Shellfish Purple Production in Iberia and the Balearic Islands in the Pre-Roman Period: Archaeological Evidence in its Mediterranean Context

ENRIQUE GARCÍA VARGAS

Universidad de Sevilla. egarcia@us.es

Abstract:

This paper tries to synthesize the archaeological evidence known to date regarding the production of purple dye in Phoenician and Punic Iberia from the very beginning of the Phoenician colonization (ninth century BC) until the Roman arrival in the region (by the end of the third century BC). This paper begins with a technological (including purple mollusc fishing methods), biochemical and archaeographic synthesis about purple dye production techniques in antiquity, before focusing on th Iberian evidence. In order to facilitate the techno-cultural and geographical background of the Iberian evidence, this paper discusses the most significant evidence known until now for the pre-Roman Mediterranean purple dye production sites and their industrial facilities.

Key words: *Purple Dye, Protohistory,* Ars Purpuraria, *Archaeology of Production, Ancient Technology.*

Resumen:

Este trabajo pretende sintetizar las evidencias arqueológicas conocidas hasta hoy sobre la producción de purpura marina en la Iberia fenicia y púnica desde los mismos inicios de la colonización fenicia (s. IX a. C.) hasta la presencia romana en la región (fines del s. III a. C.). Con carácter previo a la presentación y estudio de la evidencia arqueológica se realiza un estudio tecnológico (incluyendo métodos de pesca de los moluscos purpurígenos), bioquímico y arqueográfico acerca de la tecnología de la producción de púrpura en la Antigüedad. Igualmente, para facilitar la contextualización tecno-cultural y geográfica de la evidencia ibérica se presentan y describen brevemente los principales establecimientos conocidos de fabricación de tinte púrpura en el Mediterráneo prerromano y sus instalaciones industriales.

Palabras clave: *Púrpura, Protohistoria,* Ars Purpuraria, *Arqueología de la Producción, Tecnología de la Antigüedad.*

INTRODUCTION

Shellfish purple is the oldest natural, colourfast dye known to humans. It is produced from the secretions of marine molluscs, which are subject to a process that turns these secretions into a water-soluble dye that can effectively and permanently colour textile fibres. The *chaîne opératoire* involves the following steps: capturing the molluscs; extracting their hypobranchial gland; generation of the dye through fermentation; and, reduction and dyeing of fabrics.

Archaeological evidence for the production of purple is scarce, apart from accumulations of shells which, if found broken in a certain way, may be an indication of dyeing. However, these shells were often reused for building or lime extraction (Alberti 2008), so their discovery can be used to argue for the presence of dye production somewhere near, but are not, strictly speaking, a direct evidence for purple production.

Recent years have seen the excavation of a number of purple-making facilities dated to the pre-Roman and Roman periods. This new evidence has revealed important information concerning the purple-making process. At the same time, biochemical research has also contributed to increasing our understanding of what was in fact a relatively simple process (Koren 2005). As such, we are now in a much better position to detect and interpret artisanal facilities, which would otherwise go unnoticed, despite the presence of shell middens.

This work presents archaeological evidence for the production of purple in the Iberian Peninsula and on Ibiza in the pre-Roman times. The period under consideration extends from the arrival of the Phoenicians, who were apparently responsible for bringing this technique to the West, to the effective Romanisation of Hispania, in the last quarter of the second century BC, during the Republican period. This evidence is presented within a predominantly Mediterranean setting (even if some of the evidence was found in Atlantic settings). Similar, and not necessarily well known, evidence from other Mediterranean regions is also presented. I do not aim to be exhaustive, but rather to select locations which best complement the Spanish evidence and which correspond well with the identification criteria outlined by Alberti (2008), Sussmann (2011) and MacDonald (2017).

Finally, the evidence is contextualised within the *chaîne opératoire* of purple dye (for purple dye productions infrastructures, see Macheboeuf 2008), starting from the capture of the molluscs and ending with the transformation of their secretions, which is now much better understood thanks to the application of biochemical research and experimental archaeology to past productive processes (Ruscillo 2005). The evidence is placed within a sequence of steps which, in my opinion, must be the key reference for the interpretation of evidence of purple-making in the Iberian Peninsula and the Balearics.

THE CAPTURE OF PURPLE MOLLUSCS

Different techniques can be used to capture purple molluscs, chiefly members of the *Muricidae* (*Bolinus brandaris, Hexaplex trunculus*) and *Rapaninae* (*Stramonita haemastoma*) families. *B. brandaris* and *H. trunculus* are adapted to sandy sea beds, while *S. haemastoma* thrives on rocky soils, which means that, while all species can be manually collected by divers, only *B. brandaris* and *H. trunculus* can be obtained by means of rakes and other trawling techniques. Purple molluscs, which are voracious predators, can also be attracted into fish traps by using other molluscs as bait.

Ancient sources mention the use of fish traps for capturing *Muricidae* (*cf*. García Vargas 2004), but recent experimental studies (Ruscillo 2005; Alfaro and Mylona 2014) suggest that this technique would not provide shellfish in sufficient numbers unless it was complemented with the manual collection by divers of specimens congregated around, but not inside, the trap. In fact, rather than a trap as such, the device was conceived as a 'meeting point.' For this reason, the technique did not involve the use of closed traps, but could be carried out with a combination of open devices to which bait was affixed and close monitoring by expert divers.

PURPLE DYE PRODUCTION: THE BIOCHEMICAL PROCESS

Purple is obtained from the molluscs but is not itself present in their hypobranchial glands (Clark *et al*. 1993: 196). Contrary to common belief, the gland does not secrete the dye, but rather releases *precursors*, a series of organic substances that, after being chemically reduced in anaerobic conditions, turn into purple. The main component of purple is 6,6'-dibromoindigo, but it also

