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Royal Purple or Pickled Fish? The use of analogy for reinterpreting the Roman “Purple Dye Factory” at Tel Dor (Israel) as a salsamenta and garum production facility

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Royal Purple or Pickled Fish?
The use of analogy for reinterpreting the Roman “Purple Dye Factory” at Tel Dor (Israel) as a *salsamenta* and *garum* production facility

A thesis submitted in partial satisfaction of the requirements
for the degree Master of Arts

in

Anthropology

by

Jackson Thomas Reece

Committee in charge:

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Professor Geoffrey Braswell
Professor Isabel Rivera-Collazo

2020

The thesis of Jackson Thomas Reece is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Chair

University of California San Diego

2020

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ABSTRACT OF THE THESIS

Royal Purple or Pickled Fish?
The use of analogy for reinterpreting the Roman “Purple Dye Factory” at Tel Dor (Israel) as a *salsamenta* and *garum* production facility

by

Jackson Thomas Reece

Master of Arts in Anthropology

University of California San Diego, 2020

Professor Thomas E. Levy, Chair

Murex-purple dye production and the production of *salsamenta* (salted fish) and *garum* (fish sauce) are two of the most common coastal industries of the Roman period. The western Mediterranean has a long history of archaeological investigation into fish-processing and dyeing facilities, with the most well-known sites concentrated around the Strait of Gibraltar. The same cannot be said for sites in the eastern Mediterranean, however, and the dearth of archaeological data on fish-processing in this region is surprising considering the importance of *murex*-dye, *salsamenta*, and *garum* to the Romans. In this thesis, I use an argument by analogy to test the hypothesis that a Roman coastal industrial complex at Tel Dor (Israel), currently known as the “Purple Dye Factory,” is actually a fish-processing facility. I form a positive analogy by

comparing the features of the Dor complex with features at Roman fish-processing facilities (*cetariae*) in Baelo Claudia (Spain) and Cotta (Morocco). Next, I develop two *chaîne opératoire* models – for purple dye production and fish-processing – to determine what features are expected for each technological process. Finally, I demonstrate that the archaeological features at Dor match the archaeological correlates of the fish-processing *chaîne opératoire* and are analogous to the features found at Roman *cetariae*.

INTRODUCTION

Murex-purple dye production and the production of *salsamenta* and *garum* are two of the most common coastal industries of the Roman Mediterranean. Regarding the former, Pliny the Elder once remarked that the Romans had a “frantic passion for purple” (Pliny, *Nat. Hist.*, 9.66). The uniquely photosensitive qualities of this particular shellfish dye, and the lengths to which one needed to go to procure it, led to it being known as “royal purple.” The Roman passion for this substance was, humorously, only matched by their equally frantic passion for the taste of pickled fish. *Garum* and other fish sauces dominated Roman cuisine, lending their salty and umami flavor to a variety of dishes. Both murex-purple and *garum* come from creatures in the sea, and the coastal facilities dedicated to dyeing and fish-processing are of great archaeological interest.

Unfortunately, archaeological data for fish-processing is not evenly distributed throughout the Mediterranean. The west has a long history of archaeological investigation into fish-processing sites, with the largest and most well-known factory-scale facilities concentrated around the Strait of Gibraltar. Excavations in the eastern Mediterranean, however, have come up empty-handed; aside from sites in the Black Sea region, there are no indicators that fish-processing occurred at anything larger than a personal scale. This dearth of evidence leaves one to wonder if the Roman taste for salted fish and fish sauce never made it to the east, or if archaeologists are to blame for its invisibility in the record.

This thesis will address the problem directly by reexamining a Roman industrial complex on the coast of Tel Dor (Israel). This complex, located on the beach just northwest of the tel proper, was originally interpreted by Avner Raban, the excavator, as a “Purple Dye Factory.” However, in light of new evidence, I hypothesize that the complex is actually analogous to the fish-processing facilities of the western Mediterranean. Thus, the purpose of this paper is to analyze indicative feature classes at Dor, compare them and the facility as a whole with those at positively identified Roman fish-processing facilities, and demonstrate that the archaeological evidence at Dor matches what we expect of a *salsamenta* and *garum* production complex.

The Analogy

The following analysis is, by nature, one of analogy – a comparison of the form and function of unknown features with the form and function of known features. However, the objective of this study is not merely to interpret, but *reinterpret*, archaeological material. This implies that one interpretation is not equal to another, meaning it is not enough to simply pose a new interpretation; I must also measure the likelihood that this hypothesis is truer than its predecessor. As such, it is helpful to begin with a discussion of analogic arguments and how to apply them within anthropological archaeology.

Lewis Binford (1967: 1) defines *analogy* as, "not strictly a demonstration of formal [as in "form"] similarities between entities; rather it is an inferential argument based on implied relationships between demonstrably similar entities." He then identifies two characteristics that indicate the success of the analogy and the strength of the inferential argument made (from Binford 1967: 2, paraphrased from Stebbing 1961: 243-56):

> 1a. If the initial resemblances are such that the inferred property would account for the resemblances, then the conclusion is more likely to be true.
>
> 2a. The more comprehensive the positive analogy and the less comprehensive the inferred properties, the more likely the conclusion is true.

To which Binford deduces two obvious corollaries:

> 1b. If the initial resemblances are not such that the inferred property would account for the resemblances, then the conclusion is more likely to be false.
>
> 2b. The more comprehensive the inferred properties, the less likely is the conclusion to be true.

Binford's model of analysis meets the needs expressed above. The analogy provides a framework within which I can form an interpretive hypothesis – the function of the Dor complex – and then assess its likelihood based on the relationship that I am implying – the form of the facility is a direct result of its function. The strength of this interpretation, as well as the interpretation that Raban provides, can be tested by answering two questions based on Binford's criteria: (1) Does the function of the facility account for its form; and (2) does the form match what would be expected for a facility with that specific function?

In light of this, my analysis requires two datasets: 1) One with analogous *form* data – in this case, comparative architectural evidence from facilities that possess many of the Dor feature classes, in a similar spatial organization to the industrial complex at Dor; and 2) a dataset pertaining to the relationship between *form* and *function* – a model of the chain of operations that occurred within such a complex and the archaeological correlates of each step in that that chain.

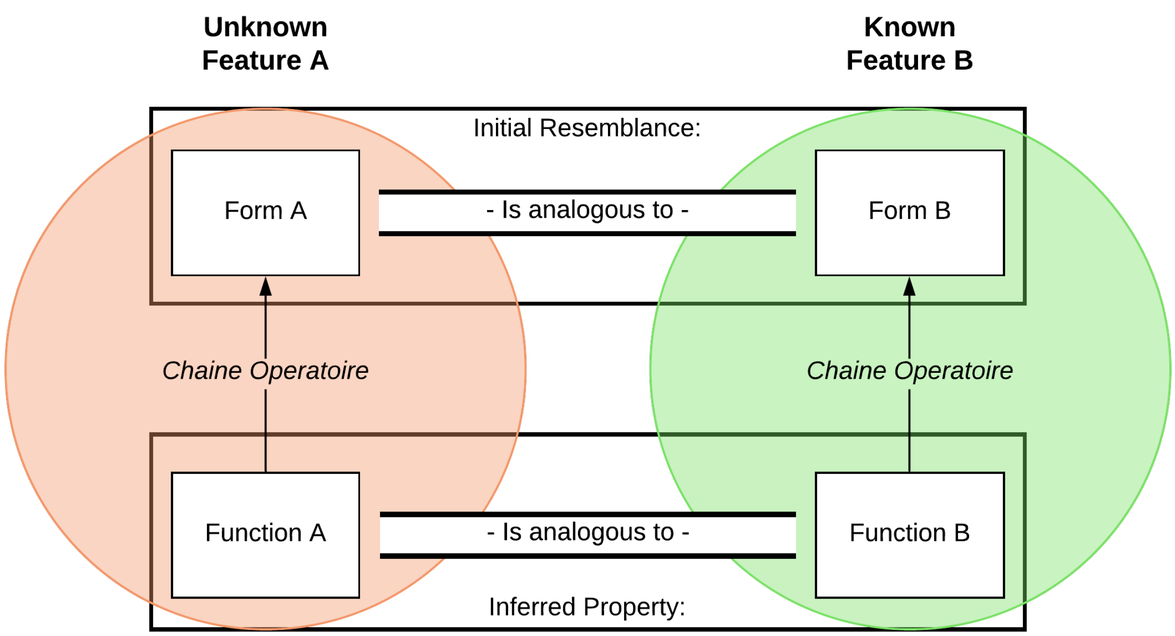

Figure 1: Diagram showing the format of the present argument by analogy, in the style proposed by Binford (1967)

DESCRIPTION OF THE ARCHITECTURAL FEATURES

The industrial complex is located on a beach about 400 m northwest of the Tel Dor mound (see Figure 2). This area is characterized by a *kurkar* (aeolianite sandstone) outcrop, partially covered by deposits of beach sand, that separates the North Bay and the Love Bay. The industrial complex occupies roughly 1000 m^2, an area spanning from the intertidal zone to about 50 m inland.

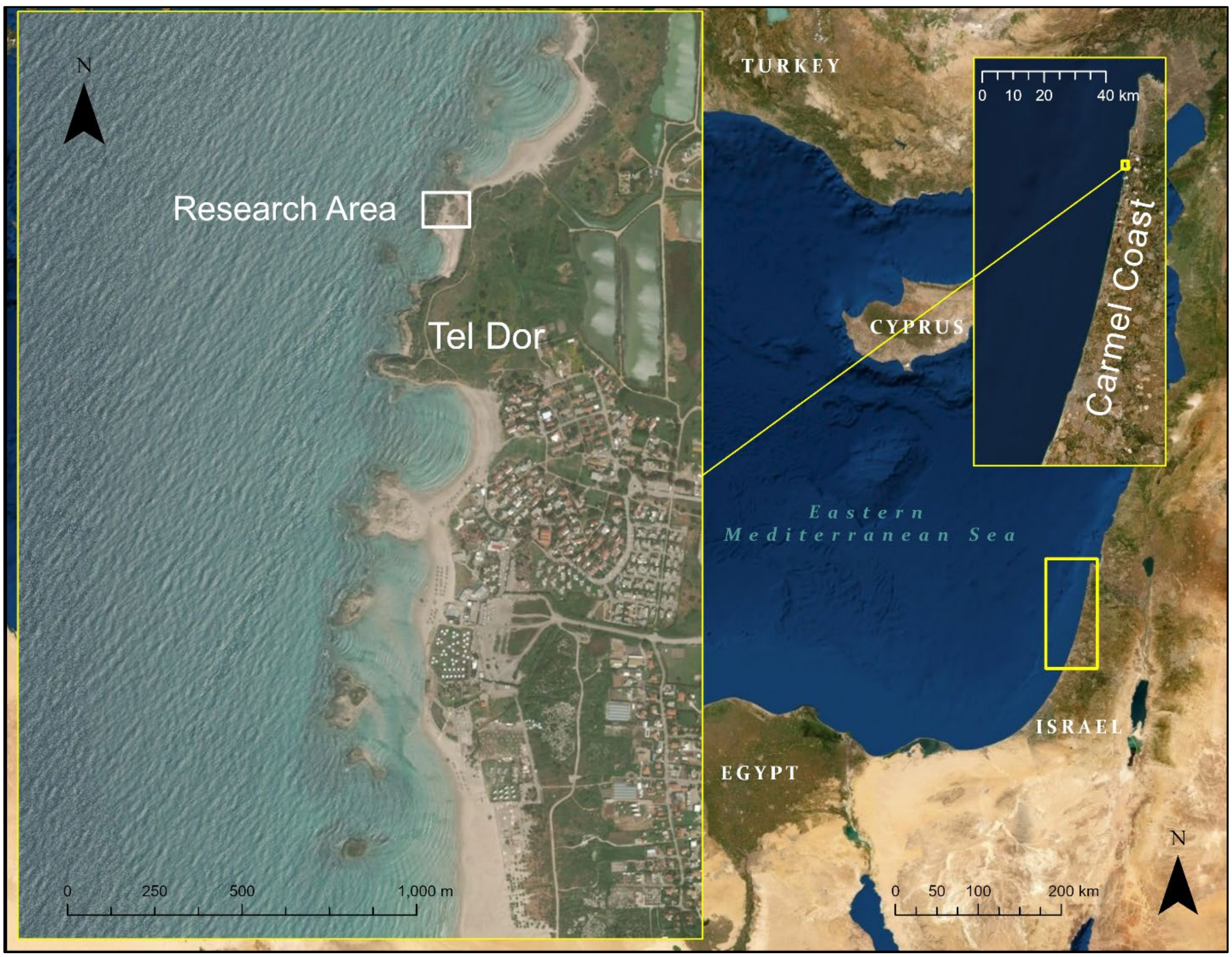

Figure 2: Regional map of the eastern Mediterranean, with inset map showing the location of the Tel Dor industrial complex (map by J. Reece, data: Esri Imagery Basemap).

The Tel Dor coast, including this industrial area, was first surveyed (see Figure 3) by Avner Raban and a team of graduate students from the University of Haifa Department for History of Maritime Civilizations from 1980 to 1984. Additionally, Raban and a group of students from Oranim College conducted an experimental excavation of the industrial complex itself over two weeks in December of 1983. Data from these surveys and excavations are published in the final report (Stern 1995) of Tel Dor Areas A and C, in a chapter (Raban 1995) dedicated to coastal and maritime installations at Dor. The descriptions of features given below are from that chapter and from observations and data that I collected in 2018 and 2019.

