Bronze Age Sea Salt Production in the Northwest Iberian Peninsula

Ana M. S. Bettencourt, Sara Luz, Pedro P. Simões, Maria Isabel C. Alves et Emílio Abad-Vidal

Résumé

Ce texte fournit les premières preuves de l'exploitation de sel marin dans le Nord-Ouest de la péninsule Ibérique à l'âge du Bronze. La production du sel s'opérait sur le site archéologique de la plage de Carreço, à Viana do Castelo entre la fin du III^{e} et le début du II^{e} millénaire avant J.-C. et montre l'utilisation d'éviers amovibles creusés dans le schiste et chauffés pour renforcer le processus d'évaporation de l'eau salée. Ce type de puits est très courant sur la côte nord. D'autres preuves de l'exploitation du sel marin se trouvent sur le site archéologique d'Areias Altas à Porto pendant la première moitié du II^{e} millénaire avant J.-C. Sur ce site, des récipients en céramique, morphologiquement similaires à ceux utilisés pour l'évaporation de l'eau salée par le processus de saumure ou comme moules pour le sel, dans d'autres contextes préhistoriques d'extraction du sel en Europe occidentale et orientale, ont été trouvés. Sur la côte nord-ouest de l'Ibérie, on trouve également d'innombrables puits creusés dans la roche, morphologiquement semblables aux puits de schiste amovibles. Une observation de leurs conditions de fabrication a révélé qu'ils étaient fabriqués par percussion, probablement avec des marteaux en pierre, et polis avec des galets roulés, ce qui leur donne une forme de coins arrondis. Ainsi, l'absence de preuves d'artéfacts métalliques dans leur fabrication indique qu'ils seraient antérieurs à l'âge du Fer, bien qu'ils aient pu être utilisés durant cette période. Les différentes méthodes d'extraction peuvent être liées aux changements climatiques qui se sont produits au cours des III^{e} et II^{e} millénaires avant J.-C.

Mots-clés

Nord-Ouest ibérique, âge du Bronze, production de sel marin.

Abstract

This text provides evidences of sea salt exploitation in the Northwest Iberian Peninsula during the Bronze Age. This took place between the late 3rd millennium and early 2nd millennium BCE, in the archaeological site of Carreço beach, in Viana do Castelo, using removable sinks excavated in schist, that were heated to enhance the process of evaporation of salt water. This type of sink is very common along the northern coast of the Iberian Peninsula. Other archaeological evidence of sea salt exploitation exists in the Areias Altas archaeological site in Porto, daring from the first half of the 2nd millennium BCE. In this site ceramic containers have been found that are morphologically similar to those used for evaporation of salt water using the brine process or as moulds for salt in other prehistoric salt extraction contexts in Western and Eastern Europe. On the Northwest coast of the Iberian Peninsula there are also countless sinks dug into the rocks, morphologically similar to removable schist sinks. Observation of their manufacturing conditions reveals that these sinks were made by percussion, probably using stone hammers, and polished with rounded pebbles, which gave them rounded corners. The absence of evidence of the use of metallic artefacts to make these sinks suggest that they were made before the Iron Age, although they may have still been used during that period. The different extraction methods may be related to climate changes that occurred during the 3rd millennium and 2nd millennium BCE.

Keywords

Northwest Iberian Peninsula; Bronze Age; Sea salt production

Between the late 4th millennium and mid 2nd millennium BCE there was a global period of neoglaciation, characterised by cooler temperatures, and significant decreases in humidity (Fábregas Valcarce *et al.*, 2003; Martínez-Cortizas *et al.*, 2009). The effects of this climate change on the Atlantic coast of the Northwest Iberian Peninsula are known and it has been verified that the coastline was further west than its current position (Alves *et al.*, 2003) and would have included more lagoons and inlets (Dias *et al.*, 1997). It is known, for example, that c. 5 000 BP (c. 4th millennium BCE) there was a complex system of lagoons along the coast of the territory now occupied by Portugal. Examples include the deposits of the Lagoa da Apúlia and Rio de Moinhos beach, in the municipality of Esposende. There is evidence that the lagoons had variable levels of salinity, typical of alternating periods of freshwater and seawater (Granja *et al.*, 2010; Granja *et al.*, 2016). In Roman times this lagoon system still existed, as well as large estuaries (Granja, 1993). Today the northern coast of the Iberian Peninsula is more rectilinear, characterised by rocky outcrops of granite or metamorphic composition (essentially slates, phyllites and mica schist) that formed part of the Iberian Massif, often covered by beaches or sand dunes. Sometimes, these outcrops developed at higher elevations, and gave rise to rocky promontories between more or less extensive sandy beaches (Araújo, 1999).

In the more western zone of the Iberian Peninsula, the first evidence of salt production dates back to the Neolithic and Chalcolithic period (between the 5th millennium and the first half of the 3rd millennium BCE), but evidence has only been found in central/southern Portugal (Cassen and Weller, 2017; Valera *et al.*, 2017). For the Northwest Iberian Peninsula (a region that includes Northern Portugal and Northwest Spain, i.e. Galicia), we have no known references of the exploitation of sea salts in Prehistory and the Bronze Age. However, for the Iron Age, there are written references that refer to the extraction of salt in the territory occupied by the Cantabrians in the North Iberian Peninsula. According to Strabo, in vol. 3 of "Geography" (Geog. III, 3,8), these people extracted a purple salt that turned white after grinding. It should be noted that for Garcia y Bellido *et al.* (1970) this salt was extracted in the mines of Cabezón de la Sal, in Cantabria (North of Iberia) that was still active in the 20th century, but was not sea salt.

In addition to pre-existing information about coastal salt exploitation during the Roman period (Almeida, 2015, among others), recent archaeological work has led to the discovery of numerous salt marshes during this period in Galicia, demonstrating the existence of genuine industrial exploitation at that time (Currás, 2017). Exploitation of sea salt during the Roman period is well documented in the *rias* (estuaries) and open coastline of Galicia, as a result of the Sea of Salt scientific project, developed by Spanish and Portuguese researchers.

During the Medieval Period there are also written records that confirm the exploitation of sea salt from the 10th century onwards along the coast of the Northwest Iberian Peninsula and in the estuaries of the main rivers of present-day Northern Portugal (Almeida, 2005).

However, from the 14th and 15th centuries most of the saltpans in the Northwest Iberian Peninsula collapsed (Rau, 1951) and the salt produced in the saltpans of the Ria de Aveiro (estuary) (North-Central Portugal) supplied this region (Marques, 1981: 41-42; Poland, 1999: 79). However, in some places in the Northwest Iberian Peninsula, such as the estuaries of the rivers Leça, Lima and Coura, salt exploitation continued to exist on a residual basis until the 18th and 19th centuries (Marçal, 1966; Fernandes, 1994).