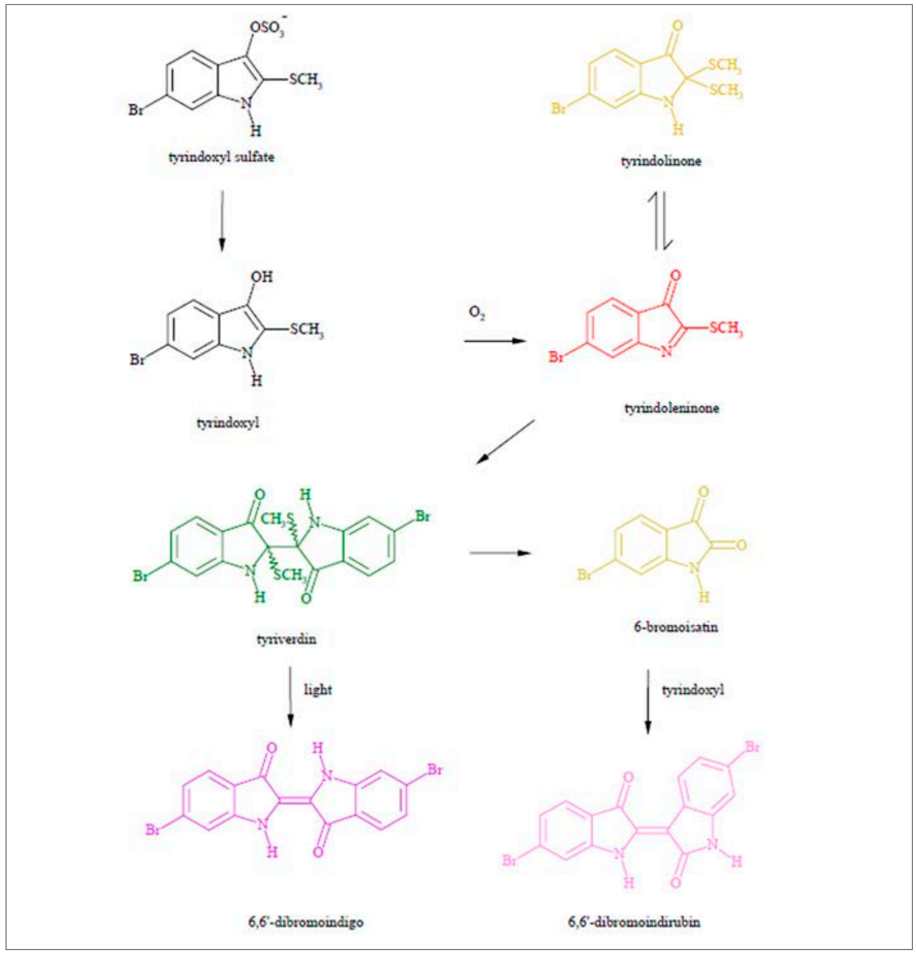

Fig. 1: The chemical process of shellfish purple dye (Cooksey 2001: fig. 11, reproduced with permission).

comprises other components such as 6-monobromoindigo, which is the main component in purple made from *H. trunculus* (*infra*).

Mollusc-based purple production is a 'lost craft'; that is to say, these processes have not been continued since Late Antiquity (Fernández Uriel 2010), thereby forcing us to enquire into the technical procedures and biochemical mechanisms (fig. 1) involved in purple production (*vide* recently Koren 2013 and Sukenik *et al*. 2017).

Regarding the latter, although some details are uncertain, chemical and archaeological experimentation have gone a long way to clarify the process by which the precursors secreted by the hypobranchial glands of the molluscs are synthesised into the dye.

The main precursor (fig. 2) in *Bolinus brandaris* is tyrindoxyl sulfate (Koren 2005), while *Hexaplex trunculus* contains four poorly defined precursors that result in blue (indoxyl sulphate) and purple compositions (Cooksey 2017). In the case of *B. brandaris*, for instance, the precursor reacts in the presence of certain enzymes such as purpurase, turning into tyrindoxyl which in turn dimerises into tyriverdin. The proteolysis of tyriverdin yields dibromoindigotin and dimethyl disulphide, which are responsible for the strong smell of the products.

The oxidation of tyriverdin (through exposure to air and light) leads to the formation of the molecule 6,6'-dibromoíndigo (DBI), the colour of which tends to be red. Non-dimerised indoxyls, that is, those which are not replaced in position 2 (Michel *et al*. 1992; Fernández Uriel 2010: 155) form indigotine (IND) and monobromoindigotin (MBI), which are the molecules responsible for bluish and purplish colours respectively (fig. 3). The presence of both IND and MBI is greater in *H. trunculus*, but they appear in different proportions within the same species. That is, some *H. trunculus* are richer in IND and

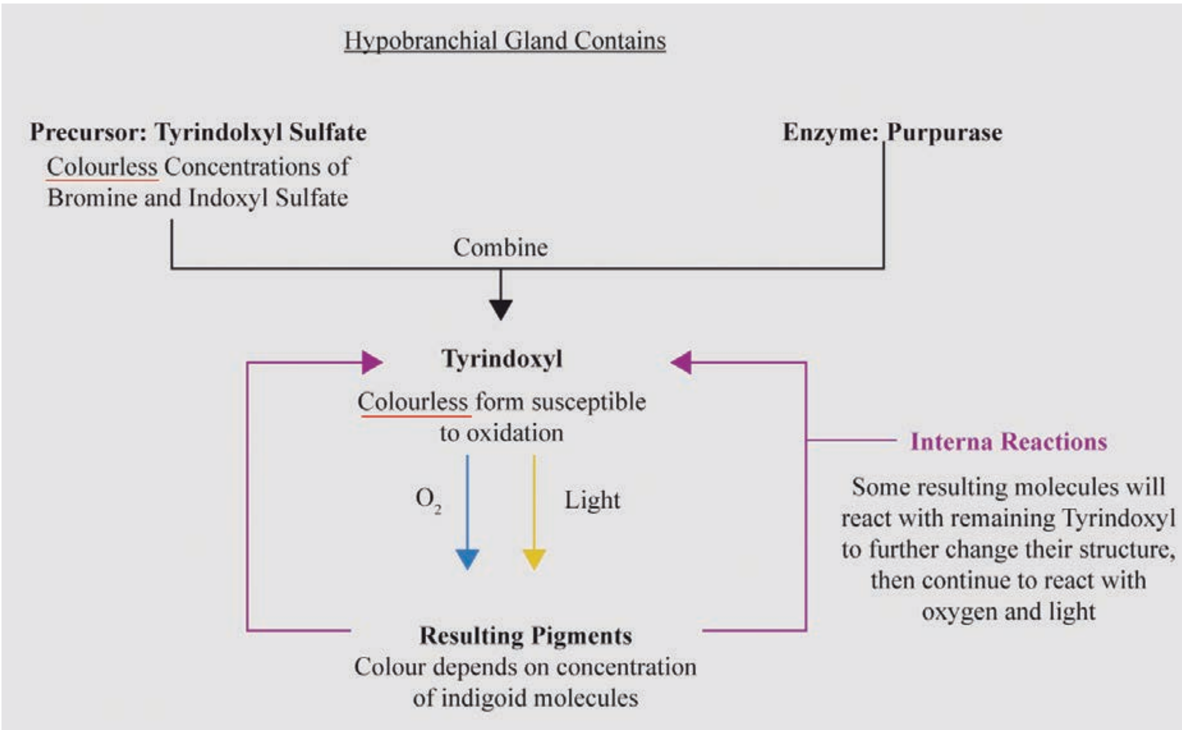

Fig. 2: Flow chart to demonstrate the chemical changes when the gland is punctured (MacDonald 2017: fig.9, reproduced with permission).

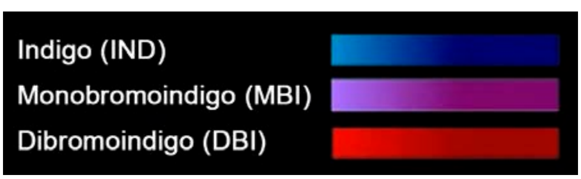

Fig. 3: Colour ranges (see online version) created from the different indigoids (MacDonald 2017: fig.10, reproduced with permission).

poorer in MBI, while for others the opposite is the case. IND is responsible for the blue colour and MBI for the purple colour (Koren 2008: 88). The proportion of MBI and IND in *H. trunculus* depends on a variety of factors: geographical provenance, age and sex of the animal, exposure to sunlight (males produce IND in dark conditions but females do not), the presence of contaminants and hygiene, etc.

'Natural' purple obtained by exposing the secretions to natural light, i. e., direct dying, can be used to dye fabrics, but this is only a superficial colour treatment, less intense and durable. In order to obtain a more penetrating dye the reaction must be controlled.