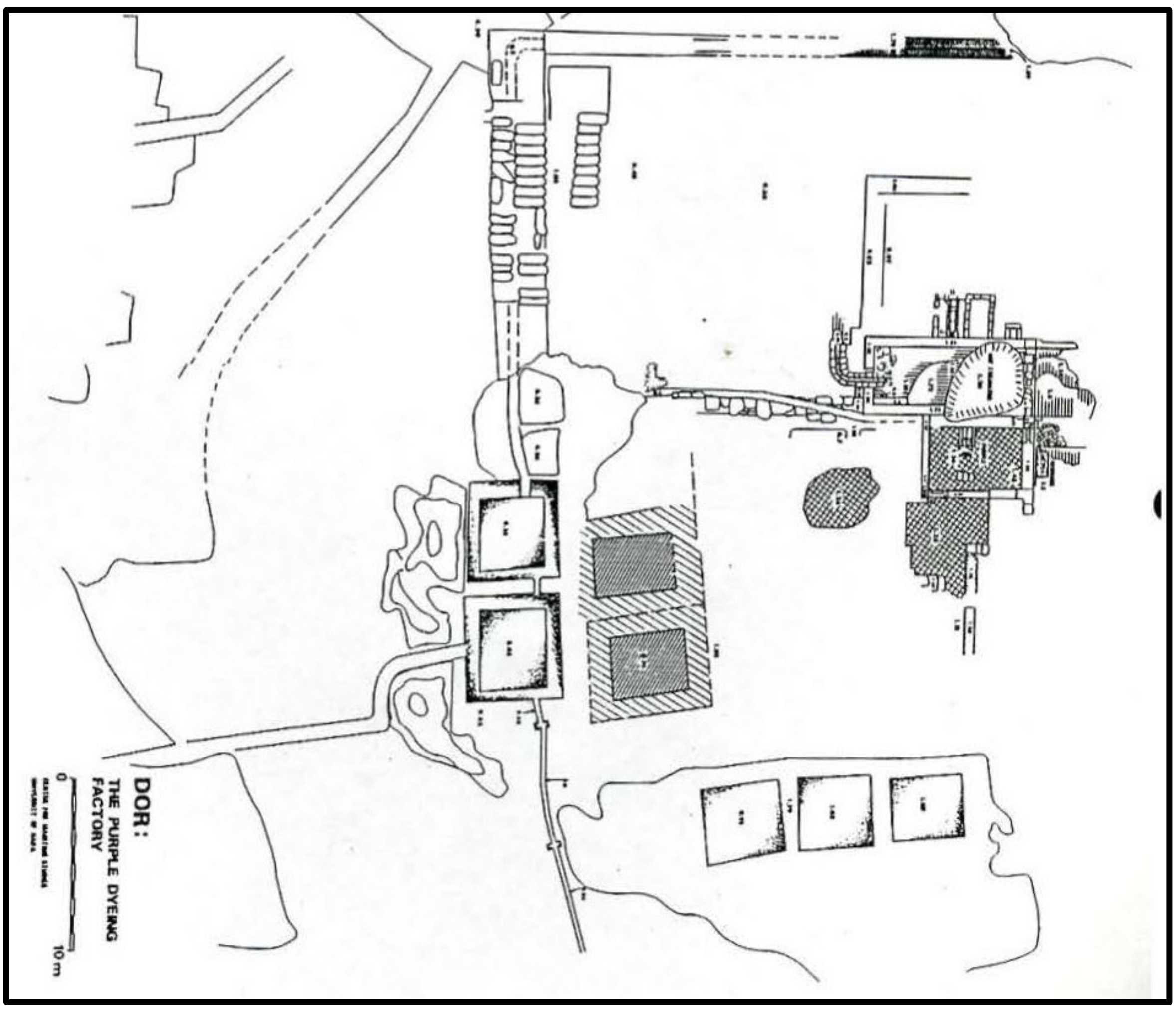

Figure 3: Top plan of the industrial area (Raban 1995, Fig. 9.5)

The industrial complex (Figure 4) is comprised of six classes of features with internal similarity: (1) rock-cut pools, (2) saltwater and freshwater channels, (3) rectangular vats, (4) oval basins, (5) a multi-phase central structure, and (6) an open courtyard.

Rock-Cut Pools

Two rock-cut pools (Figure 5), oriented north-south, are cut directly into the *kurkar* in the west of the complex, about 35 m east of the termination of the shelf in the Mediterranean. The northern pool is 5.1 × 4.2 m and the southern pool is slightly larger at 4.6 × 5.2 m. Due to

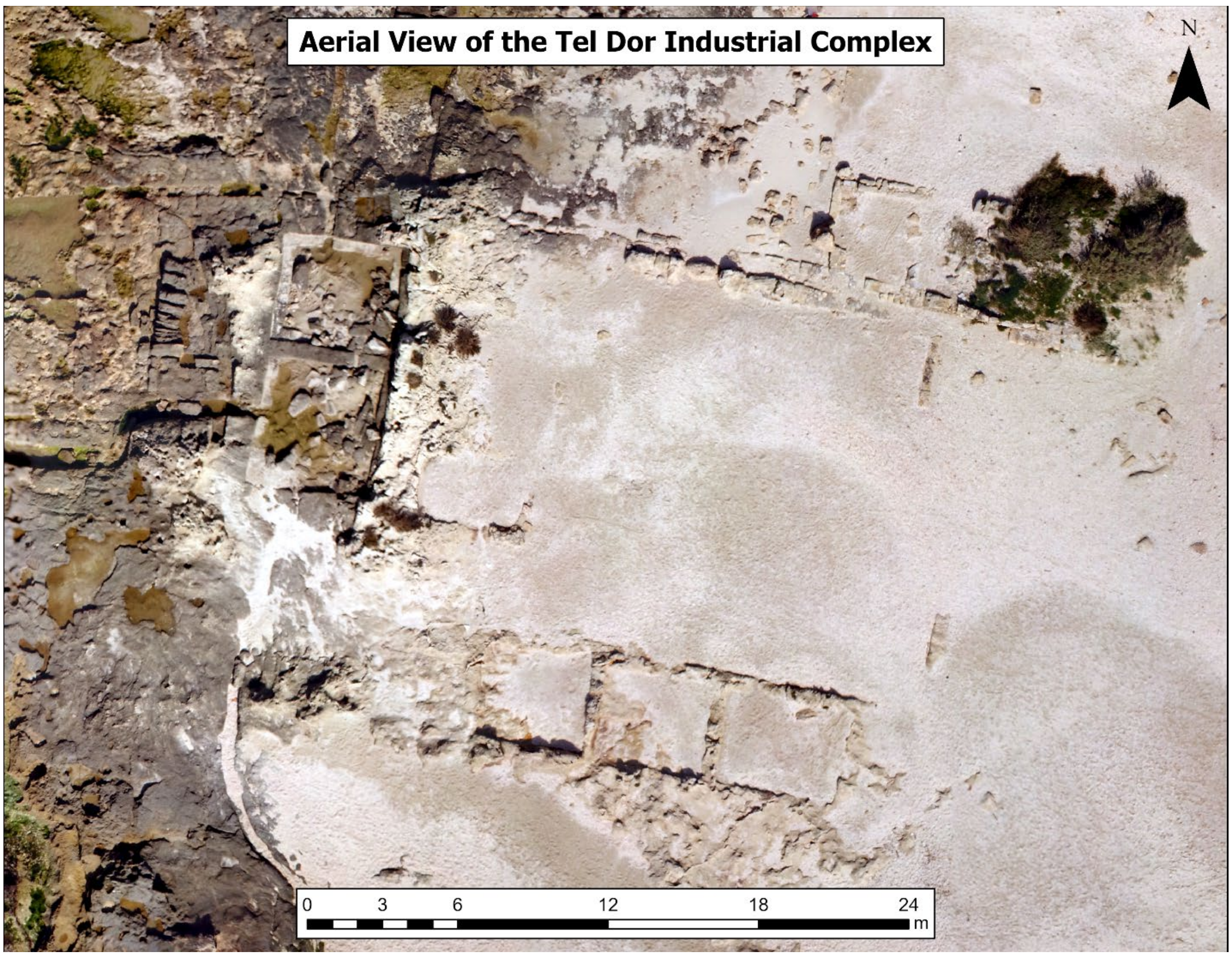

Figure 4: Aerial orthophoto-mosaic of the Tel Dor industrial area. The rock-cut pools (left), rectangular vats (bottom), the central structure (top right), and the large plastered courtyard (middle, covered in sand) are clearly visible from the air (map by J. Reece, data courtesy of A. Tamberino, SCMA – UC San Diego).

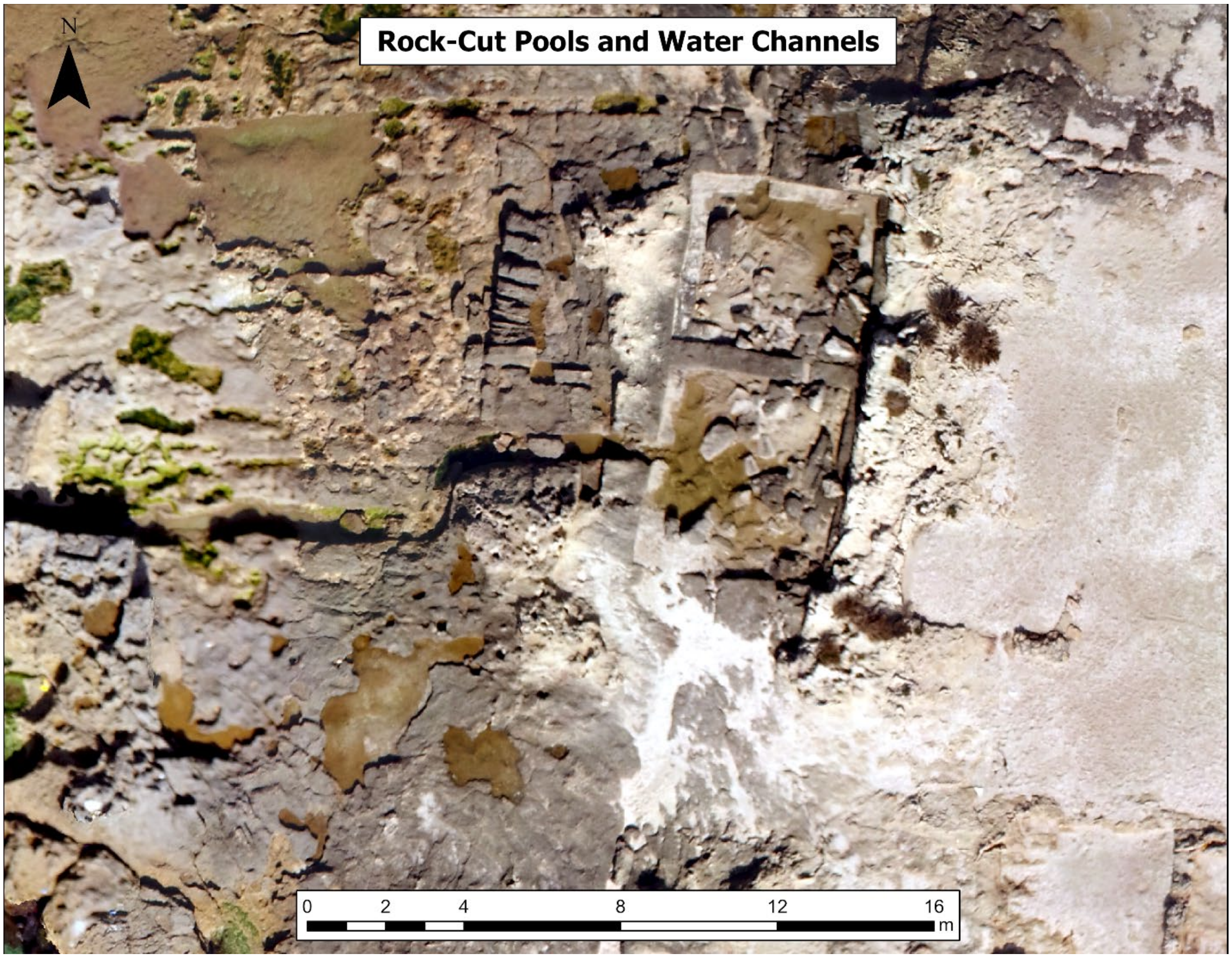

Figure 5: Aerial view of the rectangular rock-cut pools (middle) and water channels: one entering the northern pool from the north, one entering the southern pool from the west, and one leaving the southern pool from the south (filled with sand) (map by J. Reece, data courtesy of A. Tamberino, SCMA – UC San Diego).

rubble, calcareous accretion from seawater, and sand-fill, neither pool has a depth of more than 0.6 m at present; it is likely both were deeper in antiquity. A bench or shelf with an average width of 0.5 m follows the outer edge of both pools about 0.3 m below the pool rim. The north pool and south pool are connected by a small channel, 0.2 m wide and .5 m long, that allows water to freely flow between them. A 2.2 m tall outcrop of *kurkar* forms the eastern edge of both pools. The inside of the pools are absent of plaster or any other waterproofing layer, but this is not surprising consider the erosive forces active in this intertidal zone. The pools are cut at a height such that modern semi-diurnal tides fill and empty the pools, resulting in natural circulation of water, and they can become completely flooded during storms (Figure 6).

Water Channels

Three saltwater channels, cut directly into the *kurkar*, connect with the rock-cut pools and facilitate the flow of seawater into and out of the system during these tidal changes. Elevation analysis and modern observations indicate two of the channels primarily *introduce* new saltwater into the system from the Mediterranean, and the third channel primarily *removes* water at both high and low tides, where it then flows back into the sea.

The northernmost channel enters the area from the west and makes a 90° turn south where it then flows into the north pool. The bottom of the channel meets the pool at the same height as the shelf. The channel is 0.5 m wide at its extent and has a maximum depth of 0.3 m. A second, larger channel enters the southern pool from directly west, where it cuts through the inner bench. This channel has a maximum width and depth of 1 m and 0.6 m respectively. Vertical cut marks are located on both sides of the channel about 1 m west of the pool. These cuts were likely used for holding a circular stone or some other damming mechanism (e.g., sluice gate) that could regulate the rate at which saltwater flowed into and out of the system during high and low tide (Raban 1995: 298). The northernmost channel has similar, albeit much smaller, cuts near its connection with the pool that Raban also interprets as some type of sluice notch. These channels allow new saltwater into the pools during high tide but remained dry during low tide.

A third channel, also with sluice gate marks, exits the southern pool and heads due south for about 25 m before terminating in the Love Bay. The channel is roughly 0.5 m wide and has a starting height of 0.8 m above sea-level, leading Raban to hypothesize that it was a drainage channel only (1995: 398); modern elevation measurements support this, although it is considerably more eroded than the two larger inflow channels. Similar to the rock-cut pools, all three channels are partially filled with a natural calcareous cement that obscures their constructed (i.e. functional) depth; all were likely deeper in antiquity, however, the rate of accretion, and therefore the depth of the features, cannot be calculated at present.

Raban (1995: 298) describes two additional channels, different from the saltwater channels in construction and likely in function, that also enter the rock-cut pools from the north. These channels are built in a U-shape from small cut stones rather than cut into the *kurkar*, and the interiors are plastered. The first channel originates to the northeast of the complex, runs west toward the sea for 30 m, turns 90° south, and then runs for 20 m until it reaches the northern pool. The second channel also flows from the northeast but, instead of travelling directly to the pools, runs through the multiphase building where it likely distributed freshwater to

Figure 6: The rock-cut pools from the southeast, flooded at high tide during a storm. Note that the kurkar outcrop to the east (right) prevents water from spilling out of the pools and into the industrial area (photo by J. Reece).

some of the plastered features found there. From the multiphase building, the second channel runs due west and enters the northernmost pool from the north. Although neither has been traced back to the source, Raban hypothesizes that both channels brought freshwater into the area from an aqueduct east of Dor that originates in the River Dalia (see also, Peleg and Porath 1985: 24).