On the basis of all these data it is assumed that salt mining could have taken place in the Northwest Iberian Peninsula before the Iron Age, especially in the Bronze Age. It is on this premise that we began to interpret certain materials: either found in archaeological excavations or dug in the rocks along the coast.

This paper therefore aims to disseminate this data, supposedly related to salt exploitation; to discuss the respective chronology; to interpret the different salt exploitation techniques before the Roman period and to articulate this activity with local settlement strategies.

1. The Data

The data supposedly related to salt exploration discussed in this text encompasses three types: removable sinks, rock sinks and archaeological pit sites with ceramic containers and evidence of combustion structures related to this subject (fig. 1).

1.1. Removable sinks

One of the objects that provide evidence of sea salt exploration is the removable sink. Many specimens exist, essentially in the current sandy and schist coastline, although some have also been found in granitic areas. Knowledge of this phenomenon is limited, due to the fact that most of these pieces have been found out of context, swept onshore during high tides in the spring and autumn equinoxes, which tend to be the largest tides recorded during the year. This means that many of their original contexts are currently on the coastline, destroyed by ongoing marine transgression.

Evidence of removable sinks has been found in the beaches located on the border between the parishes of Estela (Póvoa de Varzim) and Apúlia (Esposende), such as the beaches in Rio Alto (Campsite) and Ramalha; Robaleira (unpublished) and Rio de Moinhos (at the mouth of the Ribeira de Peralta stream) (both in the parish of Marinhas, Esposende); Lontreiras beach (São Bartolomeu do Mar parish); Sublago

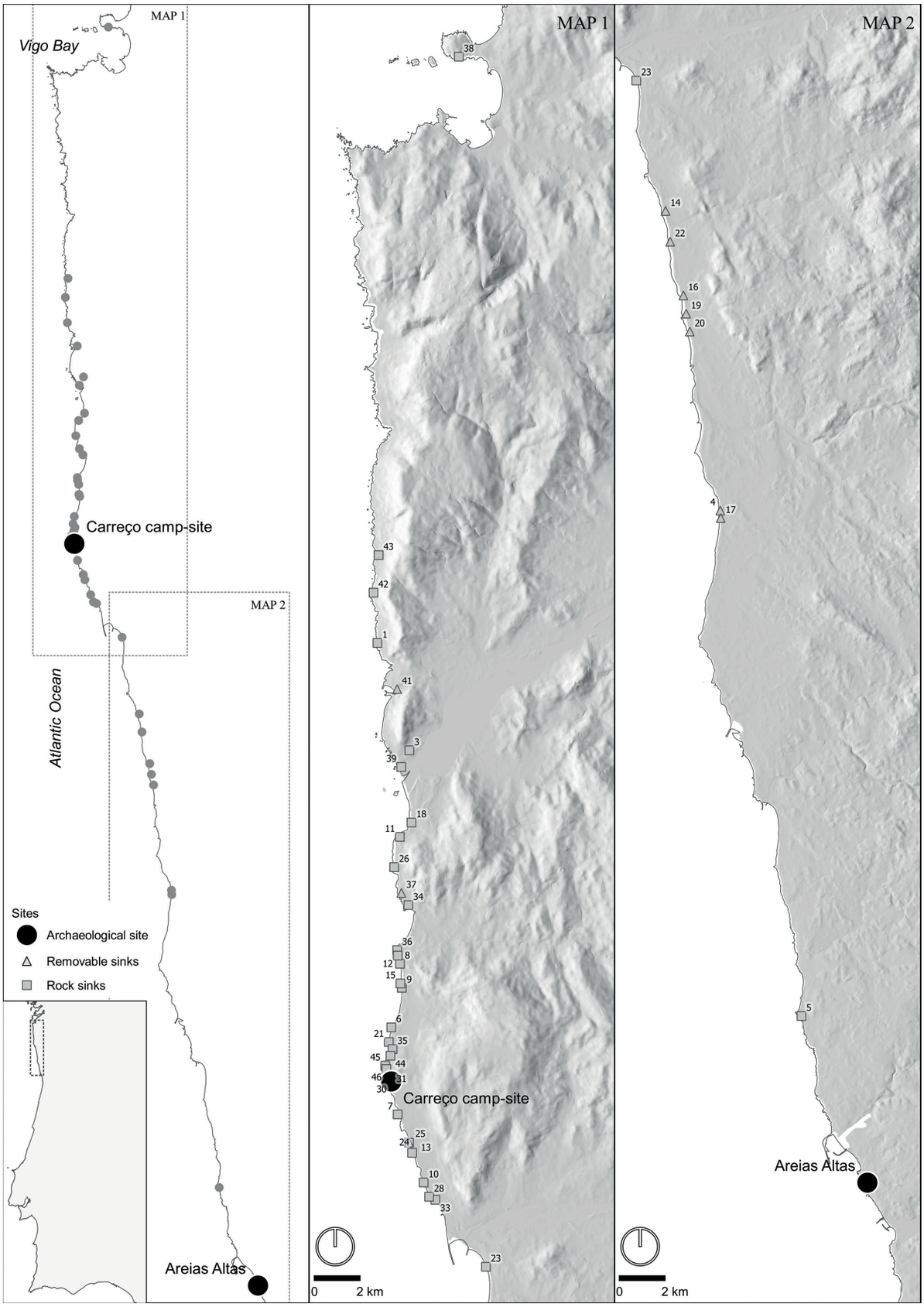


Figure 1 - Places related to salt exploration cited in the text: 1. Altiña; 2. Areias Altas; 3. As Lagoas; 4. Ramalha; 5. Agudela; 6. Bico; 7. Canto Marinho; 8. Carrasqueira; 9. Celeiro; 10. Corgo; 11. Estrada Real; 12. Estremo or Cão; 13. Gandaral; 14. Guilleta; 15. Ínsua; 16. Lontreiras; 17. Rio Alto; 18. Preces; 19. Rio de Moinhos; 20. Robaleira; 21. Sarrosa; 22. Sublago; 23. Foz do Rodanho; 24. 25. Campo do Amo / Moinho do Moca; 26. Santo Isidoro; 27. Carreço camp-site; 28. Cobidalto; 29. Fornelos 1; 30. Fornelos 2; 31. Fornelos 3; 32. Fornelos 4; 33. Fort Velho da Vinha; 34. Fort of Lagarteira; 35. Fort of Paçô; 36. Fort of Cão; 37. Lagarteira; 38. Monteferro; 39. O Puntal; 40. Outeiro Pequeno; 41. Porto de A Guarda; 42. Punta Bazar; 43. Sarrido; 44. Sinadora 1; 45. Sinadora 2; 46. Sinadora 3.

