt, which could be related to social needs in a specific context. Nevertheless, the production of moulds seems to be a completely new innovation technology for our two remote case studies.

5.2. Other remains related to salt production

In order to replace this particular vessel in the salt production process, we have examined the others artefacts or features in relation with ceramic moulds (Fig. 11).

At Provadia, other finds from the pit included a few ladles of various sizes. They had an internal rim to slowly pour the salt water and a large perforation for a long wooden handle. We also discovered about 50 fragments of disks, 20 to 25 cm in diameter and 2 cm thick. These 20 or so units present a slightly conical perforation of 2–3 cm and digital depressions on their edge to facilitate handling. It seems that these are simple rotary devices used in the manufacture of the moulds, in



Fig. 11. Associated clay artefact and feature: ladle, disc, fired clay, stove (Photos O. Weller and V. Ard).

particular the medium and big vessels. A third category consists of fired clay pieces. There are few, less than 1 m^3 , and without the characteristic surfaces of grilles, tables or oven floors. They could be parts of walls from stoves, with the wooden frame still visible.

We therefore have relatively little information about combustion features from this pit, besides small layers of charcoal, burned clay layers and possible parts of stoves. The exact functioning of these heating structures has yet to be investigated.

In the salt marshes of West-Central France, some combustion features can be reinterpreted as structures related to the exploitation of salt. This includes a pit within the site of Muron (Charente-Maritime) including many fragments of salt moulds, fired clay pellets and charcoal fragments, as well as a stove in the site of La Sauzaie which had walls in wattle and clay (Ard and Weller, 2012). More recently, on the Aquitaine Atlantic coast, large baskets have been discovered on the foreshore, interpreted as structures for harvesting and filtering brine (Verdin et al., 2018). For us, they are undoubtedly saline sand filter baskets (leaching) to obtain the most salt saturated brine possible. These exceptionally well-preserved structures allow us to document an earlier stage in the salt production process. The number of baskets discovered on the beaches for several years testifies to the importance of this production.

A link between salt moulds and ovens has recently been found in Britain (Sherlock, 2021), which is slightly older than in western France (3800–3700 BCE), corresponding to the early Neolithic in this region.

For this author, this discovery also testifies to the importance of salt production for the first Neolithic communities, probably related to increasing sedentarization and the need to preserve meat and food products.

6. Conclusions

To conclude, in both cases, we cannot reconstruct the whole *chaîne opératoire* of salt exploitation and only the last stages of production remain well-documented with the salt cakes moulding. Nevertheless, the two ceramic traditions for salt moulding present numerous similarities in spite of very different chrono-cultural contexts. And it seems that the particular function of these containers and the large quantities (one-time use) required have determined identical technical choices at opposite ends of Europe. Experimental approaches carried out with Romanian salt moulds have also highlighted the importance of technical choices and the high level of savoir-faire of producers (Tencariu et al., 2015).

In the European Neolithic, most salt exploitation centres have been recognized through work on fired clay artefacts known as briquetage used for crystallization and moulding of salt cakes (Fig. 12). The dominant hypothesis is that salt was used for food consumption. In reality, far from being homogeneous across Europe, production of salt, or rather of salt cakes, was probably an integral part of a broader process of intensification of social relations and exchange systems in which control