Rectangular Vats

Three (possibly four) rectangular vats form an east-west line along the southern edge of the industrial complex. These vats are cut directly into the *kurkar* outcrop and sparse remains of heavily eroded *opus signinum* plaster, “a paving material formed of crushed terracotta set in a matrix of cement” (Tsakirgis 1990: 425), is visible on the walls of two of the vats, at sand level. Raban’s team did not clear or measure these features during his excavations; I took all measurements given here during the 2019 geospatial survey and calculated the minimum depths from the top of the highest surviving wall to the lowest elevation within the vat (i.e. at the top of the sand deposit). The eastern vat measures 4.9 × 3.8 m, with a minimum depth of 0.5 m. The middle vat measures 4.6 × 3.7 m, with a minimum depth of 0.7 m. The westernmost vat measures 4.2 × 3.7 m, with a minimum depth of 1.1 m. The remains of a possible fourth vat, measuring roughly 3.7 × 3.5 m and with an unknown depth, can be found closest to the coast but are too heavily eroded to positively identify.

Although he does not mention them in his publication, Raban’s hand drawn top plan indicates the northernmost edge of two additional, rectangular features. These are directly south of the freshwater channel that leads from the administration complex to the rock-cut pools and appear to run along the northernmost edge of the central courtyard. Estimations from his top plan indicate they have a surface area of roughly 4 m^2 if square.

Oval Basins

Directly east of the rock-cut pools, on the inland side of the *kurkar* outcrop wall, are a pair of oval basins, partially cut into the *kurkar* outcrop and partially built of rubble, all “plastered with an impermeable cement” (Raban and Galili 1985a: 342). The only exposed remains at present are the southeast corner (built of plastered rubble) and the west edge (cut directly into the kurkar) of the southern basin. This basin measures 4.0 × 2.6 m and has a minimum depth of 0.4 m. In his notes, Raban (1995: 299) clearly describes the presence of a second basin neighboring the first, measuring roughly 4.7 × 3.0 m and 0.3 m deep, as well as a third basin

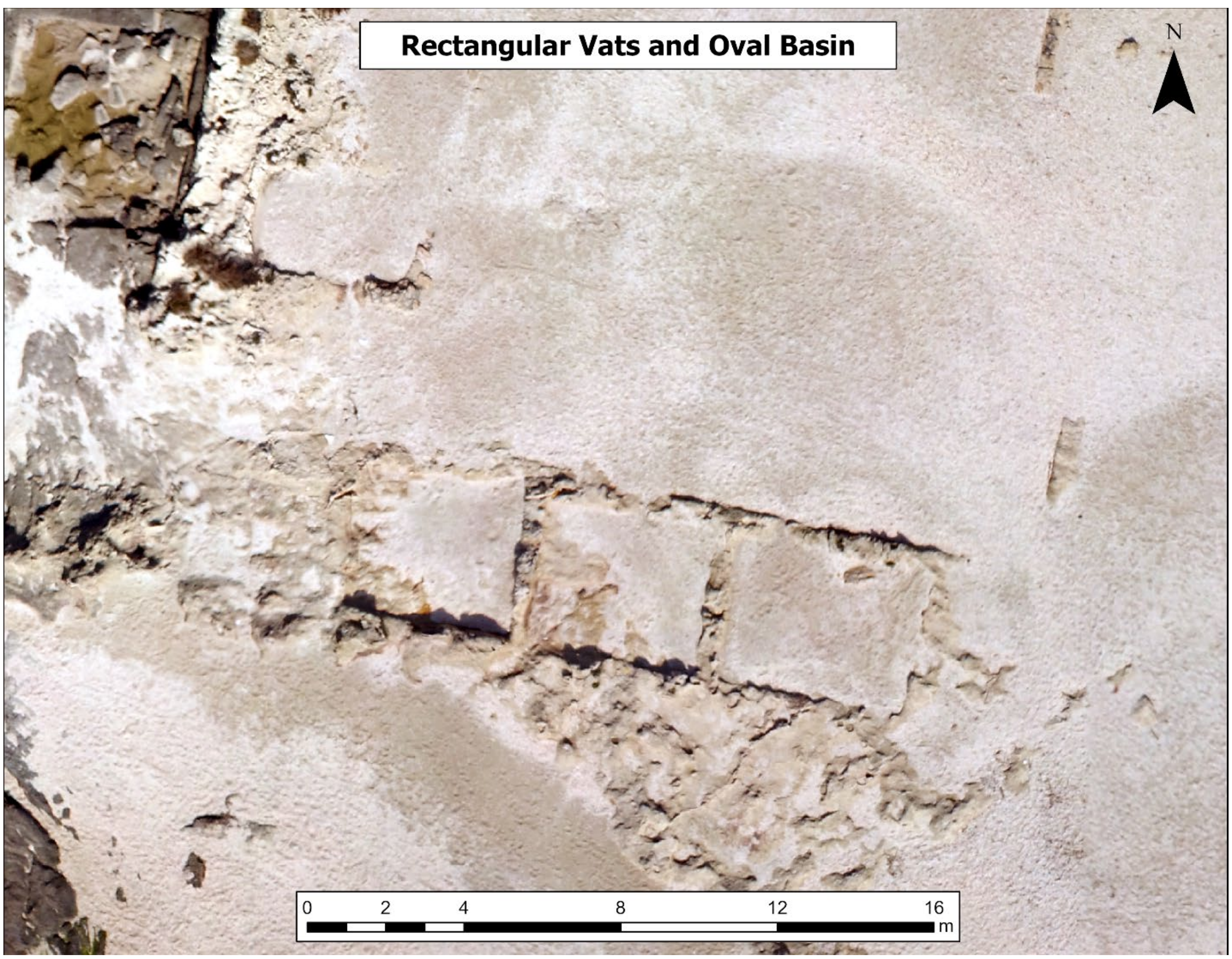

Figure 7: Aerial view of the three rectangular vats (bottom middle) and the one exposed oval basin (top left).

adjacent the other two to the north. By 2019 both of these basins are completely covered by sand or eroded.

Central Building

Raban's 1983 excavation focused primarily on a complex central building with many room and phases. This area is almost completely covered by sand at present, so the publication notes are duplicated below as it is the only description of the area:

> The central structure was built of rather large and carefully laid ashlars. There was a central room measuring 6.10 × 3.60 m. and facing south, with a door on the western side of its southern long wall leading to the main open courtyard through a wide passage. This passage, with a paved floor at 1.25 m. above MSL [Modern Sea Level], is 2.80 m. wide on its eastern side and 2.60 m. on the west, at the opening to the courtyard. It continues to the south as far as 4.80 m. from the entrance to the central room, and there is another opening 1.20 m. wide on the western side of what may have been another water conduit, built on top of a stone wall with its U-shaped channel at 1.56 m. above MSL. This conduit fed three rock-cut basins, leading to the northeastern corner of the easternmost one some 12 m. to the south. These basins, which flank the southern side of the complex, measure (from east to west respectively) 3.50 × 4.30 m., with a floor at 1.07 m. above MSL; 4.20 × 4.30 m with a floor at 1.03 m; and 4.20 × 4.70 m with a floor at 0. 91 m. The central room of the building has a rectangular structure in its center, built of ashlar blocks around a raised podium of ashlar slabs measuring 1.10 × 1.60 m. In front of it, 1.70 m from the southern wall of the room, there were three upright slabs. On the plaster floor of this room between the two structures was a large spot of bright purple color. Laboratory tests at the Weizmann Institute failed to detect chemical residues of *murex* purple, or any other organic components. However, this purple spot is thus far the only clue we have as to the possible purpose of this multi phased industrial complex.
>
> Behind the central room to the east, on the other side of a 0.70 m. wide ashlar wall, there were at least two more rooms, with a similar type of plaster floor covering a fill of small pebbles at the same elevation of 1.30-1.35 m. above MSL. Only the western part of the partition wall between the two rooms and of the one on the northern side of the structure were preserved. Their length (north-south) was 5 m. each. Both these walls and the eastern one of the central rooms were rebuilt in Phase 4.
>
> The second major component of the central structure is a large rectangular space with a floor consisting of rubble fill covered with heavy plaster which continues over the side walls. This space, apparently a water tank, was 9.20 m. long (east-west) and 3.40 m. wide, with ashlar walls 0. 5 5 m. wide. The floor is at 1.22 m. above MSL. This basin was drained through a curbed ashlar-built U-shaped plastered channel, 0.30 m. wide on its western side, around the rock-cut

> ledge and the western wall of the earlier structure, to the northern side of the leveled bedrock. Over the northern wall of the basin and adjacent to it from the outside, there was a series of ashlar-built basins and dividing slab-covered channels that brought fresh water for use in some kind of sieving process (Photo 9.32). There were some stone-cut grilles and pierced architectural members that demand further study in order to establish their exact function.
> (Raban 1995: 299-300)

The central structure is rich with plastered features – basins, pits, channels, and the floors of whole rooms. Many of these features are connected with conduits and channels, and although their exact function is not known, the abundance of plastered features indicate that liquids factored prominently in their function. The building had access to fresh water (from the aforementioned channel that connects to the Dalia aqueduct) and saltwater from the immediately adjacent sea.

Central Courtyard

All of the features described above are distributed around what is today a large (roughly 160 m^2) expanse of beach sand that is void of any architectural elements. Fortunately, Raban's excavation of the central structure uncovered part of this expanse and he found that the area nearest the central structure contained a large plastered floor built on top of ashlar stones and the *kurkar* bedrock. In July of 2018, a team from Haifa University used a Ground Penetrating Radar (GPR) to assess the presence of additional architectural features in this expanse; however, the data is inconclusive because of limitations in GPR due to saltwater intrusion from the sea (for more on this limitation, see Heteren, Fitzgerald, and McKinlay 1994). Architectural elements break the sand in all areas surrounding this expanse, therefore it is safe to assume at

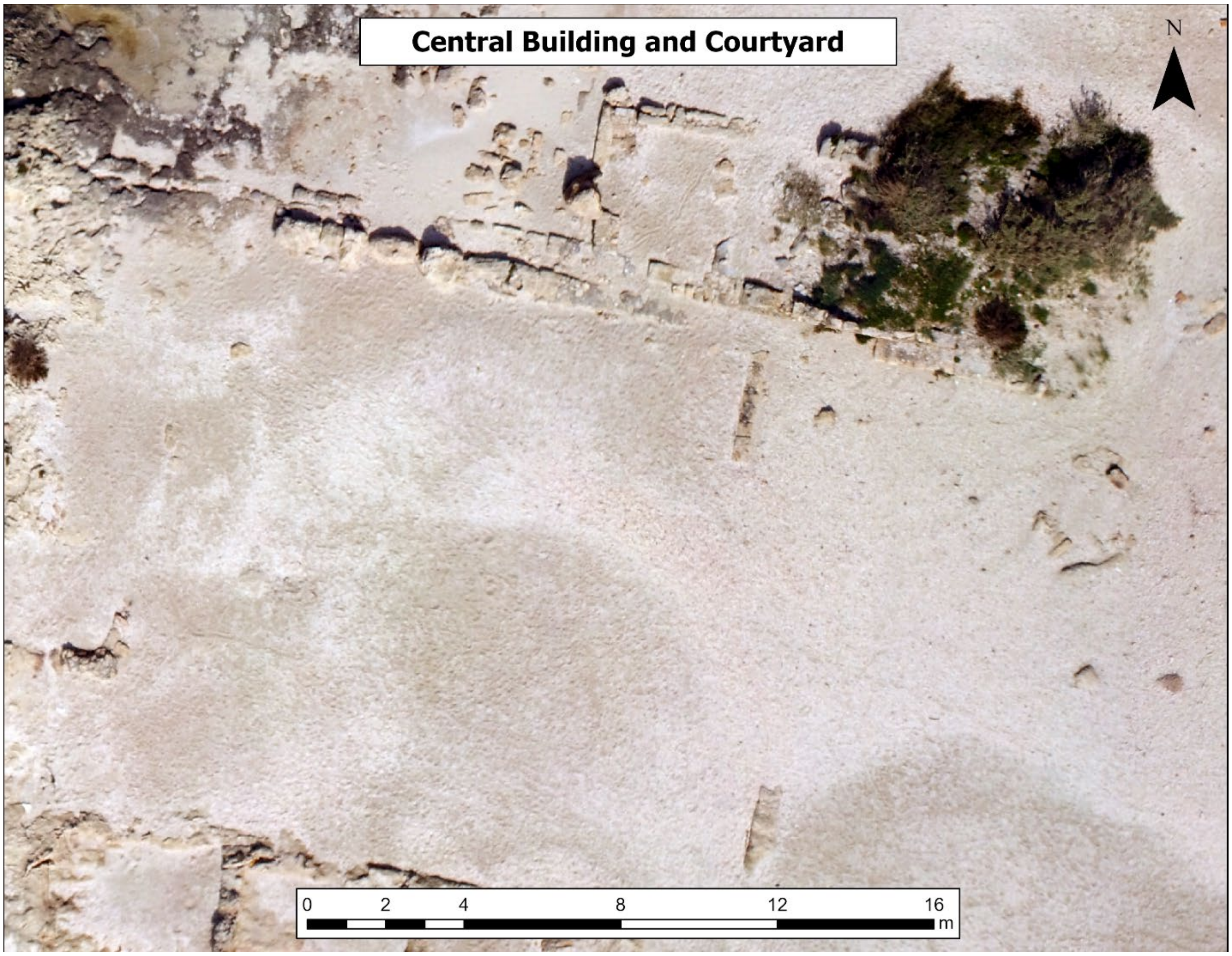

Figure 8: Aerial view of the central building (top right) and the central courtyard (middle, sand expanse). The western room of the central building is partially exposed, revealing a plastered floor.

present that this central area is a large courtyard likely covered by the same plaster floor that Raban found in the northeast corner. This is further supported by Raban, who calls it a "rectangular ashlar paved court" in later publications (Raban and Galili 1985a: 342), indicating it was more clearly exposed in the early 1980s.

Dating and Original Interpretation

Raban separates the complex into four discrete phases, dating from the late Hellenistic to the 6th century. However, ongoing work on the pottery from the site indicates that the relevant loci date only to the 1st c. BCE – 1st c. CE, with most of the fill layers that seal them dating to the 2nd c. CE (A. Raztlaff, pers. comm.). The rock-cut pools, which are void of pottery, are difficult to date as they are in the high-energy intertidal zone, subject to constant weathering and mixing of datable material. Raban does not date these features in his publication, but paleo sea-level measurements from the region (see Nir 1997; Sivan et al. 2004; Toker et al. 2012; Vunsh et al. 2018) demonstrate that the pools could have been used during the 1st c. BCE – 8th c. CE. Thus, it may be assumed that the pools were used concomitantly with the rest of the complex.