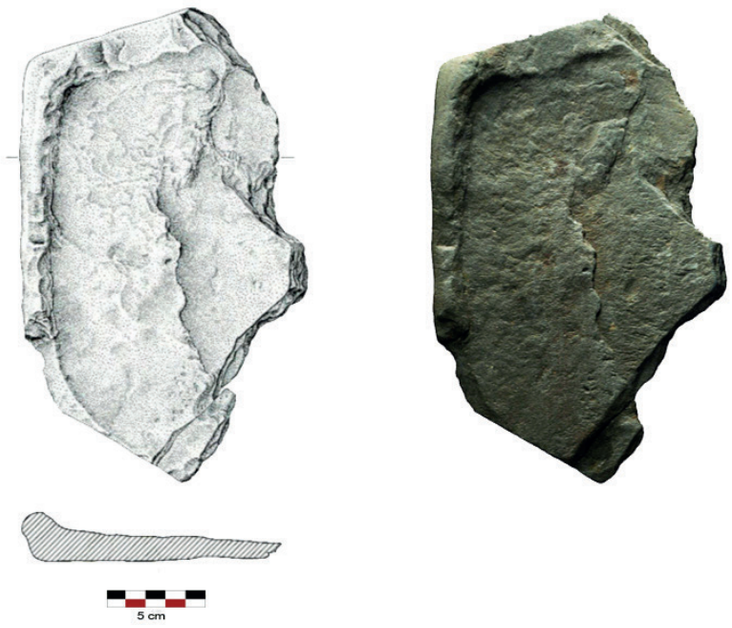


Figure 2 – Photograph and drawing of the removable sink of the Carreço beach camp-site (Drawing Baptista, 1982).

beach (Belinho parish) [Almeida, 2005] and Guilheta beach (São Paio de Antas parish) at the estuary mouth of the Neiva river (Esposende). In Robaleira beach, fragments of these sinks lay in special association with a granite hand mill (non-existent rock at the site) discovered during a very low tide in the autumn equinox. Further north, in the municipality of Viana do Castelo, evidence has also been found in the beaches of Campo do Amo / Moinho da Moca (Areosa parish), unpublished, and Carreço, north of Forte da Lagarteira, in Vila Praia de Âncora (Caminha), on a surface of about 200 metres, in the current gravel pit and in a secondary position (unpublished). In Galicia, evidence has been found in the municipality of A Guarda, in particular in the area of Porto (Currás, 2019).

On Carreço beach, a fragment of a removable sink was detected, the only one found in an archaeological context (fig. 2). It is a camp-site, without ceramics, but with numerous carved lithic artefacts (including fishing net weights on pebbles, which indicates coastal activities, such as fishing).

The sink excavated into the mottled schist rested on a structure constituted by innumerable pebbles cracked by the action of fire (suggesting that it was a large area of combustion). These thermoclasts were dated by the thermoluminescence to the late 3rd millennium, early 2nd millennium BCE (fig. 3), which, in regional terms, is considered to be the period from the end of the Chalcolithic to the Early Bronze Age (Baptista, 1992) [fig. 3].

In the context of reuse, such sinks are also found in the Castro (pre-Roman hillfort) of São Lourenço (Vila Chã parish, municipality of Esposende) (Almeida, 1998) and in the Castro of São Silvestre (Cardielos parish, Viana do Castelo), in the estuary of the river Lima (Costa *et al.*, 2019). Fragments of these sinks also exist in the Castro of Santa Tegra Museum, in the municipality of A Guarda, in Galicia, but their exact provenance is unknown (Carballo Arceo, 1989). Fragments of these objects also appeared during the excavation of the Late Roman villa in Agra do Relógio, São Paio de Antas, Esposende, in a secondary context (Costa *et al.*, 2019).

They are excavated in the schist, less than 1 metre long (when they are found whole, which is rare), surrounded by a perimeter edge. They have a sub-rectangular or oval outline, rounded corners and are very shallow - about 2 to 4 cm deep. Some are more than 35 cm wide.

Although they are considered to be primarily from the Iron Age (Almeida, 2005; Costa *et al.*, 2019), according to the data obtained in the Carreço beach camp-site, it can be considered, that salt extraction through the use of removal sinks, occurred from, at least, the end of the 3rd millennium until, the beginning of the 2nd millennium BCE. Its association with a hand mill at Robaleira beach also indicates its use in Prehistory. Its reuse in the region from the Late Iron Age (from the 2nd century BC) should be considered to be its end of use.

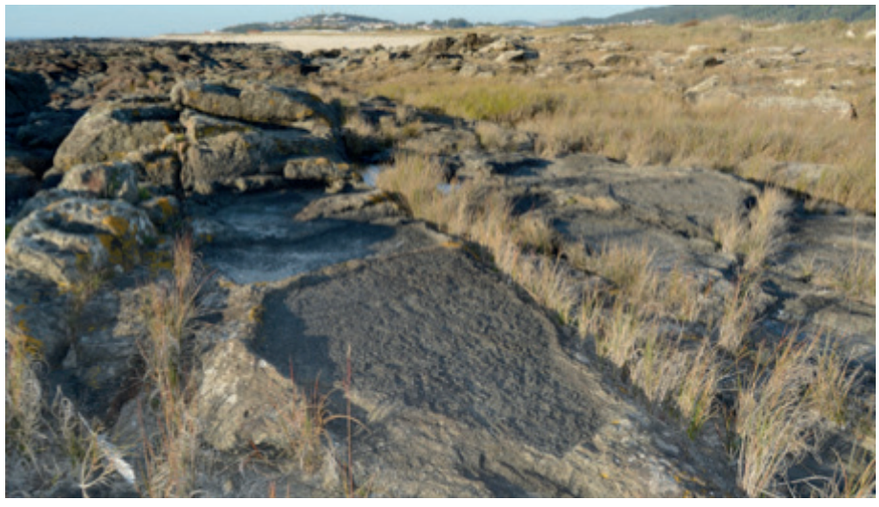
1.2. Rock sinks

The best-documented material evidence of sea salt extraction in the Atlantic coast of Northwest Iberian Peninsula (in thousands) correspond to rock sinks with different measurements and contours, always shallow, directly cut into the upper section of rocky outcrops. These structures only appear in areas of where there are many granite outcrops or other rocks, other than schist. Like portable sinks, those structures were also used to extract sea salt by evaporation of the natural seawater.

Site	Lab. Ref	Conv. Rad. age (BP)	Cal BC (2 sigma)	References
Carreço beach camp-site	Thermoluminescences media	3855±207	2280 (1865) 1450	Baptista, 1992

Figure 3 – Thermoluminescence dating of the Carreço-beach camp-site.