PURPLE DYE PRODUCTION: THE TECHNICAL PROCESS

The production of an intense and durable dye is a more complex process, chiefly known to us through an account by Pliny the Elder (*Naturalis Historia* 9.63). According to his description, the glands were kept in salt water for three days. Afterwards, they were heated in a lead container; the proportions of the solution were one hundred amphorae of water to five hundred pounds of glands, and the heat was moderate, constant and direct. Heating continued for seven days without interruption.

Pliny the Elder's 'recipe' is not entirely explicit and presents some translation problems, not only with regard to the proportions but also to other important technical details, such as the use of a *plumbum* container, which could refer to lead or tin (*plumbum nigrum* and *plumbum album*, respectively), and the apparent contradiction between the use of the verb *fervere* (to boil) and the need, verified experimentally, to keep temperature below 50ºC in order to obtain a bright colour (Koren 2008; MacDonald

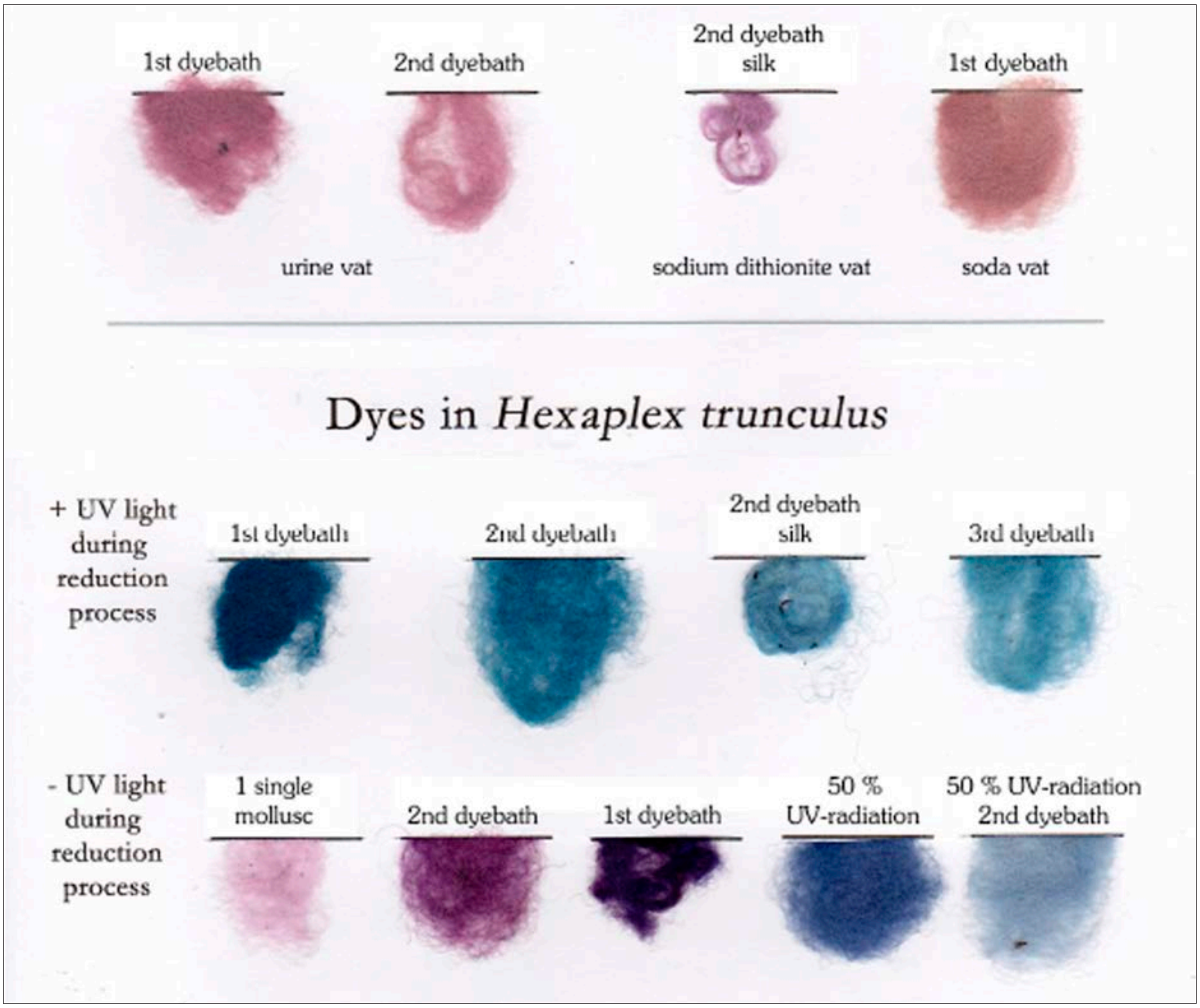

Fig. 4: Colour samples (see online version) on wool and silk from the experimental series with purple snails *Bolinus brandaris*' and *Hexaplex trunculus*' made by F. Meiers (2013: fig. 9, reproduced with permission).

2017: 27). Furthermore, some instructions are completely lacking, such as whether the water should be brine or not, and whether any other ingredients are to be added to the mixture.

The latter issue is crucial, because the heating of the glands, previously soaked in salt water for three days, takes place in this heated solution, as Pliny clarifies. The three-day soaking period produces the necessary bacteria concentration to reduce the precursor in anaerobic conditions. The reduction prevents the immediate formation of the colouring agents, DBI, MBI and IND, which are reactivated later by exposing the compound to sunlight. Reduction to a leuco base (a colourless compound resulting from the reduction of a colourant, which can be turned back into a dye through oxidation), however, does not suffice to guarantee the quality of the dye, which must not only be durable, but also soluble in water to allow for the impregnation of the fabric.

Solubility of the leuco base depends on the environment in which the dye is reduced at constant heat. The solution must be liquid and alkaline, with pH remaining below 9 (Koren 2005: 140-141). The heat must remain constant between 40-45ºC. Pliny the Elder's use of the word *fervere* must be understood in this sense, but no mention of the alkaline environment is made in either the description in *Naturalis Historia* or similar 'recipes', such as that mentioned in the Talmud (Koren 2013). The use of salt water, for instance sea water, may be enough to keep a low pH (Koren 2013: 58; but see *contra* MacGovern and Mitchell 1990: 155; Macheboeuf 2007 for salted *murex* as food). In recent experiments, various alkaline substances have been tried, such as urine, natron, potash (calcium carbonate), wood ash and lime (Koren 2005: 145). Each of these generates a different reaction and, therefore, a different colour. The use of different containers can also have an effect on colour (Meiers 2013).

Over the last two decades, significant progress has been made concerning the origin of shellfish-based dyes in the Mediterranean and in the determination of archaeological markers that suggest the presence of a purple dye workshop.

Concerning the origins of the industry, evidence suggests that some of the earliest production centres were located in the Aegean, specifically on Crete. The production sites at Kouphonisi, Karoumes, Palaikastro, Chrysi and maybe Kommos are dated to the early second millennium (Middle Minoan, *ca*. 18th-17th centuries BC) (Alberti 2008: 76; Apostolakou *et al*. 2016). In nearly all of these sites, murex middens are associated with a variety of structures, so they can be included in Alberti's group A[1]. Other Middle Bronze Age Aegean contexts, in which evidence for purple production has been found, are possibly at Kastri on Kythera in Greece, and at Tavşan Adaçi and Troy on the Turkish coast (Kremer 2017).