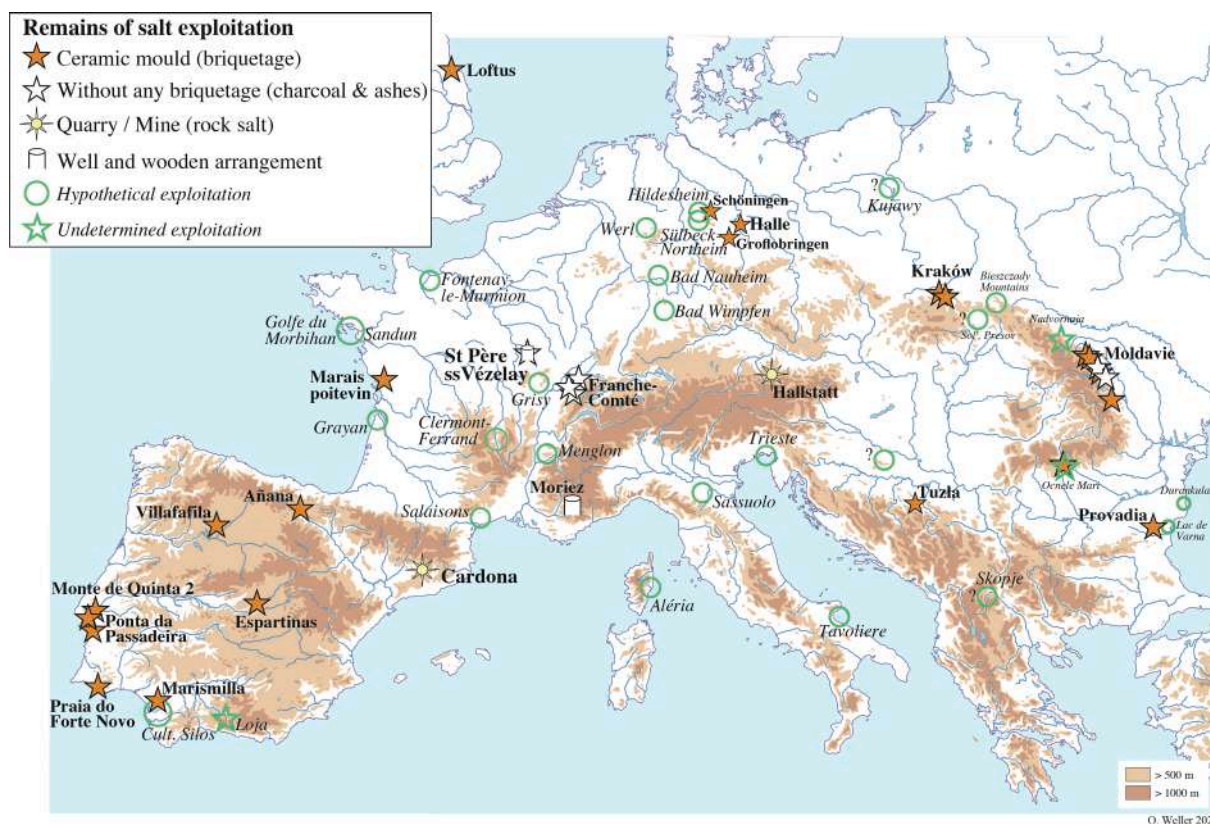


Fig. 12. Evidence for Neolithic and Chalcolithic salt production, including ceramic remains (Conception O. Weller).

over salt resources, production and distribution of salt cakes could have become a major preoccupation. Besides its role in human and animal alimentation, salt could have played, in certain contexts, the role of exchange good as a form of durable storage of a substance that is unique in terms of its qualities, of the areas suitable for its exploitation, and of its technical and economic charge. Salt could have become a 'hot food' and therefore potentially highly valued.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

We would like to acknowledge Prof. V. Nikolov and his team for their assistance in our ceramic study, their kindly welcome during 3 years on the archaeological site of Solnitsata, Provardia (2007, 2009, 2010) and for the samples used for radiocarbon dating. Many thanks also for all the museums (Bougon, Rochefort and Historial de Vendée) and excavators (A. Bolle, S. Cassen, J. Gachina, R. Joussaume, J.-P. Pautreau and S. Sicard) who allow us to study and sample salt moulds in West-Central France. Thanks to Michael S. Tite for his relevant comments on this paper and to Sarah-Jane Hathaway, John Chapman and Elaine Morris for her proofreading. We also thank the reviewers, whose comments undoubtedly improved this manuscript.