Figure 4 - Rock sinks from several sites. Top (left to right): Sarrido, Punta Bazar and Santo Isidoro; Bellow (left to right): Sinadora and Canto Marinho (source of Canto Marinho: www.garranos.pt/pt/pontos-de-interesse/pias-salineiras-do-canto-marinho#lg=1&slide=0).



These structures were first referred to by Lemos (1982), who called them "cuvetes" in the area of the Fort of Cão, Gelfa, Vila Praia de Âncora parish, municipality of Caminha, Portugal.
Remnants have also been found, from Agudela beach (Lavra parish, Matosinhos, Portugal) to Monteferra, Nigrán, in the Ria de Vigo estuary (Galicia), and it is likely that this phenomenon was much more extensive. In Galicia, although prospecting has not been intensive, evidence has also been found in Sarrido, Portocelo, municipality of Rosal (unpublished); in Punta Bazar, A Guarda (Cortegoso Comesaña 2019); in Altiña, A Guarda (unpublished); in Outeiro Pequeno, Camposancos, A Guarda (unpublished); in As Lagoa, Camposancos, A Guarda (Currás, 2019) and in O Puntal, also in Camposancos, A Guarda (unpublished). In Portugal, Almeida (2005) mentions the existence of a nucleus in the estuary mouth of the Ribeira de Anha stream (Vila Nova de Anha/Darque parish, Viana do Castelo); in Fort Velho da Vinha (Areosa parish, Viana do Castelo); between Montedor beach and the Fort of Paçô (Carreço parish, Viana do Castelo); in the Fort of Cão and Fort of Lagarteira (both in Vila Praia de Âncora, Caminha) and in Moledo beach, Caminha. The nucleus of the Anha stream is also known as Foz do Rodanho beach. Other examples include the beaches of Campo do Amo/Moinho do Moca, Gandaral, Corgo and Cobidalto (Areosa parish, Viana do Castelo), unpublished; the beaches of Estremo or Cão, Carrasqueira, Ínsua, Celeiro, Bico (Afife parish, Viana do Castelo), unpublished; the beaches of Sarrosa (unpublished) and Canto Marinho, both in Carreço (Viana do Castelo) (Costa *et al.*, 2012); the chapel of Santo Isidoro, the beaches of Estrada Real and Ribeira de Preces (Moledo, Caminha), also unpublished (fig. 4).
They may appear isolated, usually at the top of small outcrops; or in groups, but scattered throughout the outcrops, or in groups and contiguous to each other. Examples include Fornelos and Sinadora (unpublished) in Viana do Castelo (Portugal) or A Lagoa, in A Guarda (Galicia). They have mainly oval, trapezoidal or rectangular shapes and rounded corners. When carved into the top of small outcrops and in narrower spaces, they sometimes tend to adapt to the shape of the rocky surface, presenting a more irregular morphology. They can assume several dimensions, but few exceed 1 metre in length. They are always very shallow (between 5 and 9 cm).
Macroscopic observation reveals that they have been cut by percussion, probably using stone hammers and then polished with rounded pebbles, probably mixed with sand to make them more abrasive. Metallic points do not seem to have been used in the excavation of these sinks, since there are often quartz minerals, components of the local granite, at the bottom of the sinks, that have not been broken. The rounded corners do not indicate the use of metal instruments in excavation of these structures.

Figure 5 – The complex of Fornelos rock sinks (www.garranos.pt/pt/pontos-de-interesse/pias-salineiras-de-fornelos).

Figure 6 – General view of Areias Altas archaeological site (Luz, 2020).

Although many are currently found along the coastline, and therefore remain under water at high tide, attesting to its antiquity, several are further away, but always near the coast. The age of these structures is not consensual. Almeida (2005) and Costa *et al.* (2012, 2019) consider that they date back to the Iron Age, either because of their spatial proximity to settlements from that period, or because of the other items found during excavation of the complex of Fornelos rock sinks (Costa *et al.*, 2019) [fig. 5] In this area, there are carved stone artefacts on rounded pebbles, known as peaks (in a secondary position); remnants of removable schist sinks (like the one that was found in the vicinity of the Late Chalcolithic / Early Bronze Age site of Carreço beach) and fishing net weights on rounded pebbles, dated from at least the early Bronze Age (Luz, 2020), to the Iron Age (Martins, 1988, among others), were found. A very small number of fragments of Roman ceramics were also found - a rim of an amphora and a tegula, materials that, by the type of salt pans known from this period (Curras, 2017), correspond to a *terminus ante quem* of the site. Due to their manufacturing conditions, these rock sinks can be dated back to the Bronze Age in this region, although they may have persisted or been reused during the Iron Age. It should also be noted that there are settlements, among many other traces of the Bronze Age, in the vicinity of these structures with which it is possible to establish interconnections, such as the settlement of Santo António in Afife.

1.3. The archaeological site of Areias Altas

Further archaeological evidence suggesting sea salt exploitation in the northwest coast of the Iberian Peninsula was found at Areias Altas, Nevogilde parish, municipality of Porto.

The site is located between 21 and 23 metres above sea level and about 300 metres from the coastline. Its discovery dates back to the early 1950s and was first explored by Russell Cortez (1952). New archaeological work was carried out between 2008 and 2011. The surveyed areas covered around 3 000 m² with more than 200 negative features identified, including a large number of pits and some post-holes (Luz, 2010, 2020). Different kinds of pits were found, mostly with a sub-circular layout and a spherical profile, a rounded or flattened base and on average were relatively wide and shallow. There was also a group of structures that seems to have had a composite layout, i.e. similar to an "8" shape, or an "8" with a small semicircle at one end, with the particular feature that each segment has distinct depths (Luz, 2020) and some post-holes (fig. 6).

A large amount of artefacts and other remains (ceramics, lithic elements, shells, charcoal) has been recovered from the filling of the pits. The majority consisted of ceramic fragments connected to a particular type of vessel, with conical or ovoid shapes, with a pedestal or widened base and rims

Figure 7 - Bases of probably ceramic moulds used for salt; some tronco-conical containers and cracked rounded pebbles broken by fire.

that look "unfinished". These were rather fragile and fragmented, which appear to be poorly fired and to have been exposed to thermal stress. Most of the internal surfaces were fairly eroded, however it was possible to notice a difference in treatment, with the external surfaces always quite rough, while the internal surfaces exhibit traces of smoothing and greater care, particularly evident in the rims and bottoms. Moreover, it should be noted that the rim fragments are very rare, while the base fragments are abundant and often complete (fig. 7).