Additional evidence of human activity – quarry cutouts and half-quarried ashlar stones – indicate that the area directly north and northwest of the industrial complex has been subject to a long history of anthropogenic change. In most cases, the *kurkar* is cut in such a way that the seaward side remains elevated, protecting the landward side from waves to a height of almost 2 meters (Raban 1995: 296). Parts of the unquarried *kurkar* are pockmarked with additional artificial and natural pools, and channels cut between the pools allow water to flow freely during changes in the tide. Raban notes that this area of the shelf is too heavily eroded or encrusted with calcareous stone cement from the sea for anyone to deduce the function of the pools and channels. These quarries and additional pools to the north of the industrial complex, although important for a comprehensive picture of the area, are not part of the present analysis.

The central structure and the pools, vats, and basins that surround the large plastered courtyard, along with a sparse pottery assemblage, are the only indicators of the function of this industrial complex. Raban (1995: 300-301) suggests that the complex was used to produce *murex*-purple dye on account of the numerous plastered features within the central structure, as well as “a large spot of bright purple color” found on the floor of one of the rooms in the building. However, the sample sent to the Weizmann Institute for residue analysis did not exhibit any traces of 6-6’ dibromoindigotin, the dyeing compound found in purple dyes derived from the *murex* sea snail (Raban 1995: 300). This alone does not necessarily disprove his interpretation

– the floor was likely subject to numerous opportunities for contamination over the last two millennia – but it does emphasize the need for further investigation. Nevertheless, the area is now known as the "Purple Dye Factory" in discussions of Dor (e.g., Kingsley and Raveh 1994: 291, 294; Raban 1987: 120; Sterman and Sterman: 54) and additional publications on purple dyeing (e.g., Reese 2010: 122).

ARGUMENT BY ANALOGY: RELEVANT ARCHAEOLOGICAL PARALELLS AS ANALOGOUS *FORM* DATA

Analogous examples of the six individual feature classes occur in abundance across the Roman Mediterranean. For example, rock-cut pools and tidal channels are ubiquitous on the coasts of Italy (see, Northern Adriatic: Busana 2018; Tyrrhenia: Evelpidou et al. 2012; Istria and Dalmatia: Florido et al. 2011; Central Italian Coast: Higginbotham 1997), Crete (see, Davaras 1974; Francis 2010; Leatham and Hood 1959; Mourtzas 2012a, b), and the southern Levant (see, Caesarea: Flinder 1976; Akhziv: Spier 1993; Central Israel: Stanley 1999), where they have largely been interpreted as fish-ponds, or *piscinae*. Likewise, both sides of the Strait of Gibraltar (see Trakadas 2005; 2015), as well as the shores of the Black Sea (see Bekker-Nielsen 2005a), are rife with the plastered vats, basins, open courtyards, and administrative

Figure 9: Regional map showing the locations of the fish-processing facilities at Baelo Claudia and Cotta (map by J. Reece, data: Esri Imagery Basemap).

buildings of what archaeologists of these regions argue are Roman fish-salting factories, or *cetariae*.

The similarities between the architecture of the Dor industrial complex and the architecture of other coastal industry sites – in particular those associated with fish-processing – are compelling. To this end, I have chosen two Roman *cetariae*, at Baelo Claudia (Spain) and Cotta (Morocco), because both display complex formal similarities to the industrial complex at Dor. With the noteworthy exception of rock-cut pools (discussed later), every feature class at Dor is also present at Baelo Claudia and Cotta, and in a notably similar spatial organization.

Roman *Cetariae* in Baelo Claudia

The city of Baelo Claudia, located in the Roman province of *Baetica*, has arguably the most thoroughly excavated and documented fish-processing factories in the entire Roman Mediterranean. Excavations led by Darió Bernal-Casasola first began in 2003, and to date, his team has uncovered eight discrete fish-salting factories, or “Conjuntos Industriales” (*Cetariae* C.I. I, IV, V, VI, VII, X, XI, and XII), dating from the 2nd c. BCE – 5th c. CE (Bernal-Casasola, Expósito, and Díaz 2018: 329). The *cetariae* are spatially organized in two industrial zones in the southern part of the city (see Figure 10).

The *cetariae* do not follow a standard plan and are internally organized in such a way as to fit between other buildings in each city block. This constraint produces interesting variability between the factories, variability that is especially useful for highlighting those features that,

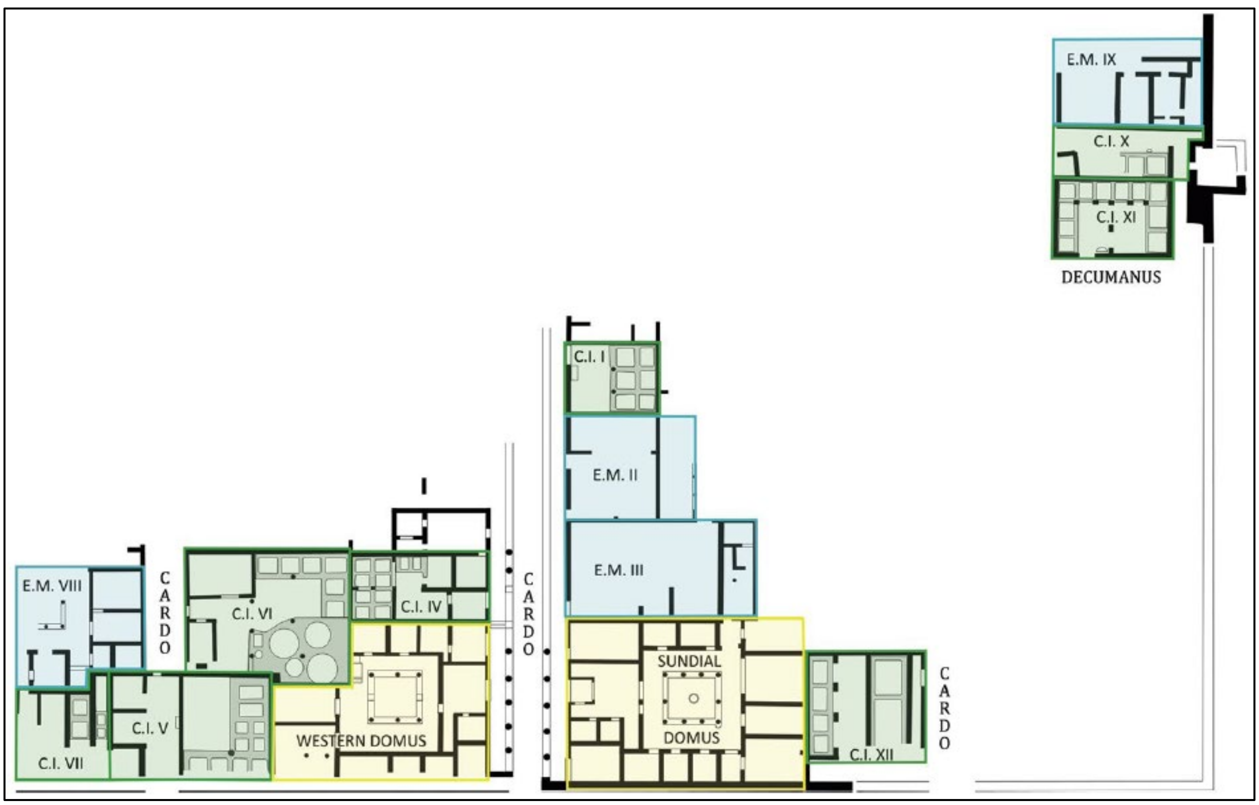

Figure 10: Location of the eight cetariae (green) in the southern industrial area of Baelo Claudia (Bernal-Casasola, Expósito, and Díaz 2018: 331, Fig. 2).

regardless of layout, are present in nearly all cases – rectangular vats and open preparation areas, all plastered with the traditional *opus signinum*. What follows is a description of the layouts and features of each of the *cetariae*. Descriptions of facilities C.I. I – C.I. VIII (translated from Spanish and paraphrased) are from RAMPPA (Bernal-Casasola et al. 2016), an online database of *cetariae* in the western Mediterranean curated by a multi-national team of scholars led by Bernal-Casasola (facility-specific pages are the last citation in each section). Excavation data for *Cetariae* C.I. XI and C.I. XII have been published in English by Expósito, Bernal-Casasola, and Rodriguez (2018), and are quoted verbatim.

Figure 11: Aerial photo of the southern group of cetariae at Baelo Claudia, looking south (Arévalo and Bernal-Casasola 2007).

1. *Cetaria* C.I. I

The earliest constructions at *Cetaria* C.I. I are dated to the 1^{st} – 2^{nd} c. CE, and it is one of two (with C.I. XII) that is not adjacent to additional fish-processing facilities. The building is small, almost 90 m^2, and comprised of two rooms. The west room is plastered in *opus signinum* and possesses a single rectangular pool on the west side. Bernal-Casasola et al. have interpreted this room as intended for cleaning and gutting fish prior to salting. The east room contains six vats. All are rectangular in shape, plastered in *opus signinum*, and have similar

Figure 12: View from the north of the preparation area and vats, which are both rectangular (foreground) and round (background), of C.I. VI (Trakadas 2015: 10, Fig. 7).

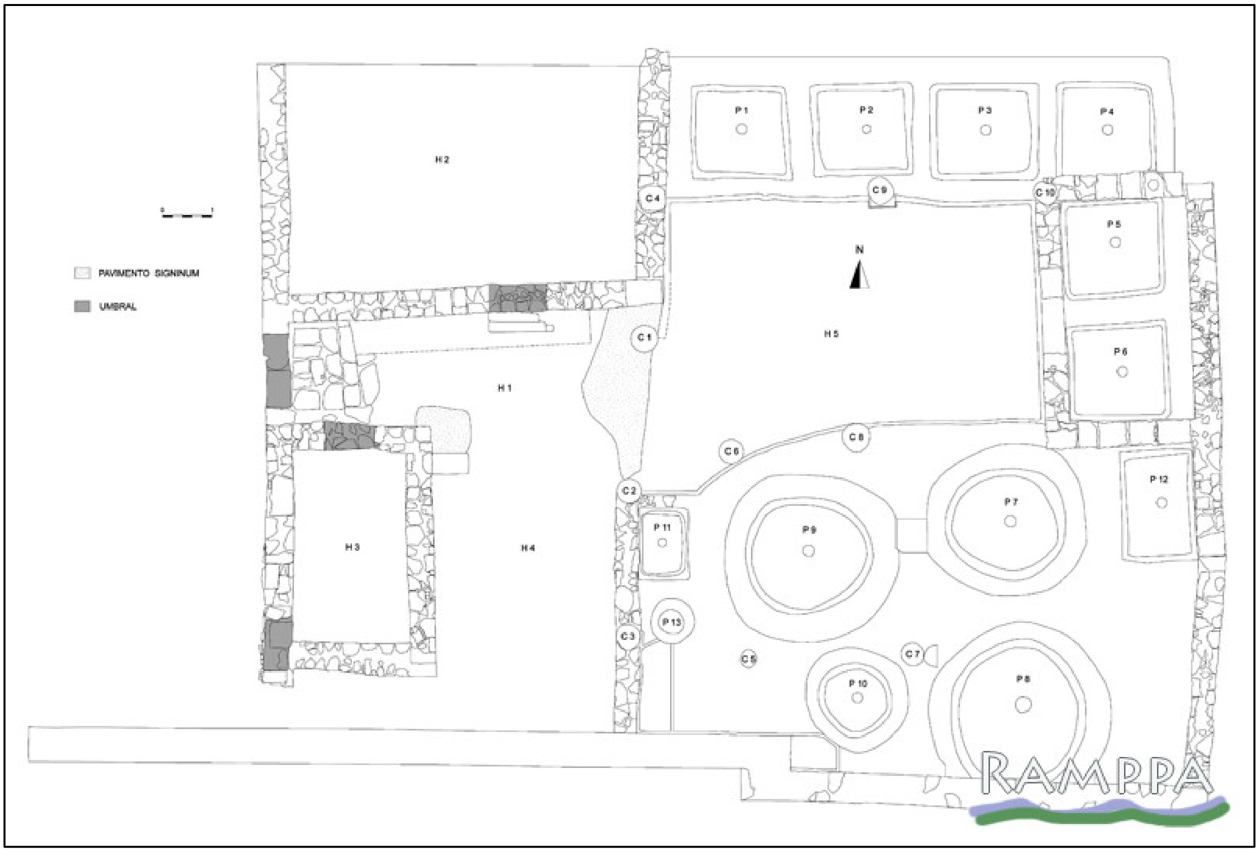

Figure 13: Top plan of Cetaria C.I. VI. Note the distribution of vats, both rectangular and round, around the preparation area, as well as the size of the round vats (Bernal-Casasola and Expósito Álvarez 2016d).

dimensions – about 2 × 2 m wide and 2.5 m deep (Bernal-Casasola and Expósito Álvarez 2016a).

2. *Cetaria* C.I. IV

Cetaria C.I. IV is about 140 m^2 is dated to the 2nd c. CE. The facility is split into six rooms: two empty rooms in the front (east), two rooms in the middle with an additional top locus dating loosely to the late-Roman period (3rd – 5th c. CE), and two rooms in the back (west) that contain eight vats. Excavations here have also unearthed a cistern for storing freshwater, directly beneath the facility (Bernal-Casasola, Expósito, and Díaz 2018: 345). The vats are rectangular and 1.5 × 1.6 × 2 m on average, which is slightly smaller than those in C.I. I. One of the central rooms contains two more smaller vats, approximately 1 × 1 m and 1 m deep, with later dates. All vats are plastered with *opus signinum* (Bernal-Casasola and Expósito Álvarez 2016b).

3. *Cetaria* C.I. V

Cetaria C.I. V is the second largest factory, at about 240 m^2, and is divided into 2 wings (similar to C.I. IV). The western wing includes four rooms, and the eastern wing is comprised of a single room with ten rectangular salting vats. The vats are 1.5 × 2.5 m wide and 1.8 m deep, and surround a plastered floor that, like at C.I. I was likely used as a space for cleaning and gutting fish. This room also has five rectangular windows, likely for air circulation (Arévalo and Bernal-Casasola 2007: 135). This facility is unique among the *cetariae* at Baelo Claudia because its façade is almost completely preserved and indicates the factory had a second floor or vaulted ceiling. Little remains of the material culture beyond the architecture itself, and as such the facility cannot be dated more precisely than the late-Roman period (ca. 3rd - 5th c. CE) (Bernal-Casasola and Expósito Álvarez 2016c).