ORIGINS OF THE PURPLE-DYE INDUSTRY IN THE AEGEAN AND THE LEVANT

Tracing the origins of purple production on the Levantine coast, which was believed to be the region where this activity first emerged until the Cretan evidence was discovered, is trickier. The earliest evidence may be that of Minat-el-Beida, the harbour of Ras-Shamra in Syria, where shell middens have been found in association with various structures and ceramic containers stained with

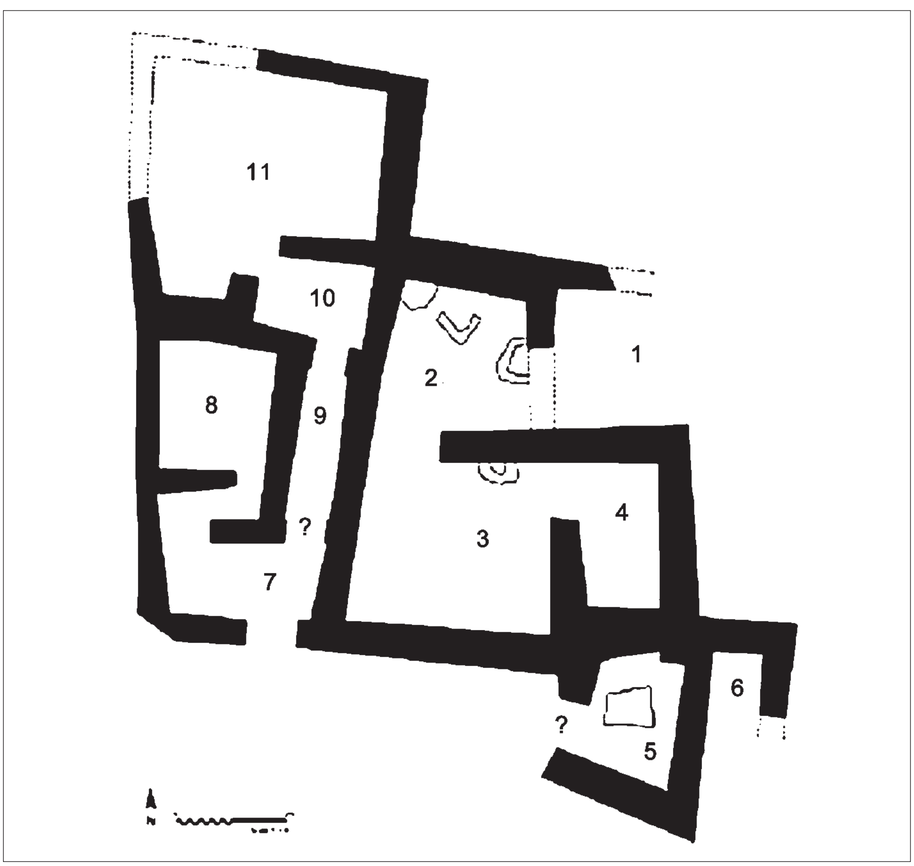

Fig. 5: Chryssi. Site plan of Building B1 (Apostolakou *et al*. 2016: fig. 5, reproduced with permission).

purple dye (Kalaitzaki *et al*. 2017). These finds include the site in Alberti's category A (*supra*). The evidence found in Sarepta (previously dated to the 13th century BC) has been recently argued to be coetaneous to that in Ras-Shamra; in this case, the evidence comprises shell middens (chiefly of *H. trunculus*) and fragments of stained pottery vessels, which themselves may be securely dated to the 13th century BC (Reese 2010). The 13th century BC is also the date assigned to the stained pottery fragments at Tel Akko in Israel, where all three mollusc species have been documented.

At Tell Abu Hawam, also in Israel, which is roughly coetaneous with Tel Akko, a large quantity of shell remains has been found, which suggests the presence of a workshop – Alberti's B group – while Tyre and Sidon have yielded similar evidence, including both *B. brandaris* and *H. trunculus*, with dates that cannot be earlier than the second half of the third millennium BC and which continue into the Roman imperial period and beyond (Kalaitzaki *et al*. 2017).

For obvious historical and cultural reasons, the earliest evidence of purple production in the Phoenician colonies in the Central and Western Mediterranean – in sites such as Motya, Carthage, Ibiza and Cadiz – is linked to the Levantine production centres, although some Central Mediterranean workshops appear to have a connection with the Mycenaean world, for instance Coppa Nevigata in Italy (Cazzella *et al*. 2004; 2012).

PRODUCTION TECHNOLOGY: ARCHAEOLOGICAL MARKERS

Wherever direct archaeological evidence of purple extraction has been found (i.e. beyond mere coastal shell middens), the remains attests to an invariably simple technology. The infrastructure of purple production generally includes pits and hearths located in the vicinity of heaps of intentionally broken shells and purple-stained ceramic fragments. However, it is rare to find all these features in the same location.

The simplest productive model is illustrated by the remains found on the island of Chryssi, off the coast of Crete, one of the earliest known workshops, dated to the 18th–17th centuries BC (Apostolakou *et al*. 2016). This site, which is well-preserved and has been extensively excavated, provides a good account of the spatial organisation of purple production and of the structures involved in the activity. The fact that the site does not appear to have been used also for dyeing fabrics (an activity which was carried out in Pefka, on the coast opposite Chryssi: Apostolakou 2008; Apostolakou *et al*. 2016) suggests an activity mostly related to dye extraction (Apostolakou *et al*. 2016).

Fig. 6: Chryssi. The hearths of the Building B1 (room 3: Apostolakou *et al*. 2016: fig. 6A, reproduced with permission).

Building B1 at Chryssi (fig. 5) is divided into 11 rooms, the central four of which (rooms 1-4, of which Room 3 is in all likelihood a courtyard) seem to have been exclusively dedicated to the manufacture of purple dye, while the surrounding rooms appear to have had residential and other uses.

Room 3 was covered in vegetal ash (almond and olive tree), while Rooms 2 and 3 were furnished with stone slabs, mills and stone hammers used to crush the shells. The excavation of Room 3 also yielded two hearths and the *in situ* remains of ceramic containers used to heat the dye (along with the leuco base), as well as stone hammers, a triton shell, and jars and cups, which could have been used to add liquid (basic solution) to the ingredients and, eventually, to scoop out the finished dye (fig. 6).

The excavators suggest a *chaîne opératoire* that began with the crushing of the shells in Room 2 and ended with the heating of the purple dye in Room 3, where most of the evidence for combustion is found, although the excavation of the room also yielded stone hammers (Apostolakou *et al*. 2016: 203).

Although Chryssi was exclusively dedicated to producing dye, the processing of shellfish and dyeing of fabric could also be done in the same place.

Fig. 7: Horbat Shim'on. Plant of phase 1 (Dagan and Cassuto 2016: fig. 4A, reproduced with permission).

Fig. 8: Tell Dor. The southern pit looking west (Nitschke *et al*. 2011: fig. 7, reproduced with permission).

A similar case is presented by the Minoan site (MM II) of Pefka on Crete, which, despite having been recently interpreted as a fabric-dyeing establishment (Apostolakau *et al*. 2016), also seems to contain evidence for the production of dyes. This included not only *H. trunculus*-based purple, but also plant-based dyes, such as those obtained out of weld (*Reseda luteola*) and madder (*Rubia* sp.). The site has also yielded traces of lanolin, interpreted as evidence of the washing of wool (Koh *et al*. 2016).