The remaining ceramic assemblage mostly consists of vessels with flat-based bottoms, such as tronco-conical, sub-cylindrical and ovoid shapes, often with attached handles and plastic decorations (cordons and knobs), and also carinated bowls, which are the only type of fine ware. Overall, these characteristics correspond to the Bronze Age ceramic repertoire of Northwest Portugal (Luz, 2020).

The lithic assemblage (N = 1845) mainly consists of local raw materials, in particular quartzite (55 %), also including granite, quartz, schist and others (undetermined). It is important to note a significant macrolithic industry associated to rounded pebbles and flakes, largely comprised by fishing net weights, scrapers and knapped pebbles, mostly with a pointed outline, as well as an important industry using quartz, including some hammers, grinding stones and a polished stone tool. However the main characteristic of the sample is reflected in the significant amount of thermo-altered specimens (65 %), which may correspond to remains from hearths or combustion structures (Luz, 2020) [fig. 7].

The radiocarbon dating obtained for this site identifies human occupation between the 19th century and late 16th century BCE, i.e. the first half of the 2nd millennium BCE (Luz, 2010, 2020).

The archaeological evidence and the location of the site have made it possible to suggest that salt production occurred in Areias Altas alongside other activities, such as fishing and mollusc gathering (Luz, 2020). This hypothesis derives from the distinctive attributes of the predominant ceramic ware, the vessels with pedestal bases, in line with those of briquetage category (Gouletquer and Daire, 1994, apud Téran, 2011). It appears to be probable that they were used as moulds for salt production, considering their morphology, type of manufacture, signs of thermal stress and high fragmentation, since it would be necessary to break them to remove the salt cake in good condition.

Surprisingly, these vessels find more formal parallels (particularly the pedestal base) with the salt moulds documented in Central and Eastern Europe, such as those of the Bronze Age in Poland (Harding, 2013) and Chalcolithic (from mid-5th millennium to mid-4th millennium BCE) in Romania (Cassen and Weller, 2013; Sandu *et al.*, 2012; Weller, 2015), than the ones known in the Iberian Peninsula.

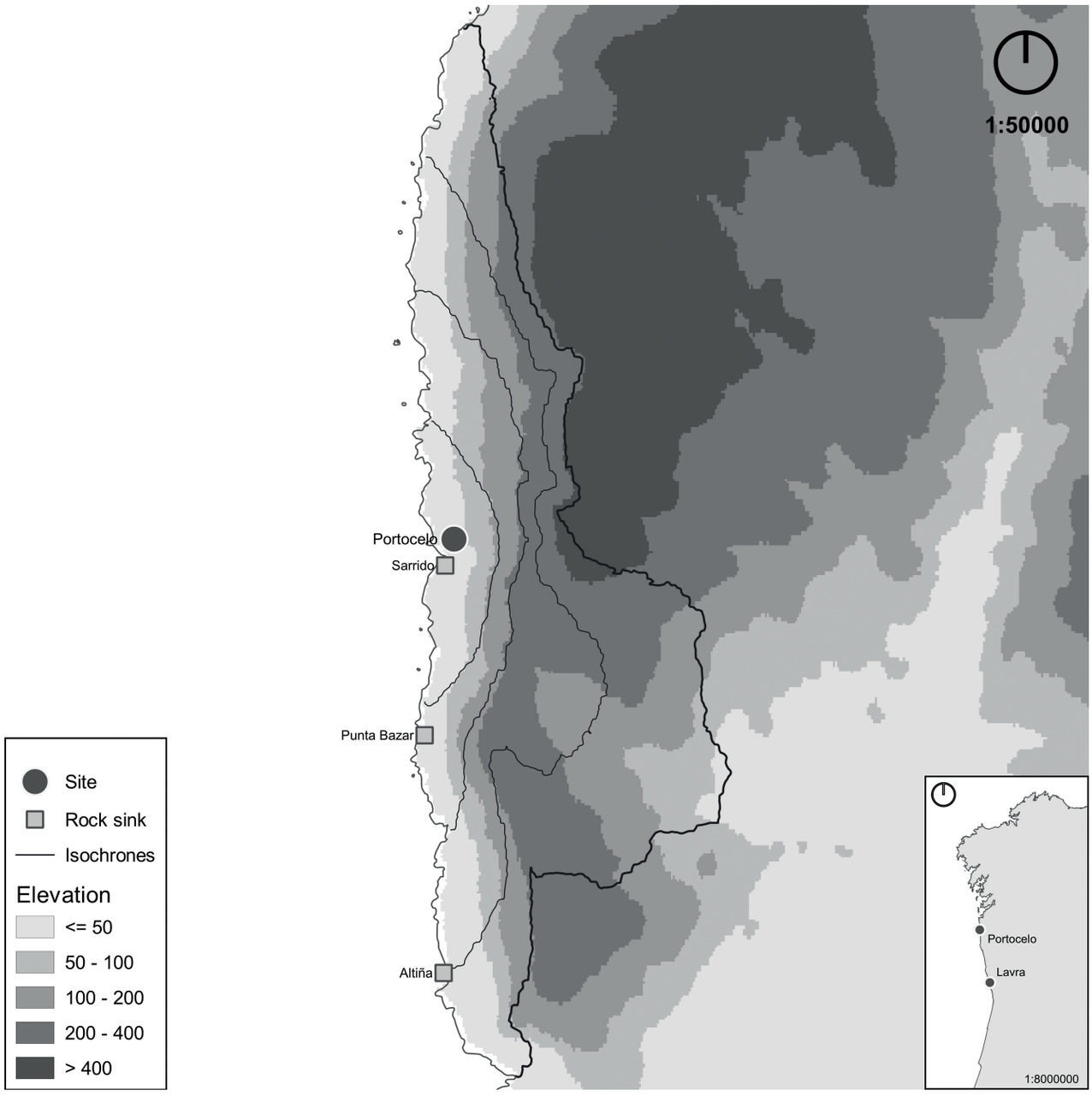


Figure 8 - Theoretical exploration territory of Portocelo settlement versus the rock sinks of Sarrido, Punta Bazar and Altiña (15-minute isochrones).

We refer, for example, to those documented in southern Portugal (Soares, 2013; Soares and Silva, 2013; Valera *et al.*, 2006; Valera, 2017), dating from the Mid-Final Neolithic/ Early Chalcolithic (first half of the 4th millennium to the mid-3rd millennium BCE), or the Zamora region in Spain (Abarquero *et al.*, 2010, 2017), from the Late Chalcolithic to the Early / Middle Bronze Age (from the mid-3rd millennium to the mid 2nd millennium BCE).

The strong evidence of combustion structures attested by the high number of thermo-altered rounded pebbles, also strengthens the possibility of salt production through artificial evaporation, although it is not clear that this process took place inside the pits.