4. *Cetaria* C.I. VI

This facility is an anomaly among *cetariae*, not only at Baelo Claudia but also across the entire Mediterranean, due to the presence of one small and four unusually large, round vats adjacent to those of the more common rectangular style. All of the vats are plastered in *opus signinum* and surround a similarly plastered, open preparation area. *Cetaria* C.I. VI is split into four rooms and takes up the largest area, over 260 m^2, with a total vat capacity of 90.45 m^3. The 13 rectangular vats range from 0.7 × 1.0 m to 1.5 × 1.5 m, with varying depths. The round vats are conical in shape but also vary greatly in size, from only 0.5 m in diameter to 3 m in diameter and 2.5 m deep (Trakadas 2015: 12). Two interpretations have been given for their abnormal shape: Ponsich (1988: 40) argues that they were used for processing whale flesh, either for salting or to extract oil; Curtis (1991: 52, footnote 39), however, proposes that the circular shape of the vats would have been conducive for stirring fish-sauces, such as *garum* or *liquamen*, in order to create a more evenly autolyzed mixture. These circular vats are the only features that loosely parallel the oval basins found at Dor, but their function remains a mystery until more vats of this formal class are discovered. The earliest loci date to the late-Republican period (2nd-1st c. BCE) and the latest to the late-Imperial period (4th c. CE) (Bernal-Casasola and Expósito Álvarez 2016d).

5. *Cetaria* C.I. VII

At slightly less than 75 m^2, *Cetaria* C.I. VII is the smallest facility at Baelo Claudia. The six salting vats here also possess the smallest cumulative volume – 37.48 m^3. Excavation data indicates that the plan of the facility likely changed dramatically during the Roman period (ca. 1st - 4th c. CE), and it is likely the facility was not initially built as a fish-processing plant. This may account for its small size and relatively small vat dimensions, which range from 1 × 1 × 1 m to 1.7 × 1.7 × 1.5 m. *Cetaria* C.I. VII is the only facility at the site that lacks a central, plastered preparation area (Bernal-Casasola and Expósito Álvarez 2016e).

6. *Cetaria* C.I. X

At present, *Cetaria* C.I. X has only been partially excavated. It exhibits the simplest style, with a long, narrow area paved with *opus signinum* bordered by three to five rectangular vats. Only one of the two known vats, rectangular in shape and 2 × 2 m square by 1.5 m deep, has been fully excavated. There is space in the building for at least one, and up to three, additional vats. This facility is dated stratigraphically to the 1st - 2nd c. CE (Bernal-Casasola and Expósito Álvarez 2016f).

7. *Cetaria* C.I. XI

> The building has been identified as a large salting factory (137.2 m^2), with an overall U-shaped, rectangular plan (14 x 9.7 m). The different spaces are distributed around a central courtyard, including a series of six salting vats to the north, two to the east, and three to the west. There are two smaller vats near the main entrance to the building, which faces the south [Figure 15]. The productive

> capacity of this *cetaria* has been calculated at 90 m^3, making it one of the city's largest. The results of the excavations suggest that the complex was in use over a long period of time; it was built in the early imperial period and seems to have remained active until the early 5th century [CE], as indicated by the materials abandoned on the pavement of the courtyard and by the contents of the fills in the salting vats… The residues collected inside the tanks indicate that, in its latest phase of activity, the *cetaria* was producing fish sauces (*garum*), the main ingredients of which were *Sardina pilchardus* and *Engraulis encrasiculus*.
> (Expósito, Bernal-Casasola, and Rodriguez 2018: 290)

8. *Cetaria* C.I. XII

> The excavations undertaken in 2014 indicated the presence of another hitherto unknown *cetaria* in this area, to the east of the so-called '*domus* of the sundial'. The excavations carried out since have confirmed the presence of a large salting factory, 168.14 m^2 in size, rectangular in plan and equipped with two rows of salting vats (with four and two vats respectively), distributed around a central courtyard where two additional vats, dating to the earliest phase of the building, were also documented [Figure 17]. The productive capacity calculated for this *cetaria* is 106 m^3, more than any other in the city, and the exceptional *in situ* halieutic remains have revealed that its latest productions were tuna belly *salsamenta* and *garum,* made with *Sardina pilchardus* or *Pagellus acarne*… The stratigraphic sequence and the associated ceramic finds indicate that, like C.I. XI, C.I. XII was abandoned in the early 5th century [CE].
> (Expósito, Bernal-Casasola, and Rodriguez 2018: 290)

9. Discussion of Common Features at Baelo Claudia

A few feature classes are common across all of the *cetariae* at Baelo Claudia. The first, and perhaps most obvious feature class present, is the building itself (insofar as a building can be considered a "class" of feature). Each of the *cetariae* constitutes a discrete structure separate from the those immediately adjacent. This is not always the case elsewhere; for example, at Praia de Angeiras in northern *Lusitania* (modern Portugal), 16 salting vats are cut directly into roughly 55 m ^{2} of bedrock in an unorganized fashion (Gil Mantas 1999: 135-156). Since "most fish salteries, large and small, most likely operated independently of any state control" (Curtis 2005: 37), one likely explanation for the organization of each *cetaria* at Baelo Claudia is that they were privately owned, competing factories. Another is that each *cetaria* simply had to fit within the confines of the space available since they are all located within the city walls (Bernal-Casasola, Expósito, and Díaz 2018: 330, 344).

The buildings possess a number of morphological variations. Many (C.I. IV, V, VII, XI, XII) have wall remains with entrances and exits. Rectangular cavities resembling windows remain *in situ* in the walls of facility C.I. V. All have rooms that were likely open to the sky, while roofs supported by pilasters (C.I. XII) and columns (C.I. I, VI, XI) protected others from sunlight and the elements (Bernal-Casasola, Expósito, and Díaz 2018: 345). There are dramatic differences in the surface area of each structure – from 73.15 m^2 (C.I. VII) to 263.29 m^2 (C.I. VI) – and the number of rooms – from 1 (C.I. I, XI) to 5 (C.I. V) – but the largest factories did not necessarily possess the most rooms (see Table 1). In spite of these variations, the Roman practice of organizing fish-processing activity into dedicated facilities is clear.

The second shared feature class is the salting vats – the prime indicator of fish-processing activity throughout the Mediterranean. The vats at Baelo Claudia do not seem to conform to a prescribed size – instead ranging from 0.7 × 1.0 m wide and about 1 m deep (C.I. VI), to 3.0 × 5.8 m and about 2.5 m deep (C.I. XII). All but five of the vats are quadrangular, and most of the medium-sized vats are square (sides are equal length). The smallest and largest vats tend to be more rectangular rather than square, possibly as a result of instances where a building was converted into a *cetariae* or two *cetariae* were merged together; the vats were built to fit or fill the space provided (Bernal-Casasola, Expósito, and Díaz 2018: 345). As mentioned above, the five round vats in C.I. VI are an anomaly in the Mediterranean.

Despite variations in size, the vats were constructed using similar architectural techniques. The vats are built of cut stones set with mortar and sunken into the ground so that the top of the vat is at or slightly above ground level. Most of the rectangular vats have a reinforcing layer of hydraulic mortar along the wall joints. Additionally, *opus signinum* plaster

Table 1: Number of features, dimensions, and production volume of the factories at Baelo Claudia (adapted from Bernal-Casasola, Expósito, and Díaz 2018: 343, Table 4)

Plant	Whole surface (m^2)	No. of vats	Volume (m^3)	Courtyard/ cutting rooms	Surface (m^2)	Other rooms	Surface (m^2)
CI – I	87.36	6	54.44	1	31.5		-
CI-IV	141.81	9	41.32	1	30.72	3	38.43
CI-V	239.4	10	51.75	1	37.59	5	61.87
CI-VI	263.29	13	90.45	1	36.75	4	97.15
CI-VII	73.15	6	37.48	-	-	3	34.27
CI-X	100.5	3/5	17.5/29.16	1	17.51	3	30.72
CI-XI	137.2	11	90	1	40.88	-	-
CI-XII	168.14	8	106	1	36.76	1	12.5
Total	1210.85	66/68	488.94/500.6	7	231.71	19	274.94

waterproofs the inside of many of the vats. Excavations have revealed multiple layers of plaster, indicating frequent repairs (Bernal-Casasola, Expósito, and Díaz 2018: 345).

Large preparation areas, both courtyards and rooms, are the third feature class present in all but one of the factories (C.I. VII). Sizes vary from 17.51 m^2 to 40.88 m^2, as do the location of the preparation area within the *cetariae*: in the front of the building (C.I. I), in the back (C.I. IV, VI), in the middle of the building surrounded by vats (C.I. XI), and in the middle with vats off to one or both sides (C.I. VII, XII after P7 and P8 were covered to increase work space) (Bernal-Casasola, Expósito, and Díaz 2018: 344). Nevertheless, in all cases the preparation area is adjacent to or surrounded by the salting vats, never separated, and plastered with *opus signinum*.

Finally, a fourth feature class – water channels – deserves brief mention. The RAMPPA database makes no reference to water channels bringing freshwater or saltwater to the *cetariae.* However, during a 1979 survey of the area pre-excavation, Dardaine and Bonneville (1980: 386-388) describe finding an ancient pipe or channel (French: *canalization*), buried under the buildings and the street.[1] Trakadas (2005: 57) proposes this channel carried freshwater to the facilities to help with cleaning, however she does not mention its date. Whether the channel was used for this purpose, and where the freshwater came from (two streams flow within 400 m of the site in the present day: *Arroyo de las Viñas* to the west, and *Arroyo del Alpariate* to the east), remains unknown.

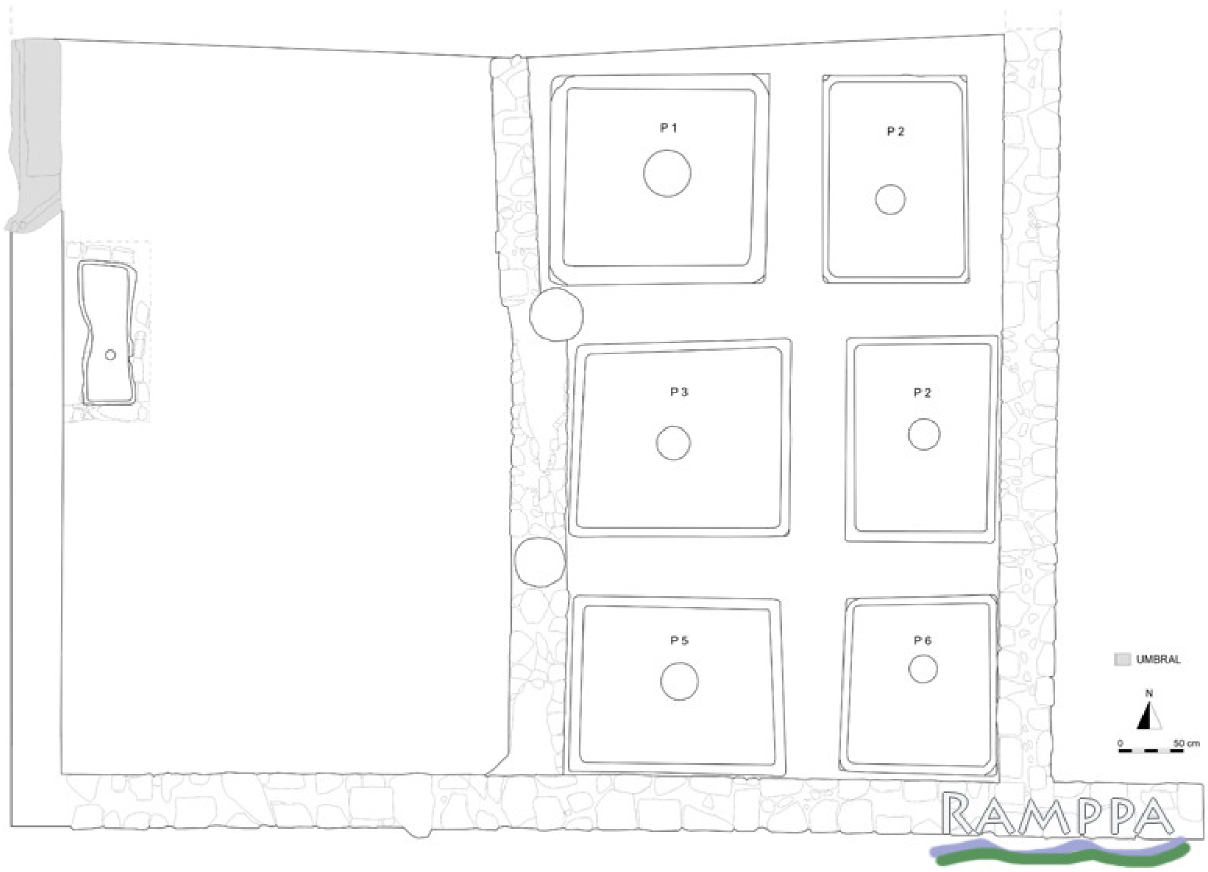

Figure 14: Top plan of Cetaria C.I. I with rectangular vats (P1-P6) adjacent to a large plastered preparation area with a washing basin (Bernal-Casasola and Expósito Álvarez 2016a).

[1] *"Le sol de la pièce I est parcouru par **une canalization** d'aspect très rustique don't la couverture, irrégulière, dépasse parfois le niveau du sol. De cette **canalization**, qui est orientée grosso modo nord-sud, part une ligne de dalles vers l'est qui bute sur le mur de cloture de l'insula le long de la rue 4: leur depose n'a fait apparaître aucune ramification de **la canalization** susdite…*

*On remarguera en effet que **la canalization** contourne par l'oust la pierre-socle et ménage un espace qui est à peine plus grand que le diameter de la vasque en question. Si cette hypothèse est exacte, la ligne de dalles qui part de **la canalization** et va jusqu'au mur oriental reçoit alors une explication: le dallage de **la canalization** complete par des dalles supplémentaires, le tout formant un vaste arc de cercle, aurait constitué une aire d'évolution renforcée au-desus du sol qui apparaît relativement fragile sous la pioche"* (Dardaine and Bonneville 1980: 387, emphasis added).

Even amidst great variation in the internal spatial organization between the *cetariae*, three classes of features stand out as emblematic of Roman fish-processing factories – a single unifying structure (the “factory”), rectangular salting vats of varying sizes, and a large preparation area. O*pus signinum* plaster, especially when used to waterproof a prodigious number of surfaces (e.g., whole rooms, floors, vats, and basins), is also a strong indicator of fish-processing activity. Additional features are present on a case-by-case basis, but the aforementioned three features are ubiquitous at Baelo Claudia.