References

- Alessandri, L., Belardelli, C., Attema, P., Cortese, F., Rolfo, M.F., Sevink, J., van Gorp, W., 2021. Bronze and Iron Age salt production on the Italian Tyrrhenian coast. In: Gnade, M., Revello Lami, M. (Eds.), *Tracing Technology*. Peeters, Leuven, pp. 25–40.
- Andonova, M., Nikolov, V., 2022. Pots on mats: mat-impressed salt-extraction pottery at Chalcolithic Provardia-Solnitsata (Bulgaria). *Antiquity* 96 (385), 51–66. <https://doi.org/10.15184/aqy.2021.145>.
- Ard, V., 2013. Ceramic Traditions and Cultural Identities: West-Central France during the Late Neolithic II Period (c. 3400–2900 cal. BC). *Oxf. J. Archaeol.* 32 (4), 367–389.
- Ard, V., Weller, O., 2012. Les vases de « type Champ-Durand » : témoins d'une exploitation du sel au Néolithique récent dans le Marais poitevin, in: Joussaume, R. (Ed.), *L'enceinte néolithique de Champ-Durand à Nieul-sur-l'Autise (Vendée)*. Association des Publications Chauvinoises, Chauvigny, pp. 309–333.
- Ard, V., Weller, O., 2014. Des enceintes qui ne manquent pas de sel. Les vases de « type Champ-Durand » comme témoins d'une activité spécifique aux pourtours des marais poitevins et charentais, in: Joussaume, R., Large, J.-M., Corson, S., Le Meur, N., Tortuyaux, J.-P. (Eds.) - *Enceintes néolithiques de l'Ouest de la France de la Seine à la Gironde*, Actes du colloque CrabeNéo, Les Lucs-sur-Boulogne, 19–21 septembre 2012. APC (Mémoires ; XLVIII), Chauvigny, pp. 371–385.
- Ard, V., 2014. Produire et échanger au Néolithique. Traditions céramiques entre Loire et Gironde au IVE millénaire avant J.-C. CTHS (Documents Préhistoriques ; 33), Paris.
- Arnold, D.E., 1985. *Ceramic theory and cultural process*. Cambridge University Press, Cambridge.
- Bowser, B.J., 2000. From pottery to politics: an ethnoarchaeological study of political factionalism. *J. Archaeol. Method Theory* 7 (3), 219–248.
- Brigand, R., Weller, O. (Eds.), 2015. *Archaeology of Salt. Approaching an invisible past*. Sidestone Press, Leiden.
- Cassen, S., Scarre, C., 1997. *Les enceintes de La Mastine et de Pied-Lizet (Charente-Maritime)*. Association des Publications Chauvinoises, Chauvigny.
- Daire, M.-Y., 2003. *Le sel des Gaulois*. Errance, Paris.
- Daire, M.-Y., (Ed.) 1994. *Le sel gaulois*. Dossiers de Centre de Recherche Archéologique d'Alet (suppl. Q), Saint-Malo.
- De Brisay, K.W., Evans, K.A., (Eds.) 1975. *Salt. The Study of an Ancient Industry*. Report on the Salt Weekend Held at the University of Essex, 20–22 sept 1974. Colchester Archaeological Group, Colchester.
- Gaydarska, B., 2003. *Preliminary research on prehistoric salt exploitation in Bulgaria*. Изследвания в чест на Хенриета Тодорова. Добруджа. 21, 110–122.
- Gaydarska, B., Chapman, J., 2022. "Add salt to taste": the place of the Provardia-Solnitsata salt exploitation site in relation to the East Balkan Neolithic and Chalcolithic and the Varna cemetery. *Thracia Balcanica*. 1, 77–120.