The site of Horbat Shim'on in Israel (fig. 7), dated to the eighth century BC, has yielded evidence of the entire process being carried out in one complex, the dyeing of the fabric occurring in a separate room (Room C), which contained mortars, pestles, stone hammers and stone containers (Dogan and Cassuto 2016).

Other Mediterranean sites, such as Tel Dor and Tel Mor, in Israel, present similar facilities dated to the Iron Age (Kalaitzal *et al*. 2017), although the remains are not as well contextualised and characterised as in the previous examples.

At least two, chronologically distinct, areas in the industrial quarters of Tel Dor have been related to purple dye production (Stern and Sharon 1986; Nitschke *et al*. 2011):

- Area G includes a shell-filled pit found in association with ceramic containers and fragments of calcite, one of the ingredients potentially used in the production of the leuco base (*supra*), which is a likely indication of dye extraction. These structures, originally detected in 1986 (Stern and Sharon 1987) have not been excavated, or at least no publication yet exists following their discovery.

- Area D1, later relabelled as Area D-5, was also detected in 1986, and has been excavated and published in some detail (Nitschke *et al*. 2011). The area includes at

Fig. 9: Tell Shikmona. Crushed shells (Sukenik *et al*. 2017: fig. 1, reproduced with permission).

least two circular pits, approximately 0.90 m in diameter and *ca*. 1 m deep, linked by a mortar-lined channel, inside which remains of calcite were found (Koren 2013: 57). The southern pit (fig. 8) was full of *H. trunculus* shells, and was attached to a small receptacle demarcated by clay slabs, which has been interpreted as the support for an anvil on which the shells were crushed. The pit, which is nearly 1 m deep, has been interpreted as a shell dump, but it is possible that the fill was deposited after the pit was no longer in use. Both the channel that links the pits and the fragments of calcite found within it are stained with purple, and it is therefore possible that the channel was a sort of drain that fed excess leuco base from the southern pit to the other one, where it was collected to be either reused or discarded, for neither pit is lined with hydraulic mortar (Nitschke *et al*. 2011). These structures are dated to the third century BC.

Other than these sites, the evidence for purple extraction in the Eastern Mediterranean is very sporadic. The presence of shells crushed in a regular manner, in association with purple-stained ceramic fragments, is generally admitted as solid evidence for purple extraction fairly close by. This is the case with Tel Shiqmona in Israel (Iron Age II), for example, where heaps of broken shells (80% *B. brandaris*; 11% *H. trunculus*; and 9% S. *haemastoma*) were found in connection with rim and neck fragments of purple-stained ceramic containers (fig. 9; Sukenik *et al*. 2017). Gas chromatography tests performed on these ceramic fragments have revealed a high content of BMI and IND, and a low content of DBI, which agrees with the important proportion of *H. trunculus* in the middens.

Fig. 10: Tell Kabri. Interior of a purple-stained potsherd, part of the upper mouth of a dye vat, dated in the seventh century BC (Koren 2013: fig. 5, reproduced with permission).

Tel Kabri in Israel has yielded similar evidence from the seventh century BC, especially concerning ceramic containers with purple staining on the inside and burn marks on the outside (fig. 10; Koren 2013). The interior marks are located on the upper neck, which indicates that this was the only area exposed to sunlight during the production of the purple, presumably because the lid had to be occasionally removed for stirring the liquid during heating (Koren 2013: 52).

In summary, it appears that much progress has recently been made in the characterisation of purple workshops during the Middle-Late Bronze Age and the Early Iron Age in the Aegean and the Levant, although, paradoxically, more is known about the earliest periods than about later ones (Carannante 2014: 274).

Fig. 11: Teatro Cómico (Cádiz). Kiln structure filled with *H. trunculus* shells (Image courtesy of José Mª Gener).

Fig. 12: Teatro Cómico (Cádiz). Kiln structure filled with *H. trunculus* shells, detail (Image courtesy of José Mª Gener).

The information provided by archaeometry and biochemistry matches the rather scant evidence yielded by the few known workshops. Although this evidence is rarely as eloquent concerning the *chaîne opératoire* as could be wished, it may be said that the process undertaken in order to extract the dyes is now fairly well understood.

PRODUCTION AREAS IN THE WESTERN PHOENICIAN COLONIES AND THE ORIGINS OF PURPLE EXTRACTION IN THE IBERIAN PENINSULA

Evidence for shellfish-based dye production in the west has only started emerging in recent years. This evidence is generally partial and fragmentary, but in some cases it is remarkably early.

The earliest known shell middens in the region were found on the Atlantic coast of the Iberian Peninsula, and are dated to the earliest Phoenician colonisation of the west, a phenomenon that is currently dated to the ninth century BC. Evidence of remains of murex shells crushed in the way consistent with purple dye production have thus far been limited to Phoenician colonial sites, and it is therefore not implausible that the *ars purpuraria* was directly imported from the cities on the Phoenician coast.

The report concerning the presence of possible middens in Huelva's 'pre-colonial' Phoenician levels (Calle Mendez Núñez 11-13 / Plaza de las Monjas 12) is umbiguous (González de Canales *et al*. 2009: 11). These deposits, dated to between 930 and 830 BC, seem to have contained *B. brandaris* and *H. trunculus* (González de Canales *et al*. 2009: 16), but their use for purple production is merely speculative; the report does not clarify whether the shells had been treated in some way or whether they were found forming substantial heaps.

Several Phoenician colonies on the Iberian Mediterranean coast, such as Baria (Villaricos) and Abdera (Cerro de Montecristo, Adra) present a similar case (García Vargas 2004). The identification of purple production at these sites is generally little more than optimistic speculation based on the presence of whole or fractured murex shells, which in itself is insufficient to infer purple production in the vicinity of where they were found.

Similarly, Room XX in Sa Caleta, on Ibiza, has been interpreted as a purple production area, but the number of murex shells is so small (three specimens of *S. haemastoma*; Ramón Torres 2004: 167) that this cannot but be substantiated. The rest of the site has yielded dispersed murex remains found in association with other species which are unrelated to purple production, such as *Patella* sp. and *Monodonta turbinata*, which suggests that all these species were used as food. Although the report for the 1994 excavations (Ramón Torres 2004: 168) has pointed out a substantial number of, sometimes fractured, specimens of *H. trunculus* and *S. haemastoma* in the Phoenician contexts

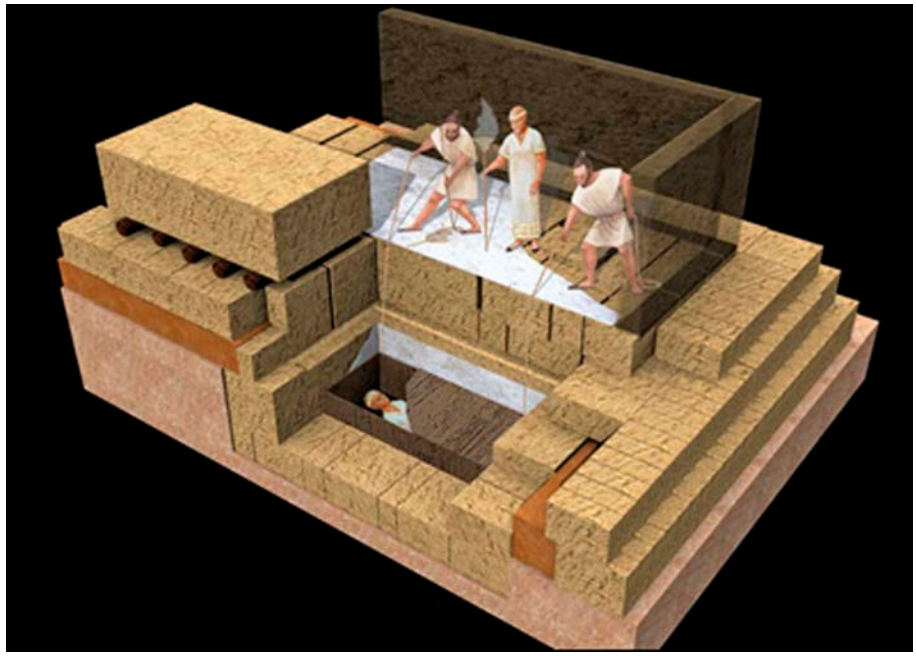

Fig. 13: Reconstruction of the monumental tomb of Casa del Obispo, Cádiz (Image courtesy of José Mª Gener).