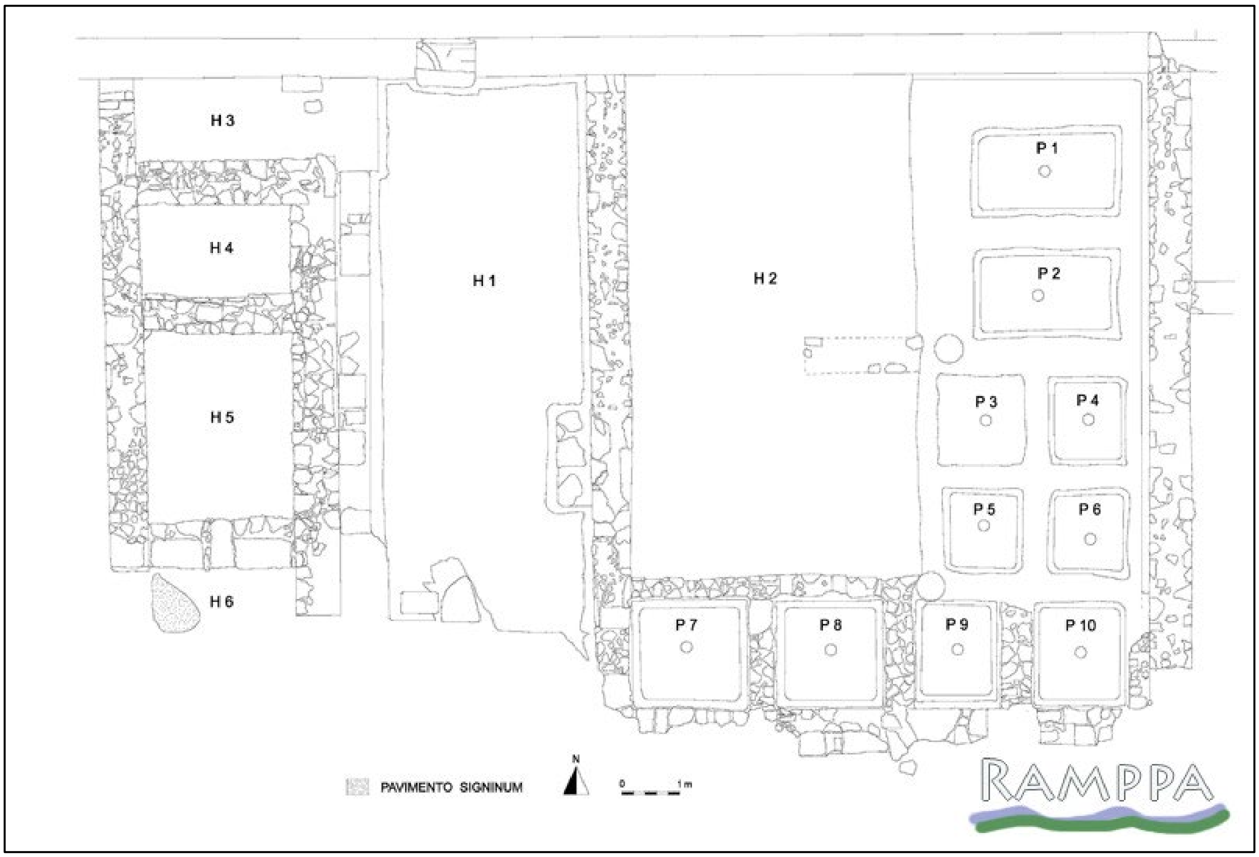

Figure 15: Top plan of Cetaria C.I. V with rectangular vats (P1-P10) and a large plastered preparation area (H2) (Bernal-Casasola and Expósito Álvarez 2016c).

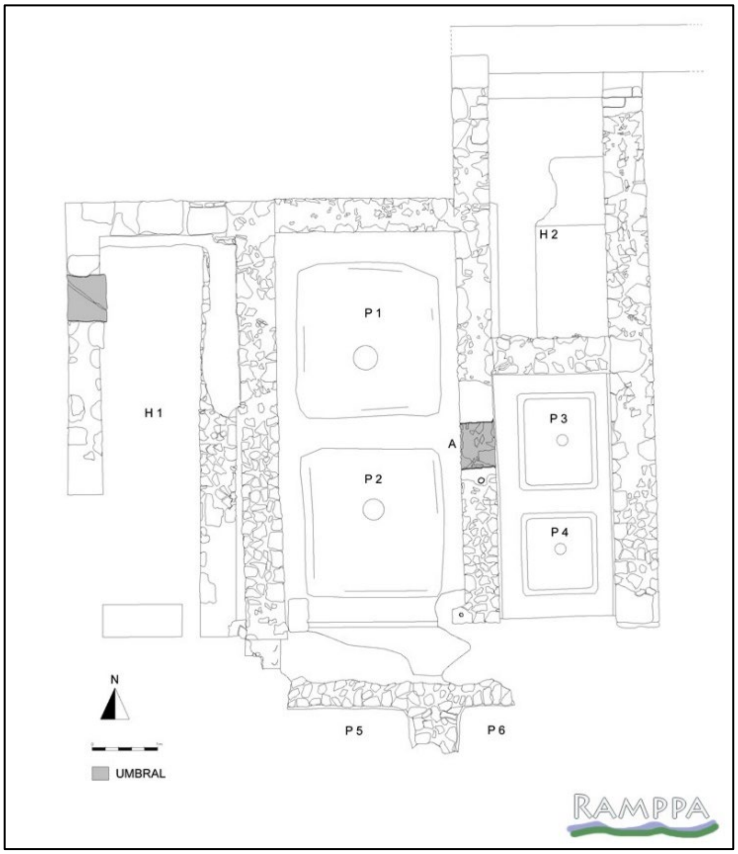

Figure 16: Top plan of Cetaria C.I. VII with rectangular vats (P1-P6) (Bernal-Casasola and Expósito Álvarez 2016e).

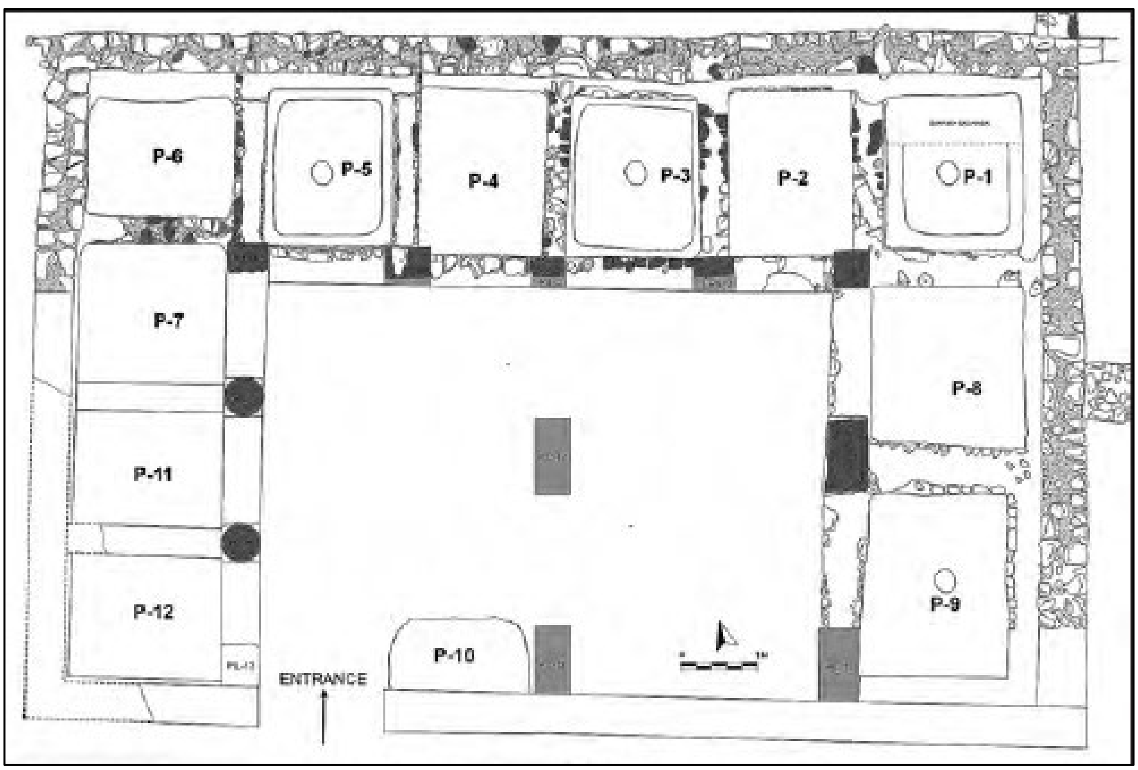

Figure 17: Top plan of Cetaria C.I. XI with rectangular vats (P1-P12) in a U-shape around a large preparation area (center) (Expósito, Bernal-Casasola, and Rodriguez 2018: 292, Fig. 2).

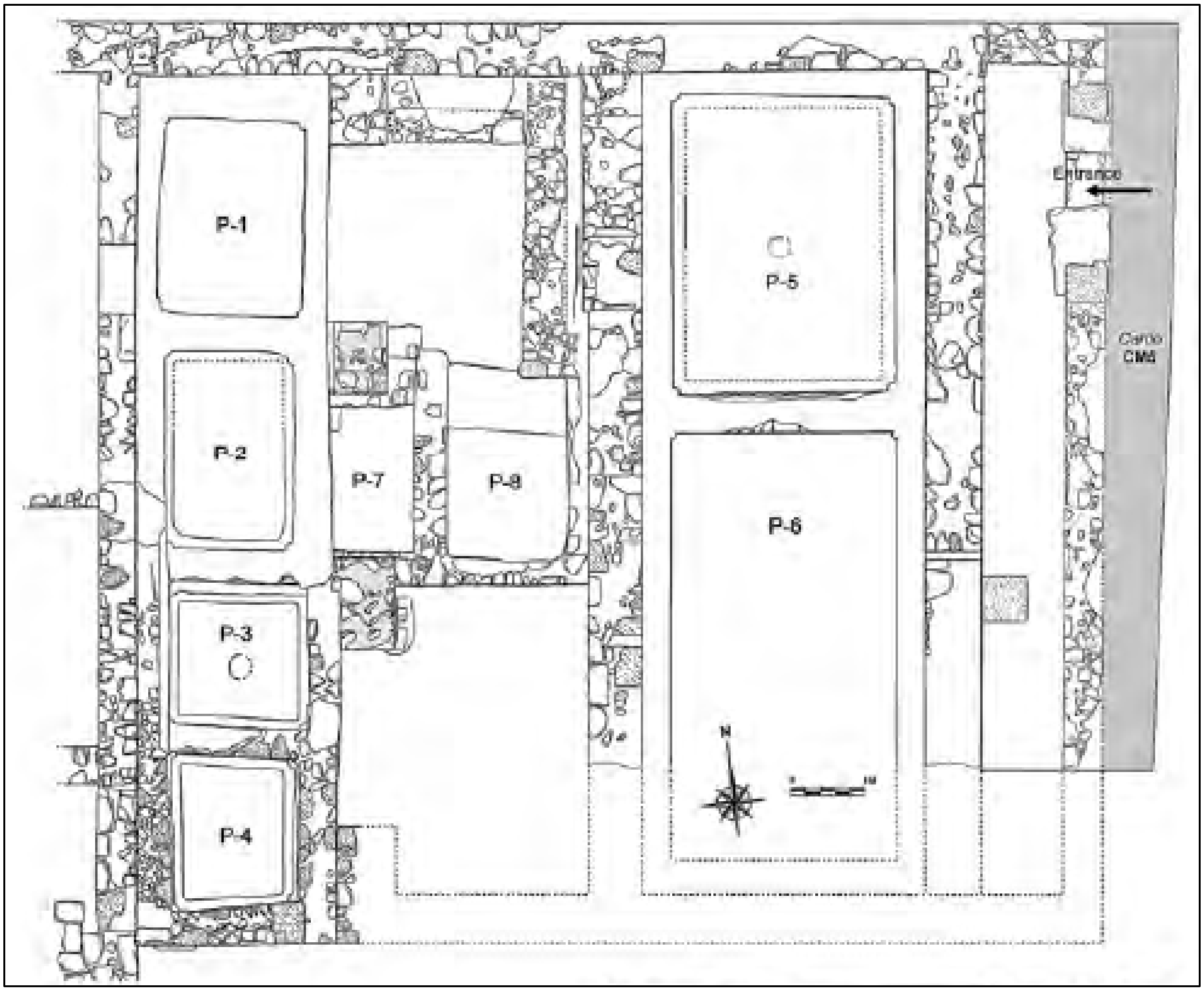

Figure 18: Top plan of Cetaria C.I. XII with rectangular vats (P1-P8). A small preparation area is situated south of P8 and east of P3-P4 (Expósito, Bernal-Casasola, and Rodriguez 2018: 293, Fig. 3).