2. Final considerations

In view of the above data, it may be assumed that sea salt exploration has taken place in the coastal area of Northwest Iberian Peninsula since at least the end of the Chalcolithic period, and remained active during the first half of the 2nd millennium BCE. It is also possible to admit that, since that time, salt was extracted through the use of removable sinks excavated in schist rocks (Bettencourt, 2009). Taking into account the context of the sink in the Carreço beach, placed on a paving composed of numerous thermoclasts, everything indicates that these structures, filled with salt water or great salinity from the coastal lagoons, would have favoured evaporation aided by the action

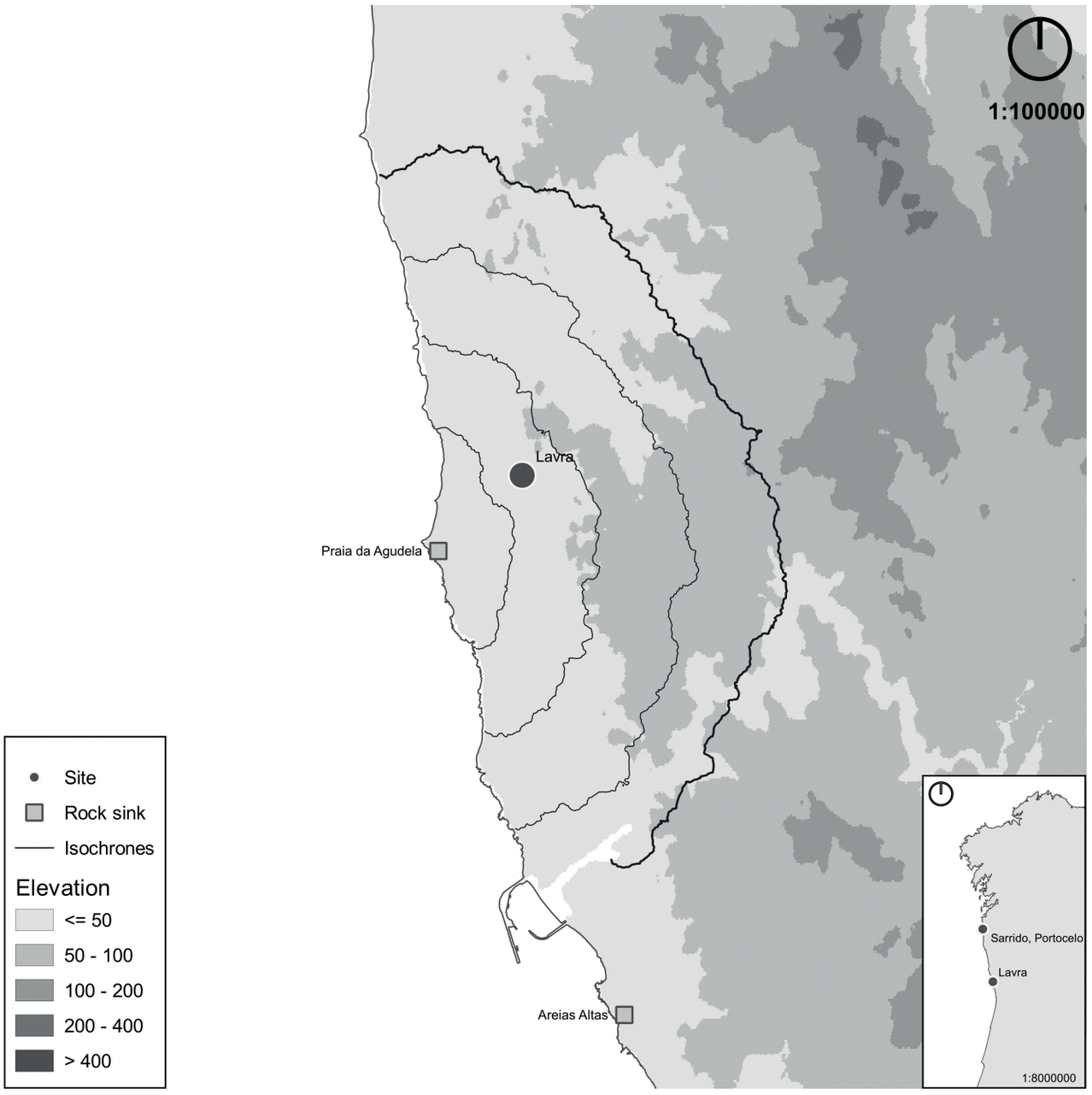


Figure 9 - Theoretical exploration territory of the Lavra settlement versus the rock sinks of Agudela beach (15 - minute isochrones).

of fire. It should be noted that during the end of the 3rd millennium and first half of the 2nd millennium BCE, communities lived in a colder period than today, although warmer than in the Chalcolithic (Fábregas Valcarce *et al.*, 2003; Martínez-Cortizas *et al.*, 2009) so the heating process of the schist sinks may have been one of the solutions found for the rapid evaporation of water and the success of this activity. However, the sharp decrease in humidity during that period (Fábregas Valcarce *et al.*, 2003; Martínez-Cortizas *et al.*, 2009) may also have been an important factor in the evaporation process of salt water. The fact that there are also removable sinks associated with manual granite hand mills currently under water in Robaleira beach (only observable at low tide in the spring and autumn equinox) also indicates the antiquity of this phenomenon.

From 1400 BCE until the beginning of the 1st millennium BCE there was progressive and significant global warming (Fábregas Valcarce *et al.*, 2003; Martínez-Cortizas *et al.*, 2009), which would have facilitated the production of salt by direct evaporation. These phenomena associated with the execution characteristics of rock sinks, the fact that many are on the current coastline and their formal similarity to removable sinks, suggest that this new technology emerged, almost during the Bronze Age. It is also important to note the concentration of settlements and other types of sites throughout the Bronze Age along the Northwest coast which, among other factors, may be related to this phenomenon, as has already been advocated for the region located between the rivers Neiva and Cávado (Bettencourt, 1999:

1078). Several examples exist in this respect. In the Spanish autonomous region of Galicia, the case of the coastal settlement of Portocelo, dating from the 15th century to the early 12th century BCE (CSIC-7444: 3050±50 BP) (Cano Pan and Vázquez Varela, 1988; Fábregas Valcarce and Ruiz-Gálvez Priego, 1997, 192), is worth noting. Based on the model of anisotropic displacement of 60 minutes according to the Tobler method, considering the slope as a friction surface (Tobler, 1993), the populations of this site would have access, in their theoretical exploration territory of 15, 30 and 45 minutes, to the core set of rock sinks of Sarrido, Punta Bazar and Altiña, respectively (fig. 8).