- Gelbert, A., 2003. Traditions céramiques et emprunts techniques. Etude ethnoarchéologique dans les haute et moyenne vallées du fleuve Sénégal (CD-Rom). MSH (Epistèmes), Paris.
- Gosselain, O., 2000. Materializing identities: an african perspective. *J. Archaeol. Method Theory* 7 (3), 187–217.
- Gouletquer, P., 1970. Les Briquetages de l'âge du Fer sur les côtes sud de la Bretagne. *Bulletin De La Société Préhistorique Française*. 67, 399–411.
- Gouletquer, P., 1974. The development of salt making in Prehistoric Europe. *Essex Journal* 8, 2–14.
- Gouletquer, P., Weller, O., 2015. Techniques of salt making: from China (Yangtze River) to their world context. In: Brigand, R., Weller, O. (Eds.), *Archaeology of Salt. Approaching an invisible past*, Sidestone, Leiden, pp. 13–27.
- Harding, A., 2013. Salt in Prehistoric Europe. Sidestone Press, Leiden.
- Higham, T., Slavchev, V., Gaydarska, B., Chapman, J., 2018. AMS dating of the Late Copper Age cemetery of Varna. *Bulgaria. Radiocarbon*. 60 (2), 493–516.
- Huet, N., Ard, V., 2012. Analyse pétrographique des céramiques, in: Joussaume, R. (Ed.), *L'enceinte néolithique de Champ-Durand à Nieul-sur-l'Autise (Vendée)*. Association des Publications Chauvinoises, Chauvigny, 351-365.
- Николов, В., Люнчева, М., Самичкова, Г., 2021. Специализираното производство на сол в Провадия-Солнищата през VI и V хил. пр. Хр. и обществено-икономическото му въздействие. София.
- Николов, В., Петрова, В., Бъчваров, К. (Eds.), 2009. *Провадия-Солнищата: Археологически Разкопки и Изследвания През 2008 г. Предварителен отчет*, София.
- Joussaume, R. (Ed.), 2012. *L'enceinte Néolithique De Champ-Durand à Nieul-Sur-L'autise (vendée)*. Association des Publications Chauvinoises, Chauvigny.
- Joussaume, R., 1981. Le Néolithique et le Chalcolithique de l'Aunis et du Poitou occidental dans son cadre atlantique. Université Rennes I (Travaux du laboratoire d'Anthropologie, Préhistoire, Protohistoire et Quaternaire Armoricains), Rennes.
- Lane, T., Morris, E.L., (Eds.) 2001. A millennium of Saltmaking: Prehistoric and Romano-British Salt Production in the Fenland. Heritage Trust of Lincolnshire (Lincolnshire Archaeology and Heritage Reports Series 4), Sleaford.
- Lemaire, F., 2002. L'atelier de saunage augustéen du site de Conchil-le-Temple, Fond de la Commanderie (Pas-de-Calais), in: Weller, O. (Ed.), *Archéologie du sel. Techniques et sociétés*. Actes de la table ronde du Comité des Salines de France, Paris, mai 1998. VML GmbH. (Internationale Archäologie, ASTK 3), Rahden, 53-62.
- Leroi-Gourhan, A. (Ed.), 1988. *Dictionnaire De La Préhistoire*. PUF, Paris.
- Manolakakis, L., 2020. Modalités de la différenciation sociale en Europe au 5^e millénaire - Apport de l'approche techno-économique des industries lithiques. Prestige, richesses et pouvoir dans le Chalcolithique des Balkans nord-orientaux. Thèse d'Habilitation à Diriger des Recherches. Archéologie Et Préhistoire. Université Nice Côte D'azur 2.
- Morris, E., 1985. Prehistoric Salt Distributions: Two Case Studies from Western Britain. *The Bulletin of the Board of Celtic Studies*. 32, 336–377.
- Nenquin, J.A.E., 1961. Salt. A Study in Economic Prehistory. De Tempel (dissertationes Archaeologicae Gandenses 6), Bruges.
- Nikolov, V., 2010. Salt and gold: Provadia-Solnitsata and the Varna Chalcolithic cemetery. *Archäologisches Korrespondenzblatt*. 40 (4), 487–599.
- Nikolov, V. (Ed.), 2008. *Provadia-Solnitsata Prehistoric Salt-Producing Center. The 2005-2007 Excavation Seasons*. National Institute of Archaeology and Museum. Bulgarian Academy of Sciences, Sofia.
- Olivier, L., Kovacik, K., 2006. The Briquetage de la Seille (Lorraine, France): Proto-industrial Salt Production in the European Iron Age. *Antiquity*. 80(109), 558-566.
- Roux, V., 2010. *Lecture anthropologique des assemblages céramiques. Fondements et mise en œuvre de l'analyse technologique*. *Les Nouvelles De L'archéologie*. 119, 4–9.