A Roman *Cetaria* in Cotta

The *cetaria* at Cotta is possibly the best-preserved fish-processing facility in the northwest Maghreb, an area with over 30 identified fish-processing plants to date. Cotta is located on the Atlantic coast of modern Morocco, 4 km south the Strait of Gibraltar and only 40 km south (across the Strait) of Baelo Claudia in Spain. A cursory survey of the site occurred in 1878 (see Tissot 1878), but it was largely left untouched until Michel Ponsich and Miguel Tarradell conducted excavations there in the early 1960s and published their findings soon after

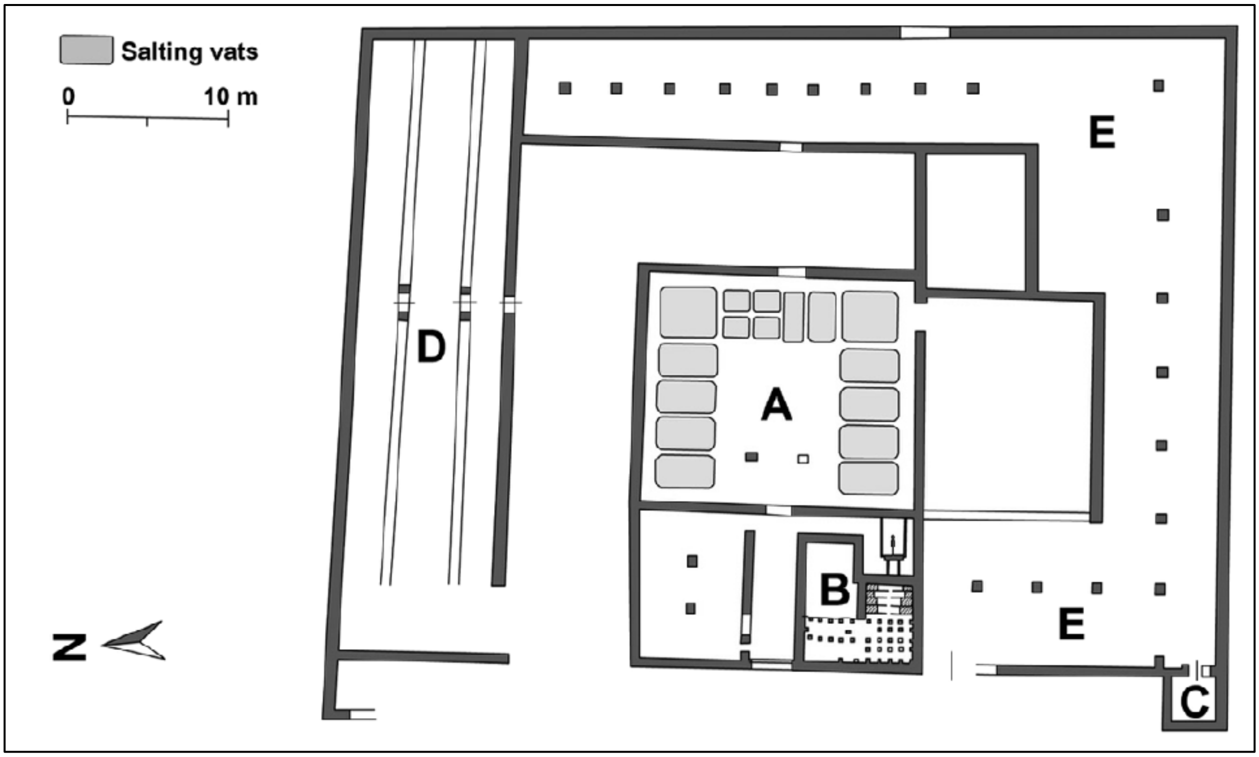

Figure 19: Top plan of the cetaria at Cotta, Morocco: (A) large paved floor surrounded by salting vats; (B) room with hypocaust heating system. (C) possible tunny watchtower; (D) preparation area; (E) storage area. Note the centralized location of the preparation floor within the salting vats (Marzano 2013: 103, Fig. 18).

(Ponsich 1988; Ponsich and Tarradell 1965). Athena Trakadas returned from 1999-2005 to survey the site for a gazetteer on fish-processing plants in the northwest Maghreb (Trakadas 2015), and found the factory overgrown with vegetation but still visible. Trakadas notes in her entry on Cotta that the dimensions published by Ponsich and Tarradell are inaccurate; therefore, the measurements given below are from her publication (2015: 40-43) unless otherwise noted.

1. **Factory Structure and Salting Vats**

Cotta has been dated to the 1st c. BCE – 3rd c. CE (Marzano 2013), with most of the material dating to the middle of the 1st c. CE (Trakadas 2015: 40). The site itself is large, about 56 × 40 m, and the main work area within the factory is 25 × 19 m (Figure 18). The 16 salting vats are arranged in a U-shape around a plastered (likely *opus* signinum, but not specified) central preparation area, a configuration similar to *cetariae* C.I. V (Figure 14) and VI (Figure 12), and nearly identical to C.I. XI (Figure 15) in Baelo Claudia. The vats vary in size – from 1.3 × 1.3 (the four smallest, grouped on the east side), to 3.5 × 3.5 m (the two square vats in the NE and SE corners) – and set into the floor so that their top is slightly above the walking surface. Ponsich and Tarradell suggest that the group of four small vats was used to manufacture fish sauces rather than *salsamenta* (Trakadas 2015: 40). Why this may have been the case is not specified. Depths are difficult to determine due to collapse, but all of the vats are deeper than 2 m (Marzano 2013: 103). Altogether, the factory had a total capacity of 258 m^3.

2. Storage Area

Near the salting room to the east and south is a large, L-shaped storage area. The bases of columns run through the middle of this area, indicated it was protected by a roof. Trakadas (2015: 40) mentions that "a 'large number of amphorae' (unspecified as to type)" were found during excavations in the 1960s. To the north is another long room of unknown purpose (possibly additional preparation or storage space).

3. Tunny Watchtower

In the southwest corner of the factory lies a small, thick-walled room that Ponsich and Tarradell (1965: 60-61) propose was a watchtower. Ancient texts (particularly Strabon 5.2.6, 5.2.8, 11.2.4) mention similar towers, which fisherman used to observe the movement of passing schools of migratory fish. As Cotta is only a few hundred meters south of a major promontory (Ras Achakar), it is also likely that a dedicated structure was not needed to observe the movement of fish.

4. Freshwater Features

A cistern (86 m^3) for storing fresh rainwater lies beneath the central courtyard, with the roof of the cistern holding up the paved preparation floor. A perennial stream, the Oued Khil, flows nearby. Additional freshwater sources are also present: Tissot (1878: 188; citation in

Trakadas 2015: 41) mentions a deep, lined pit under the northern storage area which possibly served as a well, pools distributed around the site for collecting water from a channel that originates on a small hill to the northeast, a canal (pre-Roman) bringing water from a spring to the north, and the remains of an undated aqueduct that have since disappeared. Detailed descriptions of these features are sparse, but together they suggest that freshwater was easily accessible at site.

5. Hypocaust System

In the southwest corner of the central work area, excavations uncovered the remains of a hypocaust system and ceramic cookware. Hypocausts are rooms with hollow walls, and floors built over a hollow cavity supported by small pillars of terracotta plates. Pipes or cavities connect this subfloor space to a furnace outside, where the difference in air density draws in smoke and heat. The hot air then circulates beneath the floor and up the walls, evenly heating the room to a desired temperature (for more on hypocaust construction, see Bansal 1998). Ponsich and Tarradell hypothesize that this and the cookware suggests fish sauces were reduced in the artificial heat (rather than in direct sunlight, as is believed to be the case elsewhere, see "*Chaîne Opératoire* for *Salsamenta* Production" below). Trakadas (2005: 67-8; 2015: 40) notes that this room could also be used for heating seawater or sand to extract salt for fish-salting, but this is less likely. In either case, it is noteworthy that this type of artificial heating system is not present in any of the *cetariae* of Baelo Claudia.

6. Comparing the Features at Cotta with Baelo Claudia

The *cetaria* at Cotta is notably similar to those at Baelo Claudia. The three features indicative of fish-processing – a factory building, rectangular salting vats, and large preparation area – are all present in a nearly identical spatial configuration to those in Baelo Claudia. The building itself forms a discrete, complex facility. It covers a much larger surface area, nearly double the combined size of all *cetariae* at Baelo Claudia, but this is likely due to the extra space available at Cotta since it is not within the confines of a city wall or streets. The dimensions and shape of the vats fit within the range displayed at Baelo Claudia, and the presence and quantity of *opus signinum* plaster matches that standard as well. Additionally, the vats surround a large, open, plastered workspace.

Cotta also shares similarities with one or more of the *cetariae* at Baelo Claudia. Access to freshwater is much more prevalent here than in Baelo Claudia, where cisterns are only present beneath C.I. IV. This suggests freshwater played a large role in the production of salted fish,[2] and further supports Trakadas' interpretation of the underground channels at Baelo Claudia. The facility at Cotta also has an immense amount of storage space that, again, is likely due to the additional space available. Some of the *cetariae* in Baelo Claudia (C.I. IV, V, VI, VII) do have storage rooms, but they are much smaller in size.

The *cetaria* at Cotta also has a few unique characteristics. The alleged fishing watchtower is, in form, unique to Cotta but, in function, analogous to the bluffs north and south of Baelo Claudia. The noteworthy anomaly at Cotta is the hypocaust system. This system suggests, if Ponsich and Tarradell are correct, that the demand for fish sauce was high enough here to warrant the construction of a dedicated facility for artificial heating. Excavations at C.I. XI and XII in Baelo Claudia revealed *garum* residue and leftover fish material in salting vats

Summary of Features at Fish-Processing Facilities

In sum, the descriptions above highlight the features and finds that are indicative of fish-processing facilities:

[2] Sánchez López (2018) argues that freshwater sources are not only common at a majority of known fish-processing facilities, but freshwater is essential to various steps of the *salsamenta* and *garum* production process.

1. A structure, of variable size and shape, that contains the architectural features and space required for fish-salting and fish sauce production
2. Rectangular salting vats, also of variable size, plastered in *opus signinum* and set into the floor
3. A large preparation area for the washing and gutting of fish, also plastered in *opus signinum*
4. Features that provide access to freshwater – wells, cisterns, channels, aqueducts

And the features and finds that are common, but not necessarily indicative, of fish-processing:

1. Space for packing and storing the finished *salsamenta* or fish-sauce product
2. A watchtower for viewing the migration of desirable fish
3. Smaller vats exposed to the sun, or ceramic pots, for mixing and heating fish sauces
4. A hypocaust system for artificially heating fish sauce in pots

These two lists will factor prominently in the following section on *chaîne opératoires*, as they contain the archaeological indicators of steps in the fish-salting and fish sauce production processes. The astute reader will have, at this point, already begun noting similarities between the six feature classes at the industrial complex at Tel Dor and the industrial complexes – *cetariae* – at Baelo Claudia and Cotta. These similarities will be explicitly discussed in the section, "Reinterpreting the Industrial Complex."

A Note About *Piscinae* and an Example from Israel

Rock-cut pools are absent at both Baelo Claudia and Cotta. Raban relies heavily on the form and function of the rock-cut pools and water channels in his interpretation of the Dor industrial complex:

> One possible use [for the rock-cut pools] could have been as hatching pools for the larvae of the gray mullet (*Mugil cephalus* and *Mugil capito*) … Another

> alternative may have been the harvesting of *murex* shells for the manufacture of purple dye, known to have taken place at Dor.
>
> (Raban 1995: 301)

Thus, the lack of rock-cut pools and water channels at Baelo Claudia and Cotta is particularly notable and deserves investigation. The form of the two pools at Dor are similar to other rock-cut features around the Roman Mediterranean, in particular the simple *piscinae* of Tunisia, Crete, and the southern Levant. The absence of *piscinae* at Baelo Claudia and Cotta is likely due to the local topography and the distance between these *cetariae* and the water. The sites are located at 70 m (Baelo Claudia) and 250 m (Cotta) from the sea, on the inland side of a wide, sandy beach with no exposed bedrock. In this setting, with the sea immediately accessible yet not directly adjacent to the factory, a set of dedicated fishponds may have been unnecessary and difficult to maintain. We are therefore left to search elsewhere for relevant archaeological parallels.

The size of *piscinae* varies dramatically from site to site, and few are found in an industrial context like at Dor, so a brief description of simple Roman *piscinae* in general and a description of a local example in Israel, the palace *piscinae* at Caesarea Maritima, will be sufficient here.

Roman *piscinae* were specifically designed to provide a suitable environment for the storage and breeding of live fish. Based on archaeological evidence, commercial aquaculture in the Roman Empire began as early as the 1st century B.C. (Kron 2008b: 175-6). It was around this time that the Roman fishing industry transitioned from standard subsistence fishing (see Kron 2008a: 206) to an intensive aquaculture enterprise that required breeding (see Kron 2008a: 211) and hydraulic engineering expertise, and often involved the construction of these specially designed pools (Marzano 2013: 205-6).

Marzano (2013: 213-33) loosely separates *piscinae* into two morphological categories – complex and simple. Complex fishponds are comprised of larger pools built from coastal bedrock and ashlar stones, with internal divisions and channels “almost like the wooden box of a painter, which has different compartments for the various pigments” (Marzano 2013: 213). This type occurs almost exclusively within the Italian peninsula. In contrast, simple fishponds are the most common type elsewhere and are usually a single pool, smaller in size, cut directly into the coastal bedrock. Surface dimensions vary significantly even within a local assemblage, and size does not necessarily proportional with complexity. Some were complex private ponds on the order of tens of square meters, like those constructed by wealthy Romans in villas (see Higginbotham 1997: 55-64), while others were large, simple, industrial *piscinae* used for mass-breeding fish for export (an impressive example is the fishpond of Torre Astura, near Anzio, which has a surface area of approx. 15,000 square meters, see Marzano 2013: 217).

A description of the criteria for Roman *piscinae* construction survives from the 1st c. CE in the works of Columella (VIII.17, 1-16). According to him, fishponds (both simple and complex) cannot function properly without a few considerations. Two traits in particular are shared by a majority of known fishponds: (1) channels connecting the pools to the ocean, allowing consistent circulation of fresh saltwater and oxygen into the system (Columella: VIII.17, 3-4; Kron 2008b: 179; Marzano 2013: 213-8); and (2) an adequate water depth of usually 2-4 m to give the fish space to move while also protecting them from the adverse effects of quick temperature changes (depth was also dependent on the local geology and prestige of the fishpond owner, see Columella: VIII.17, 3-4; Davaras 1974: 91; Leatham and Hood 1959: 265). Additional features are common in the textual and archaeological records, but they often vary by region or site, by the size of the *piscinae*, or do not leave distinct architectural evidence (e.g., extensive artificial feeding practices, see Kron 2008b: 179). Additionally, fishponds described in textual sources like Columella should be viewed as “hypothetical or perhaps ideal archetypes

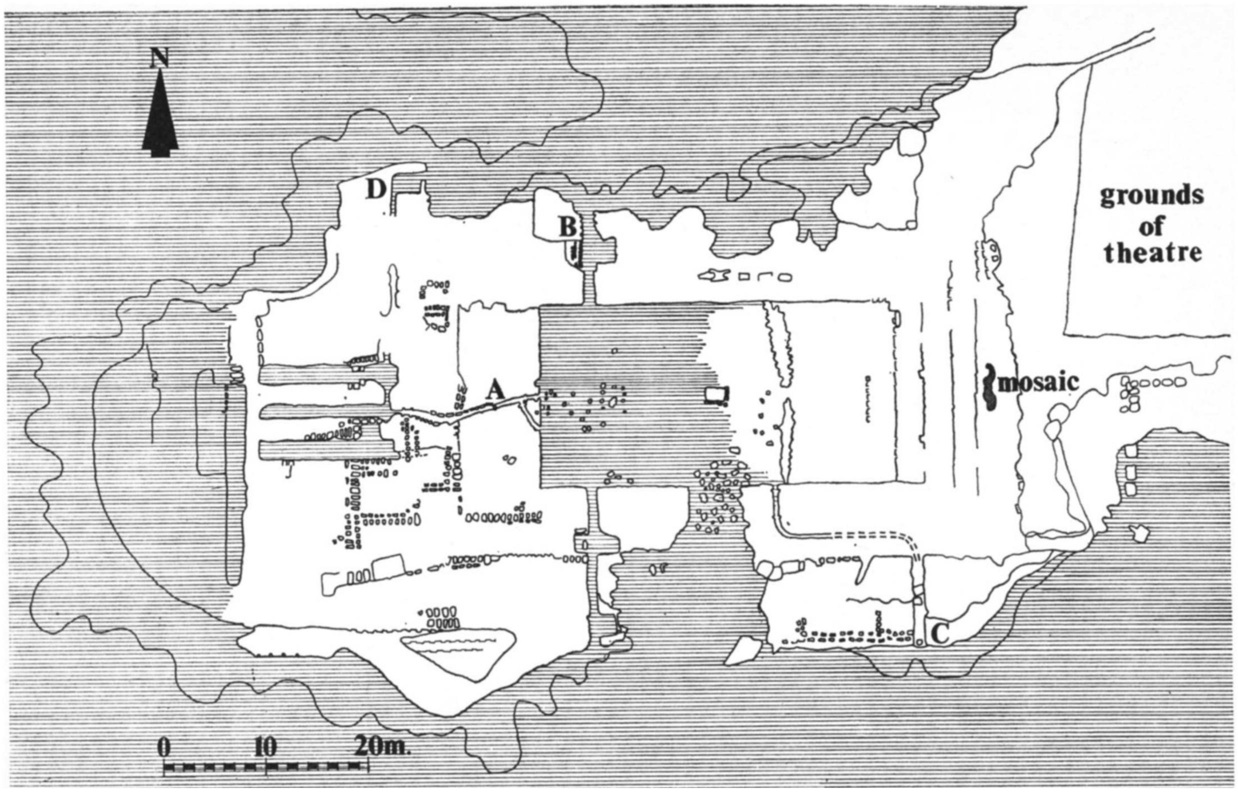

Figure 20: Top plan of the piscina at Caesarea Maritima. Note inlet and outlet channels (A and B) (Flinder 1976: 78, Fig. 1).