Another interesting case is that of the settlement of Lavra, dated between the late 17th century and late 15th century BCE (Beta-258086: 3230±40 BP; Beta-258087: 3220±40 BP) (Bettencourt and Fonseca, 2011), in whose likely area of exploration between 30 minutes the rock sinks of Agudela beach would have been accessible (fig. 9).

It can therefore be assumed that the process of evaporation of salt water through removable sinks or sinks cut into the rocks, as well as the production of salt cakes, may have been an important and specialised activity throughout the Bronze Age, destined to supply salt to the local populations and the interior. In fact, this is a simple and effective evaporation process that existed in Mediterranean Europe and others parts of the world, in many chronological periods (Cassen and Weller, 2013).

Acknowledgements

In the period of the Covid-19 pandemic and given the impossibility of leaving home and travelling to Galicia (Spain) this text has involved the collaboration of many friends whom we thank warmly: Cândido Verde, Glória Inês Vazquez Castro, Horácio Faria, José Varela, José Alvarez Alonso and Xulio Carballo Arceo.

This work has been developed within the framework of the project Funerary, ceremonial and other practices between the Neolithic and the Bronze Age approached by Archaeometry (ARQUEOM Project – Sept2014), conducted by A.M.S. Bettencourt, P.P. Simões and M.I.C. Alves and S Luz's Master's thesis project O sítio das Areias Altas, Porto, no contexto da Idade do Bronze do Norte de Portugal (The site of Areias Altas, Porto, in the context of the Bronze Age in Northern Portugal).

Ana M. S. Bettencourt

Landscapes, Heritage and Territory Laboratory (Lab2PT)
Departamento de História da Universidade do Minho
Braga, Portugal
anabett@uaum.uminho.pt

Sara Luz

Archaeologist

Pedro P. Simões

Landscapes, Heritage and Territory Laboratory (Lab2PT)
Instituto de Ciências da Terra, Polo da Universidade do Minho (ICT/UM; Departamento de Ciências da Terra da Universidade do Minho, Braga, Portugal

Maria Isabel C. Alves

Landscapes, Heritage and Territory Laboratory (Lab2PT)
Instituto de Ciências da Terra, Polo da Universidade do Minho (ICT/UM; Departamento de Ciências da Terra da Universidade do Minho, Braga, Portugal

Emílio Abad-Vidal

Fundación Centro de Supercomputación de Galicia (CESGA), Spain

Bibliography

Abarquero F. J., Guerra E., Delibes G., Palomino A. L. et Del Val J., 2010, « Excaviones en los "cocederos" de sal prehistóricos de Molino Sanchón II y Santioste (Villafáfila, Zamora) », dans Abarquero F. J. et Guerra E. (éd.), *Los yacimientos de Villafáfila (Zamora) en el marco de las explotaciones salineras de la prehistoria europea*, Valladolid, Junta de Castilla y Léon, p. 85-118.

Almeida C. A. B., 1990, *Proto-História e Romanização da Bacia Inferior do Lima*, Viana do Castelo.

Almeida C. A. B., 1998, *Esposende. Povoamento Romano do Litoral Minhoto entre o Cávado e o Minho*, Esposende.

Almeida C. A. B., 2005, « A exploração do sal na costa portuguesa a Norte do Rio Ave: da Antiguidade Clássica à Baixa Idade Média », dans Amorin I. (éd.), *Seminário Internacional sobre o Sal Português, 2004*, Porto, Universidade do Porto, Instituto de História Moderna, p. 139-170.

Alves A. M. C., Alves M. I. C., Pereira D. I., Gonçalves M. C., 2003, « Aluviões de Bertiandos (Ponte de Lima): estudo preliminar para a reconstituição ambiental holocénica no Entre-Douro-e-Minho », *Ciências da Terra (UNL)*, nº esp. V, CD-ROM, p. A1-A4.

Araújo M. A., 1999, « A zona costeira de Portugal », *Dossier do Curso de Formação Conceitos sobre Ordenamento e Gestão da Zona Costeira*, Porto, Associação Eurocoast-Portugal, Instituto de Hidráulica e Recursos Hídricos (IHRH), Faculdade de Engenharia da Universidade do Porto.

Baptista J. M., 1992, *As Indústrias Líticas Pré-Históricas do Litoral Minhoto. Contexto Cronoestratigráfico e Paleoambiental*, Cadernos de Arqueologia - Monografias, 7, Braga, Unidade de Arqueologia da Universidade do Minho.

Bettencourt A. M. S., 2009, « A Pré-História do Minho: do Neolítico à Idade do Bronze », dans Pereira P. (éd.), *Minho. Traços de Identidade. Braga*, Braga, Conselho Cultural da Universidade do Minho, p. 70-113.

Bettencourt A. M. S. et Fonseca J., 2011, *O Povoado da Idade do Bronze de Lavra, Matosinhos. Contributos para o Estudo do Bronze Médio do Litoral Norte*, Matosinhos, CITCEM/JFL.

Cano Pan J. et Vázquez Varela M., 1988, « Portocelo, un yacimiento de la Edad del Bronce », *Trabalhos de Antropologia e Etnologia*, 28, p. 181-187.

Carballo Arceo L. X., 1989, *Catálogo dos Materiais arqueolóxicos do Museu do Castro de Santa Tegra, Idade do Ferro*, Pontevedra, Diputación Provincial de Pontevedra.

Cassen S. et Weller O., 2013, « Idées et faits relatifs à la production de sels marins et terrestres en Europe, du VI^{e} au III^{e} millénaire », dans Soares J. (éd.), *Prehistory of wetlands. Ladscapes of salt*, Setúbal Arqueológica 14, Setúbal, MAEDS, p. 255-304.

Costa M., Machado J., Lopes H. et Almeida T., 2012, « Pias salineiras da praia do Canto Marinho. Inventário Arqueológico », *Cadernos Vianenses*, 46, p. 95-111.

Costa M., Almeida T. et Machado J., 2020, « A exploração de sal na Proto-História. O exemplo de Viana do Castelo », oral presentation in *Encontros monográficos co património Cultural in situ. A prudoción de sal en época romana no sur de Galicia e Norte de Portugal, A Guarda, March 29th, 2019* [www.youtube.com/watch?v=leDyyodn1AM in 1/4/2020].

Cortegoso Comesaña M., 2019, *As intervencións nas salinas de Oia e O Seixal, oral presentation in Encontros monográficos co património Cultural in situ. A prudoción de sal en época romana no sur de Galicia e Norte de Portugal, A Guarda, March 29th, 2019* [www.youtube.com/watch?v=leDyyodn1AM in 1/4/2020].

Currás B. X., 2019, *O proxecto Mar de Sal e o estudo das paisaxes do sal da Antigüidade, oral presentation in Encontros monográficos co património Cultural in situ. A prudoción de sal en época romana no sur de Galicia e Norte de Portugal, A Guarda, March 29th, 2019* [www.youtube.com/watch?v=leDyyodn1AM in 1/4/2020].