of Room XVI, purple-related species amount to a small proportion of all the marine shells in the record; as such, while 97% of marine shell specimens have been identified as *Patella* and *M. turbinata*, *S. haemastoma* represents under half of the remaining 3% (Ramón Torres 2007).

In the Phoenician colony of Cerro del Villar, large quantities of murex were found in association with sixth century BC industrial remains (Aubet Semler 1989: 75), and also in connection with other rooms containing fishing equipment; this, however, does not mean that the molluscs were necessarily being accumulated for the purpose of extracting purple. The report does not clarify if the shells had been broken, but it is to be expected that, had they been, the report would at least mention it.

The contexts at the site of Teatro Cómico in Cadiz present, on the other hand, a different case (Gener *et al.* 2012; see also Estaca *et al.* in this volume). There, a substantial quantity of *H. trunculus* was documented in relation to a kiln, dated to the late ninth century BC and also filled with murex shells (figs. 11-12). The structure is elliptical in shape and 1.60 m long; it was securely dated to phase I (820-800 BC) and was outlined by a course of local shellstone bound together with clay. Inside the structure, a succession of three layers could be distinguished:

- A base of shellstone;

- A very compact layer formed of clay and pulverised *H. trunculus* shells;

- A top layer of red clay, which had clearly been exposed to fire.

Approximately 13.5 m to the south of this structure a sequence of three hearths was identified. The excavators interpreted this structure as a purple-making workshop. The presence of wheel-thrown pottery suggests that the complex must be dated to the colonial period.

The burnt remains correspond to the area where glands were heated after being removed from the broken shells. The shells of *H. trunculus* seem to have been discarded near this structure, as though the whole *chaîne opératoire* took place around this very early structure in Teatro Cómico.

The use of purple as luxury dye is documented in Cadiz in a monumental tomb constructed in local shellstone, dated to the sixth century BC and recently excavated at Casa del Obispo (fig. 13). The analysis of sediment carried out by Salvador Domíguez Bella *et al.* (2011) has demonstrated the presence of purple dye and gold traces in the sediment from the interior of the tomb (that was robbed in Roman times); these traces were interpreted as textile remains.

No secure evidence – according to Alberti's criteria (2008: 75-76) – exists for purple production in the Iberian Peninsula in the first half of the first millennium BC other than the production facilities found in Teatro Cómico in Cadiz. Even these remains are lacking a secure structural

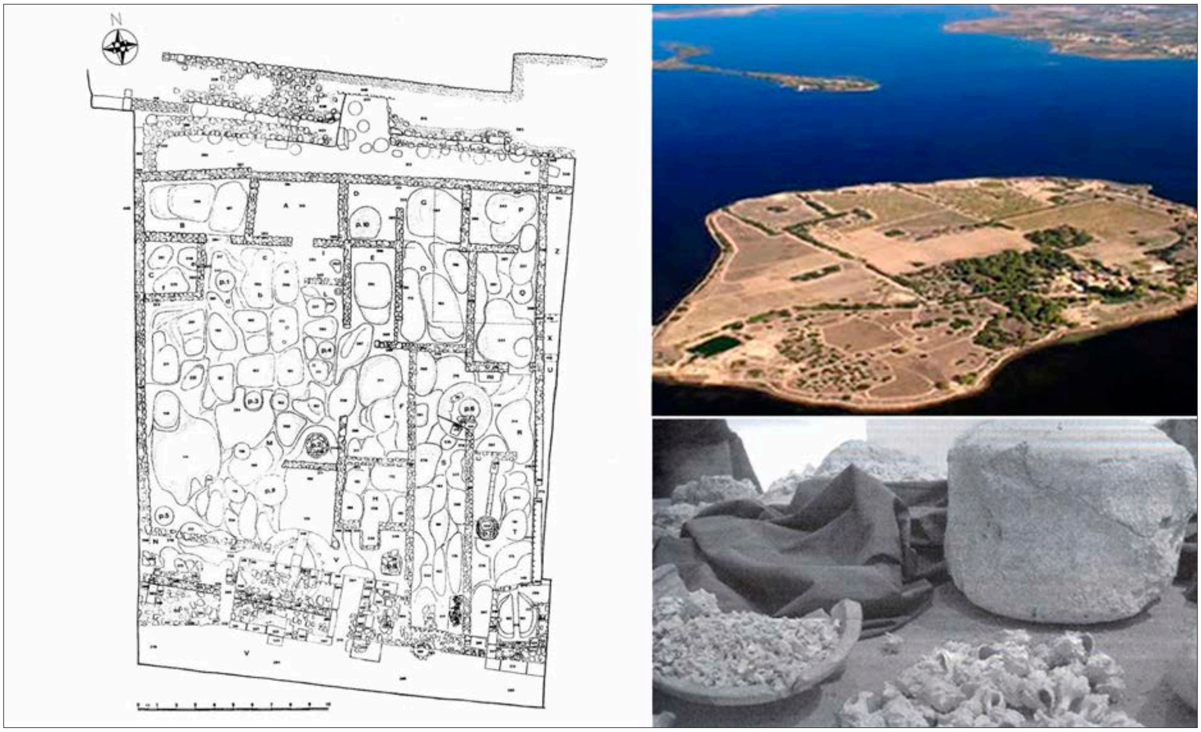

Fig. 14: Motya structures and items. Left: industrial area also known as "Luogo di Arsione". Right up: panoramic view of Mozia island. Right down: crushed shellfishes and an anvil made with a whale vertebra (Tusa 1973).

context, largely owing to the presence of later Phoenician structures on top of them, which has prevented archaeologists from excavating the older levels more extensively.

Other potential production sites, such as Huelva, Ibiza, Adra or Cerro del Villar are merely hypothetical, although the association of purple heaps with fishing-related structures and tools makes Cerro del Villar a relatively strong candidate.

PURPLE IN GREEK AND PUNIC CENTRAL MEDITERRANEAN AND AEGEAN CITIES: THE ARCHAEOLOGICAL EVIDENCE

Archaeological evidence for purple production in the Western and Central Mediterranean in the Punic period (fifth-third century BC) is somewhat more substantial than for earlier historical phases. In the so-called Luogo di Arsione, in Motya off the west coast of Sicily, a complex of approximately 20 ditches cut in the calcareous ground was found to be related to a series of rooms built in stone and sun-dried brick (fig. 14, B-C). Initially, the complex was interpreted as a cremation site related to human sacrifices, the ashes being deposited afterwards in the *Tophet* (Tusa 1972).