- Roux, V., Courty, M.-A., 2005. Identifying social entities at a macro-regional level : Chalcolithic ceramics of South Levant as a case study, in: Livingstone Smith, A., Bosquet, D., Martineau, R. (Eds.), *Pottery Manufacturing Processes: Reconstitution and Interpretation*, Actes du XIV^e Congrès UISPP, Université de Liège (Belgique), 2-8 septembre 2001. Archaeopress. (BAR International Series 1349), Oxford, 201-214.
- Rouzeau, N., 2002. Sauneries et briquetages. Essai sur la productivité des établissements salicoles gaulois du Centre-Ouest atlantique d'après l'étude du gisement de Nalliers (Vendée), in: Weller, O. (Ed.), *Archéologie du sel: techniques et sociétés*. Actes du colloque international, XIV^e congrès UISPP, sept 2001, Liège. VML GmbH (Internationale Archäologie, ASTK 3), Rahden, 99-124.
- Sherlock, S.J., 2021. Early Neolithic salt production at Street House, Loftus, north-east England. *Antiquity* 95 (381), 648–669. <https://doi.org/10.15184/aqy.2021.25>.
- Slavchev, V., 2010. The Varna Eneolithic cemetery in the context of the the Late Copper Age in the East Balkans. In: Anthony, D.W., Chi, J.Y. (Eds.), *The Lost World of Old Europe, the Danube Valley*. Institute for the Study of the Ancient World, New York.
- Sordoillet, D., Weller, O., Rouge, N., Buatier, M., Sizun, J.-P., 2018. Earliest salt working in the world: From excavation to microscopy at the prehistoric sites of Tolici and Lunca (Romania). *J. Archaeol. Sci.* 89, 46–55. <https://doi.org/10.1016/j.jas.2017.11.003>.
- Tencariu, F.-A., Alexianu, M., Coriga, V., Vasilache, V., 2015. Briquetage and salt cakes: an experimental approach of a prehistoric technique. *J. Archaeol. Sci.* 59, 118–131. <https://doi.org/10.1016/j.jas.2015.04.016>.
- Verdin, F., Ard, V., Carrère, I., Eynaud, F., Hoffmann, A., Manen, C., Marchand, G., Saint-Sever, G., 2018. Nouvelles recherches sur le site de la Lède du Gulp (Grayan-et-l'Hôpital, Gironde): résultats préliminaires. In: Marticorena, P., Ard, V., Hasler, A., Cauliez, J., Gilabert, C., Sénépart, I. (Eds.), "entre Deux Mers" Et Actualité De La Recherche, Actes Des 12^e Rencontres Méridionales De Préhistoire Récente, Bayonne, 27 Septembre-1er Octobre 2016. AEP, Toulouse, pp. 209–220.
- Weller, O., 2015. First salt making in Europe: an overview from Neolithic times. *Documenta Praehistorica* 42, 185–196. <https://doi.org/10.4312/dp.42.12>.
- Weller, O., Desfossés, Y., 2002. Les ateliers sauniers de Sorrus (Pas-de-Calais) : un apport majeur aux techniques de production de sel et à leur évolution durant le second âge du Fer, in: Weller, O. (Ed.), *Archéologie du sel. Techniques et sociétés*. Actes de la table ronde du Comité des Salines de France, mai 1998, Paris. VML GmbH (Internationale Archäologie, ASTK 3), Rahden, 63-80.
- Weller, O., 2000. Le matériel de briquetage des ateliers sauniers de Sorrus (Pas-de-Calais), in: Desfossés, Y. (Ed.), *Archéologie préventive en vallée de Canche. Les sites protohistoriques fouillés dans le cadre de la réalisation de l'autoroute A16, Nord-Ouest Archéologie*, 11, 272-280.
- Weller, O. (Ed.) 2002. *Archéologie du sel. Techniques et sociétés*. Colloque international, XIV^e congrès UISPP, Liège 2001. VML GmbH (Internationale Archäologie, ASTK 3), Rahden.
- Weller, O. 2004. Produire du sel préhistorique : de la fonction des vestiges aux fonctions du produit, in: Bodu, P., Constantin, C. (Eds.), *Approches fonctionnelles en Préhistoire*. Actes du XX^e Congrès préhistorique de France, novembre 2000, Nanterre. Société Préhistorique Française, Paris, 445-453.
- Weller, O., 2012. La production chalcolithique du sel à Provadia-Solnitsata: de la technologie céramique aux implications socio-économiques, in: Nikolov, V., Bacvarov, K. (eds.), *Salt and Gold: The Role of Salt in Prehistoric Europe*. Actes du Colloque international Humboldt-Kolleg, oct. 2010, Provadia (Bulgarie). Faber, Provadia-Veliko Tarnovo, 67-87.