Dias J. M. A., Rodrigues A. et Magalhaes F., 1997, « Evolução da linha de costa em Portugal desde o último Máximo Glaciário até à actualidade: síntese dos conhecimentos », *Estudos do Quaternário*, 1, p. 53-66.

Fábregas Valcarce R. et Ruíz-Gálvez Priego M. L., 1997, « El Noroeste de la Península Ibérica en el III^{o} y II^{o} milénios AC: propuestas para una sínteses », *Sagvntvm*, 30, p. 191-216.

Fábregas Valcarce R., Martínez Cortizas A., Blanco Chao R. et Chesworth W., 2003, « Environmental change and social dynamics in the second-third millennium BC in NW Iberia », *Journal of Archaeological Science*, 30, p. 859-871.

Fernandes A. A., 1994, *Meadela Histórica*, Viana do Castelo, Paróquia de Santa Cristina da Meadela.

García y Bellido A., Fernández de Avilés A. et García Guinea M. A., 1970, *Excavaciones y exploraciones arqueológicas en Cantabria*, Madrid, Anejos Archivo Español de Arqueología IV.

Granja H., 1993, « Os conhecimentos actuais sobre o Holocénico do Noroeste de Portugal », dans Carvalho G. S., Ferreira A. B. et Senna-Martínez J. C. (éd.), *O Quaternário em Portugal. Balanço e Perspectivas*, Lisboa, Colibri, p. 43-49.

Granja H., Monteiro-Rodrigues S. et Danielsen R., 2016, « Changing environments and human settlement during Mid-Holocene in Rio de Moinhos beach (Esposende, Northern Portugal) », *Estudos do Quaternário*, 14, p. 25-40.

Granja H., Rocha F., Matias M., Moura R., Caldas F., Marques J. et Tareco H., 2010, « Lagoa da Apúlia: A residual lagoon from the Late Holocene (NW coastal zone of Portugal) », *Quaternary International*, 221, p. 46-57.

Gouletquer P. L. et Daire M. Y., 1994, « Le sel de la préhistoire et de la protohistoire », dans Daire M.-Y. (éd.), *Le Sel gaulois. Bouilleurs de sel et ateliers de briquetages armoricains à l'âge du Fer*, Saint-Malo, CNRS, p. 5-13.

Harding A., 2013, *Salt in Prehistoric Europe*, Leiden, Sidestone Press.

Lemos F. S., 1982, *O Sítio Arqueológico de Gelfa*. Notícia preliminary, *Cadernos de Arqueologia*, 2, 1^{o} série, p. 21-48.

Luz S., 2010, « O depósito de conchas do sítio arqueológico das Areias Altas (Porto, Portugal). Discussão do enquadramento arqueológico da Estrutura 15 », dans Gomez E. G., García V. B., Rodríguez C. F et Prieto N. F. (éd.), *I Reunión Científica de Arqueomalacología de la Península Ibérica*, Villalba, MPAV, Férvedes, 6, p. 141-145.

Luz S., 2020, « The site of Areias Altas (Porto, Portugal): current knowledge of its occupation in the first half of the 2nd millennium BC », dans Lopes S. S. et Gomes S. (éd.), *Between the 3rd and 2nd millennia BC: which turning points?*, Oxford, Archaeopress.

Marçal H., 1966, *As antigas salinas da Terra de Bouça*, Matosinhos, Biblioteca pública municipal de Matosinhos.

Marques J., 1981, *A Administração Municipal de Vila do Conde em 1446*, Porto, FLUP (Complementary PhD Thesis).

Martins M. M. R., 1988, *A citânia de S. Julião, Vila Verde. Memória dos trabalhos realizados entre 1981 e 1985*, Cadernos de Arqueologia, Monografias 2, Braga, universidade do Minho.

Martínez Cortizas A. Costa-Casais M., Lopez-Saez J. A., 2009, « Environmental change in NW Iberia between 7000 and 500 cal. BC. », *Quaternary International*, 200, p. 77-89.

Polónia A., 1999, *Vila do Conde, um Porto Nortenho na Expansão Ultramarina Quinhentista*, Porto, universidade do Porto (PhD Thesis).

Rau V., 1951, *A exploração e o comércio do sal de Setúbal*, Lisboa, éd. autor.

Sandu I., Weller O., Stumbea D. et Alexianu M., 2012, « Analyses archéométriques sur les moules à sel chalcolithiques de l'est de la Roumanie », dans Nikolov V. et Bacvarov K. (éd.), *Salt and gold: the role of salt in Prehistoric Europe*, Provadia, Verliko Tarnovo, p. 143-154.

Soares J., 2013, « Sal e conchas na Pré-história portuguesa. O povoado da Ponta da Passadeira (estuário do Tejo) », dans Soares J. (éd.), *Prehistory of wetlands. Ladscapes of salt*, Setúbal, MAEDS, Setúbal Arqueológica, 14, p. 171-196.

Soares J. et Silva C. T., 2013, « Economia agro-marítima na Pré-história do estuário do Sado. Novos dados sobre o Neolítico da Comporta », dans Soares J. (éd.), *Prehistory of wetlands. Ladscapes of salt*, Setúbal, MAEDS, Setúbal Arqueológica, 14, p. 145-170.

Terán J., 2011, « La producción de sal en la prehistoria de la Península Ibérica: estado de la cuestión », *Arqueología y Territorio*, 8, p. 71-84.

Tobler W., 1993, « Three presentations on geographical analysis and modeling. Non-isotropic geographic modeling. Speculations on the geometry of geography », *Global spatial analysis- Technical Report 93-1* [www.geodyssey.com/papers/tobler93.html].

Valera A. C., 2017, « Salt in the 4th and 3rd millennia BC in Portugal: specialization, distribution and consumption », *Cuaternario y Geomorfología*, 31, 1, 2, p. 105-122 [doi.org/10.17735/cyg.v31i1-2.53656].

Valera A. C., Tereso J. P. et Rebuge J., 2006, « O Monte da Quinta 2 (Benavente) e a produção no Neolítico Final / Calcolítico do estuário do Tejo », dans Bicho N. F. et Veríssimo H. (éd.), *Do Epipaleolítico ao Calcolítico na Península Ibérica. Actas do IV Congresso de Arqueologia Peninsular*, Faro, Universidade do Algarve, Promontoria Monográfica, 4, p. 201-305.

Weller O., 2015, « First salt making in Europe: an overview since Neolithic times », *Documenta Praehistorica*, 62, p. 185-196 [doi.org/10.4312/dp.42.12].