Archaemetric work carried out by Ninina Cuomo di Caprio (1981) detected the presence of purple and traces of high temperature inside one of the pits (sample 24). This was linked to *H. trunculus* shell remains in Pit E (Tusa 1973: 19, 39, 40, 47, pls. XIII, XIV; Cuomo di Caprio 1981: 9-10, 13) and elsewhere – frequently beneath the walls (Reese 2005: 110). In Pit E, the *H. trunculus* shells were found in association with four whale vertebrae (*Physeter macrocephalus*), which were interpreted by Reese (2005: 111) as anvils on which the associated specimens of *H. trunculus* were broken (approximately 75-80 individuals), which is plausible given the discovery of stone hammers in the same context (fig 14, A; Reese 2005: 110).

In Euesperides, later known as Berenice or Sidi Khrebish, in Libya, excavations have revealed a purple production area dated to the first half of the third century BC. The workshop could be identified through the presence of heaps of broken *H. trunculus* shells and hearths in the peristyle of a residential structure adapted to house industrial activities (Wilson *et al*. 2004; Wilson and Tébar 2008). At least two phases, separated by a hiatus, have been identified; both phases present similar features: hearths upon heaps of clay and shell middens, all of which was found covered in ash (Wilson *et al*. 2004: 167). Further accumulations of shells were found nearby, potentially suggesting the presence of other workshops in the vicinity.

In the district of Le Kram in Carthage, Tunisia, the discovery of cisterns, tubs, channels and broken murex shells suggests the presence of a purple workshop in the fourth-third centuries BC in association with a third century BC fullonica (Ben Abdallah *et al*. 1980: 17-18; Annabi 1981: 26-27). These structures were overlaid by houses in the early second century BC.

Excavations on the east coast of Delos in Greece resulted in the discovery of a complex five-room building (although it is not certain that all the rooms correspond to the same complex), within which murex shells were found in association with a hearth; also found were granite hammers and two large rectangular granite tubs, which have been related to the maceration and fermentation of the glands (Brunneau 1969; Monaghan 2001: 164). More shell heaps were found to the north of this facility, which is dated to the early first century BC (Brunneau 1978; Monaghan 2001: 165).

PURPLE AND PUNICS IN IBERIA AND THE BALEARICS ACCORDING TO THE ARCHAEOLOGICAL RECORD

In the Iberian Peninsula, archaeological evidence for shellfish purple production dated to the second half of the first millennium BC is even less explicit than in the first half of the first millennium BC, at least as far as production structures are concerned, although the indirect evidence – essentially shell middens – seems to suggest larger workshops and growing production.

The most substantial site is Calle Luis Milena, in San Fernando (Cadiz), located in the south-central area of the Island of San Fernando. This area is currently densely urbanised, and has often yielded decontextualised archaeological remains. Recent quarrying works have led to the discovery of a tub and a pavement in *opus signinum*, found in association with various walls and very large shell middens (which can be up to 12 m long). Unfortunately, the remains were largely obliterated by recent

Fig. 15: Late Punic pit filled with shells and fish remains excavated at Luis Milena st. (San Fernando, Cádiz) in 2007 (Image courtesy of D. Bernal and A. Sáez).

construction work. A survey carried out in order to map archaeological sites of San Fernando (Bernal *et al*. 2005) documented further heaps of intentionally broken shells, associated with the previously mentioned evidence and Late Punic (T-8.2.1.1, T-12.1.1.1/2 and T-9.1.1.1) and Roman Republican amphorae (imitation of Greco-Italic types, LC 67), as well as Italian black glaze wares and Kouass-type red glaze wares from Cadiz, which suggest a date between the second and first centuries BC. The rescue excavation carried out in 2005 in the southern sector of the site revealed the presence of two tubs of Punic type (for all of this evidence, see Bernal *et al*. 2011: 160-161).

A new excavation in 2007 (Bernal *et al*. 2011: 161), occasioned by the construction of new houses in Calle Luis Milena, led to the discovery of an important accumulation of shells, found in association with ceramic remains (fig. 15). The trench was no more than 2 m^2 in size, but it allowed for the collection of 585 kg of marine faunal remains, along with other animal remains and sediment. These remains filled a pit which may have been oval in shape (the small size of the excavation trench precludes greater certainty) and approximately 9 x 4 m in size. This type of pit is common at Late Punic sites in Cadiz, especially in association with pottery workshops, as former clay quarries were reused to dispose of general rubbish or the halieutic waste generated by preserve- and salting factories. On average, the pit was approximately 1 m deep, but in some areas reached 1.2 m.

The total capacity of the pit would therefore have been approximately 60 m^3, 5% of which was taken as a sample. The sample contained 4261 mollusc specimens, suggesting approximately 85,220 specimens for the whole

	N UE 100	N UE 101	N UE 103	D UE 101	D UE 103	D TOTAL
H. trunculus	0	1377	1057	58.25	55.84	57.18
T. aemastoma	2	689	586	29.15	30.96	29.95
B. brandaris	2	58	57	2.45	3.01	2.70
M. Lineata		176	150	7.45	7.92	7.66
N reticulatus		13	16	0.55	0.85	0.68
O. erinacea			3	0.00	0.16	0.07
T. decussatus		13	8	0.55	0.42	0.49
G. Glycymeris		2	0	0.08	0.00	0.05
C. Angulata		4	0	0.17	0.00	0.09
S. Marginatus		29	13	1.23	0.69	0.99
A. Ephippium		3	3	0.13	0.16	0.14

Fig. 16: MNI of mollusc's species of the sample analysed from Calle Luis Milena in San Fernando, Cádiz (Bernal Casasola *et al*. 2011: fig. 20).

pit (Bernal *et al*. 2011: 165). The shells were found in association with diverse ceramic material, especially Late Punic amphorae (T-12.1.1.1/2, T-9.1.1.0 and T-8.2.1.1), Kouass-type table wares, and common and kitchen wares, some of which were subject to residue analysis. These analyses did not detect remains of purple dye, but instead traces of honey and resins.

The pit also contained metal remains of fishing tackle, such as net weights, as well as construction debris and remains of construction materials, including blocks of *signinum*, which were presumably dumped in the pit after the demolition of a nearby building.

The sample contained a high proportion of broken *H. trunculus* and *S. haemastoma*, as well as whole specimens of *B. brandaris*, which suggests that the latter species was not used for dye extraction at Luis Milena. The distribution of marine molluscs by species in the sample is as follows: together, *H. trunculus*, *S. haemastoma* and *B. brandaris* amount to 89.83% of the total (57.18% of which corresponds to *H. trunculus*). The only non-purple-bearing species which is well represented is *Monodonta lineata*, the shells of which are often perforated, which is interpreted as the result of the depredations by the murex molluscs. It is, therefore, likely that the animals were kept alive in the vicinity of each other for a while, before being used (fig. 16).

The pit was formed towards the end of the third century BC, although the area presents earlier evidence of different types of industrial production, including construction debris, which was found mixed with the murex and other mollusc remains. That is, the purple workshop (the fragmentation pattern in the specimens of *H. trunculus* strongly suggests that this activity was indeed performed in the area) was part of an industrial area which included ceramic production and the preparation of fish preserves, as suggested by the salting tubs found nearby, which could have also been used as containers to store molluscs before their processing. Punic salting factories, as well as ceramic workshops which served them, are well known in the Bay of Cadiz from an archaeological point of view. They are very different in size and nature from those dated to Roman times, and their tubs, with rounded angles and bagnerola shape, are easily distinguishable from those used as water tanks for domestic, funerary or cult functions (Sáez Romero and García Vargas 2019).

Similarly 'mixed' deposits (shells, ceramic and other finds, within an industrial complex in which various activities were carried out) were found outside the city of Cádiz's smallest island, in an area called El Olivillo, near the Hospital de Mora, and also, in connection with ceramic waste dumps and Roman Republican tubs, in Calle Gregorio Marañón.

The shells from the El Olivillo site were chiefly found at the bottom of the dump, which was active between the turn of the Common Era and the mid-first century AD, although the most recent levels contain no murex shells. The shell midden of El Olivillo, which seems to be associated with a fairly late date, was discovered only recently, and we are still awaiting its comprehensive publication.

It is also possible to reconsider the second of the shell middens found in relation to the site of Sa Caleta, on Ibiza. This midden was located near the surface, in the area known as Espai XVI, and was excavated by Joan Ramón in 1994. The midden contained eight species, the most abundant of which were *H. trunculus* and *B. brandaris*

(Ramón 2004). Both the archaeological context and radiocarbon dating pointed towards a Late Republican chronology (that is, Late Punic in cultural terms) in the late second or early first century BC, but a recent calibration of the physical data has yielded a chronology around the third or fourth centuries AD, which are outside the purview of the present work (Costa and Alfaro 2010: 176).

Also on Ibiza, Cala Olivera yielded a shell midden excavated in 2005, in which 22 species were represented but in which *H. trunculus* was clearly predominant (Costa and Alfaro 2010). The midden sits above another dump whose activity ceased in the early second century BC. The association of the midden with the remains of a hearth and the presence of fire traces in a different sector of the site make it possible to argue for the production of purple in the site before the Roman imperial period.

In contrast, the association of the basin excavated at Villaricos (Almería) with purple-making activities must be put on hold for the time being, as it is merely based on the presence of dispersed murex shells and the identification of a circular depression in the bottom of a salting vat dated to the late fourth century BC. The excavators suggest that the function of this depression may have been to house the lead containers used in purple extraction (López Castro *et al*. 2007: 16). However, salting vats often present this sort of feature, generally interpreted as drains for the collection of the waste generated during the production of *salsamenta*, making the cleaning of the vats easier between batches.

A recent discovery (Del Arco *et al*. 2017) outside the chronological limits set out for this work, but which should not go unmentioned, given its importance for the analysis of the Atlantic maritime economy and for the scale of the evidence, is a shell midden in the islet of Lobos, off Fuerteventura, which chiefly contains *S. haemastoma* (for Canary Islands and purple dye also see Mederos Martin and Escribano Cobos 2006). Based on the fracture pattern and the presence of remains of dye, in both shells and ceramics, stone hammers and anvils, these shells were used for purple extraction. The ceramic repertoire indicates that the people that worked in the workshop were supplied with food from the Iberian Peninsula. The site produced oil amphorae from the Guadalquivir, wine amphorae from the Tarraconensis and preserved fish from Cadiz. Amphorae and other ceramic wares are dated to the late first century BC and the early first century AD. It seems, therefore, that the workshop was staffed by people from the mainland, in all probability from Cadiz.

CONCLUSIONS

Shellfish purple production in the Western Mediterranean is coetaneous with the Phoenician colonisation, as archaeological evidence from Teatro Cómico (Cádiz) indicates. Here, purple dye was made using primarily *H. trunculus*, in the same way and with the same species of mollusc that was used in the Aegean and Levant from Medium Bronze times onward. These are also the first archaeological remains of purple dye production on the Atlantic littoral of Europe. It is easy to imagine the existence in these early times of similar installations on the Huelva coast, the scene of an even older colonisation episode than those of Cadiz, and also in the Phoenician settlements on the Mediterranean coast of southern Spain. Those would be the oldest purple dye 'workshops' of a long chain of establishments scattered by the end of the first millennium BC from Algarve and Andalucia, in the Iberian Peninsula, to Mogador islands, in the bay of Essaouira, southern Morocco, and, far away, to the Western Canary Islands (Mederos Martin and Escribano Cobos 2006).

Unfortunately, the Cádiz structures could not be related to Phoenician urbanism during its excavation, but evidence of urban development and explicit domestic contexts in the upper levels of the archaeological record of Teatro Cómico show that this was the site of the town of Gdr or Gadir, founded by the Phoenicians in the Far West of the *oecumene*.

The rest of the evidence for the Iron Age I is not so clear. Accumulations of crushed purple shells at Cerro del Villar (Málaga) and Villaricos or Adra (all of them ancient Phoenician sites) are similar to the evidence of Cádiz, in the sense that they can be testimonies of an urban production linked to harbour and fishing areas.

This urban-industrial context of purple production in Far West Punic cities is again the norm (however, there are relatively few contexts) in Punic towns of the southern littoral of Spain. In Cádiz again, the overall impression is that by the end of the first millennium BC the production of purple dye is related to well organised industrial areas that also included halieutic processing installations and amphora manufacture workshops. This is the case of Calle Luis Milena finds, in San Fernando (the *Antipolis* of Strabo, a sort of industrial suburb located in an island in front of the city). A similar context is the heap of crushed shells excavated last year in El Olivillo, in the urban periphery of Punic and Republican

Cádiz. Crushed shells make up the basis of an enormous dump similar to that of Calle Luis Milena and consisting of waste from halieutic workshops and ceramic manufacturing situated in the surrounding areas and dated from the end of first century BC to the middle of the first century AD.

Again, we guess a similar scenario for all the important Punic cities of the period in Spain, like Malaka or Abdera, in Almeria, but we do not have enough data for now to prove it. That is, we do not know if it corresponds to a landscape of large (public) factories or scattered small and medium-size workshops managed by private individuals.

That will be a challenge for the future. Not only to define and to discover new archaeological sites producing purple dye in the towns of Phoenician and Punic coast in the western extreme of the *oecumene*, but also to try and define models of production according to theoretical considerations regarding purple dye uses from protohistoric to Roman times in the western Phoenician-Punic world (see García Vargas 2010).

NOTE

1. Alberti (2008: 75-81) gives a table (Table 2) of six archaeological indicators that characterize production sites and divide these production sites into three groups according with the class of the indicators present at each site:
 - Group A includes sites with purple stained vats, containers with crushed murex shells, burnt organic ashes and traces of burning mixed with crushed murex shells, heaps of crushed murex shells near the installations, and working equipment. These sites are interpreted as «purple industry plants».
 - Group B includes heaps of crushed murex shells on the coast that may indicate «industry plants which were probably located inside or near the settlement».
 - Group C sites show heaps of crushed murex shells in settlement or house strata, crushed or calcined murex shells in plasters, lumps of purple dye stuff and purple pigment in frescoes. This evidence points to «purple-dye processing activities located within the settlement or some other site».

ACKNOWLEDGEMENTS

Special thanks to D. S. Reese for sending me his bibliography and a fantastic and unpublished catalogue of purple dye production sites; to Y. Sharom and Y. Shalev for their kind information about Tel Dor; to J. Mª Gener for the photographs of Teatro Comico; to G. Tyndale for his taxonomic identification; and to D. Govantes Edwards for the English translation of the Spanish text.

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