[that] do not adequately characterize the variety of designs and systems used by the Romans" (Higginbotham 1997: 10).

The fishpond at the promontory palace of Caesarea Maritima (Figure 19), just south of Tel Dor, proves that the common "simple" style described above was also used in the southern Levant. The central pool is large, about 35 × 18 m (Flinder 1976: 77), and joined via a channel to three smaller tanks to the west. The *piscina* is fed new saltwater from the Mediterranean by at least three additional channels, each with at least one sluice gate to control the flow of water in and out of the tank. A partial sluice gate, in the form of a pockmarked stone slab that could be raised and lowered, is still present in its niche in the western channel. The channels and sluice gates allowed the users to regulate the rate of circulation within the system.

The depth of the palace *piscina*, like other fishponds around the Mediterranean (including the two at Dor), is difficult to accurately measure due to sedimentation and rubble fill. However, Flinder (1976: 80) comments that, "the fact that with some clearance and reconstruction, the tanks very likely could be brought back to an operating condition, shows that the level of the sea in relation to the tanks is little different from that when the complex was first built." Contemporary observation at Caesarea also indicates that the modern sea-level still fills the pool as intended during tide changes. If the tide at Caesarea during Roman times fluctuated by about .5 - .8 m (Sivan et al. 2004: 322), and the heavily eroded floor surrounding the pool now sits almost .5 meters above MSL (Gleason et al. 1998: 43), it follows that the pool would have been 1-1.3 m deep *at minimum*, just shy of Columella's recommended depth of 2 meters. As it is likely that the depth was much more, the *piscina* is around the normal prescribed depth for fish aquaculture.

Having thus presented two sites – Baelo Claudia and Cotta – with formal similarities to the Dor industrial complex, and another – Caesarea Maritima – with similarities to the rock-cut pools and channels, I now transition to developing a dataset that addresses the function of these sites.

ANALYSIS BY ANALOGY: THE *CHAÎNE OPÉRATOIRE* AS ANALOGOUS FUNCTION DATA

A History of an Anthropology of Technology

The function of a specific artifact or feature derives from the technological processes that occur as part of that function. For technology and technological processes to be analyzed rather than merely described, *technology* must itself be defined, and then those processes quantified.

A consensus in anthropological literature on the definition of “technology” has not yet been established, however, and a brief discussion of the term is warranted before any attempt can be made to address it in the archaeological record. The word *technology* – from the Greek word *τεχνολογία* (*tekhne* [skill or art] + *logos* [discourse]) – entered colloquial English sometime around the early 1930s in response to the growing need to unify such terms as “useful arts,” “manufacturing,” “industry,” “invention,” “applied science,” and “the machine” (Schatzberg 2006: 486-9). Similarly, the recent popularization of personal computers has led to “technology” or “tech” being used synonymously with “digital” or as a label for any object or process that requires an electrical current and computer chip. One might speak of someone’s addiction to technology, tech company stock, or perhaps the advent of technology (if there can be such a thing). The fact that the word was rarely used before the twentieth century notwithstanding, this

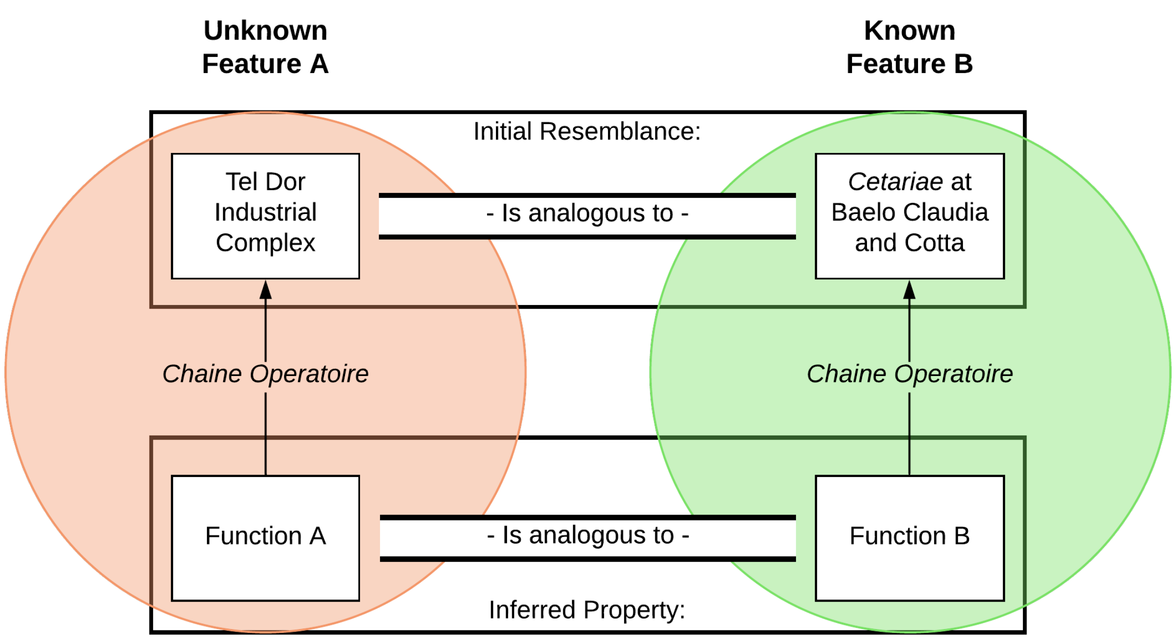

Figure 21: Diagram of the analogy, showing the proper situation of relevant archaeological form datasets within the model.

modern connotation is of little use to any anthropologist interested in a time before IBM's first room-sized computers or even Edison's lightbulb, and should be discarded. Nevertheless, in their attempts to produce a more universally useful definition of technology, anthropologists have fallen into two disproportionate views of technology's role as a cultural force.

On the one hand, it is sometimes assumed that technology is merely the process of making and using – a ubiquitous relationship between actor and action "too obvious to merit serious reflection" (Pfaffenberger 1988: 238), or bear more than cursory investigation. This definition results in what Langdon Winner (1986) has dubbed *technological somnambulism*, whereby the complex pattern of cultural decision-making inherent in any technological process is oversimplified into an instance of action and result. Doing so ignores the social factors that influence components of the technological process, such as what materials are used, what actions and gestures are performed, what actors are participating, and most importantly, why these components are a part of one process when similar components that result in the same finished product are arbitrarily rejected (Lemonnier 1992: 51). While this simplification may have its uses as a way of dealing with these complex questions when they are not the primary subject of investigation, it does not allow for any quantification of technological components or a discussion of significant differences between technological processes across space or time.

On the other hand, some (e.g., Ellul 1964; Habermas 1970; Heilbroner 1967; Miller 1984) use technology as an umbrella term incorporating all cultural subsystems (and in the case of Heilbroner, even culture itself), thereby assigning technology "the *central* place and *directive function* in human development" (Mumford 1966: 4). When technology is given such transformative power in the cultural system, technological innovation can be interpreted as linear and autonomous (to varying extents, see Bimber 1990: 340; Pfaffenberger 1988: 239). The path of technological development is somehow predetermined or universal and one innovation in turn necessitates the development of further technologies to facilitate it. This *technological determinism* gives technology more power to change cultural subsystems than the technology users themselves have, and largely ignores the possibility of external, non-technological influences. As a result, individual moments of change within a technological sequence over space or time seem predestined, thereby losing significance as indicators of cultural activity or social preference.

Defining *Technology*

My approach synthesizes definitions of technology given by Pierre Lemonnier (1992; 1989) and Blanca E. Maldonado (2018). First, Maldonado asserts that an anthropological view of technology should include three features: (1) that it is "the manipulation of the material world to effect energy transformations" and represents "a set of knowledge, skills, and materials (apparatus) necessary to alter the order… of some set of energy forms or achieve an energy conversion"; (2) that it is "a subsystem of culture subject to evolutionary processes of adaptation and selection"; and (3) that it is "human-generated, and thus the result of human intentions and human decisions… [and] therefore, is intrinsically behavioral (2018: 8). Lemonnier takes this further, defining *technology* as "all aspects of the process of action upon matter" (1992: 1), and dividing it into five constituent parts:

1. *Matter*—the material, including one's own body, on which a technique acts (e.g., clay, water, iron, sweet potatoes, aluminum).

2. *Energy*—the forces which move objects and transform matter.

3. *Objects*, which are often called artifacts, tools, or means of work. These are "things" one uses to act upon matter: a hammer, hook, steam-roller, or artificial salt-pond. It must be noted that "means of work" includes not only things that can be held in the hand; a factory is as much a means of work as is a chisel.

4. *Gestures*, which move the objects involved in a technological action. These gestures are organized in sequences which, for analytical purposes, may either be subdivided int "sub-operations" or aggregated into "operations" and then

into "technological processes" [all of which are called "operational sequences" by Lemonnier] …

5. *Specific knowledge*, which may be expressed or not by the actors, and which may be conscious or unconscious. This specific technological knowledge is made up of "know-how," or manual skills. The specific knowledge is the end result of all the perceived possibilities and the choices ["social representations"], made on an individual or a societal level, which have shaped that technological action… Some examples of social representations which shape a technology or technological action are: (a) the choice to use or not use certain available materials; (b) the choice to use or to use certain previously constructed means of action on matter (a bow and arrow, a car, a screwdriver); (c) the choice of technological processes (i.e., sets of actions and their effects on matter), and the results of these processes (e.g., a cooked meal, a house, or recently killed game); and (d) the choice of how the action itself is to be performed (a conception that it is the woman's role to cut firewood, or the man's to make fences for gardens).

(Lemonnier 1992: 5-6)

Matter, energy, objects, gestures, and specific knowledge are not often displayed clearly in the archaeological record, and almost never as a complete set. Although all five components can leave behind some form of material evidence, matter and objects are often considered to be the most accessible to archaeologists; they make up a majority of what we would call *material culture*. Nevertheless, we must always be cognizant of biases in the archaeological record resulting in some materials (e.g., stone, iron) preserving more readily and completely than others (e.g., bone, wood) due to their physical properties (Renfrew and Bahn 2012: 307), or artifacts that survived due to them being hidden away from destruction or looting (e.g., in burials or shipwrecks). Energy is not observed directly but can leave behind traces (e.g., chisel marks) that may indicate – always with proper context – the forces applied for a specific task. Specific knowledge survives most readily (although not exclusively) in ancient texts. While we do have an ever-growing library of texts from the Roman period, it will quickly become apparent below that ancient texts alone provide limited data for us to use, even regarding two technological processes as significant as *murex* dye and *salsamenta* production.

Finally, gestures (also called techniques) are perhaps the most significant of all of the components since they unite the other four in the form of an action. It is a gesture that brings energy to bear on matter through an object (e.g., a hammer is *swung* to hit nails into a wood plank); an object is only useful as a tool when specific knowledge produces a correct gesture to be used (e.g., a hammer is only useful for hitting nails if *swung*); specific knowledge produces an operational sequence of gestures (e.g., hitting nails with a hammer is only possible if a carpenter first *grabs* a hammer and nail, then *positions* the nail with their fingers out of the way, then *swings* the head of the hammer onto the nail). Yet paradoxically, gestures are often the most overlooked component in archaeology, likely due to the (understandable) preference given to the material culture itself and not techniques that produced it (Lemonnier 1992: 6).

*Chaîne Opératoire*s and the Relationship Between Form and Function

An operational sequence of gestures, known as a *chaîne opératoire*, is the analytical tool used here to produce an analogical dataset for the technological processes practiced at Tel Dor. The six feature classes found at the Dor industrial complex possess a unique set of physical attributes (i.e. the form of the architectural elements and their spatial relationships) analogous to the features at fish-processing facilities. This is not, however, enough to argue that their formal similarities indicate functional similarities. Recalling Binford, the strength of the analogy is conditional upon whether or not the inferred property – the functional similarities between Tel Dor, Baelo Claudia, and Cotta – accounts for the positive analogy – the formal similarities between Tel Dor, Baelo Claudia, and Cotta (Figure 21).

The *chaîne opératoire* method, developed in the 1950s by French archaeologist André Leroi-Gourhan, is a way to quantify technology that facilitates the comparison – across cultures, over space, and through time – of operational sequences of similar technologies (Lemonnier

1992: 26). A *chaîne opératoire* is often presented as a flow diagram, with the gesture component driving a series of discrete inputs and outputs along the sequence. The four other components are plotted on the flow diagram as they relate to the sequence of gestures. *Chaîne opératoire*s can rapidly become complex, as seen in Figure 22, where parallel *chaîne opératoire*s for net, salt, and storage jar production should be expanded to fully understand the process of turning fish into *salsamenta*.

Chaîne opératoire models are well-suited for defining technological processes, especially when it is not possible to ethnographically observe those processes in real time. In many circumstances, ethnographic observation of analogous, modern sequences can illuminate steps that might otherwise be hidden to the archaeologist (i.e. those steps that would not leave behind material evidence for us to excavate); however, we do not always have that luxury. In all cases, it is important to note what data are observed in the archaeological record, those

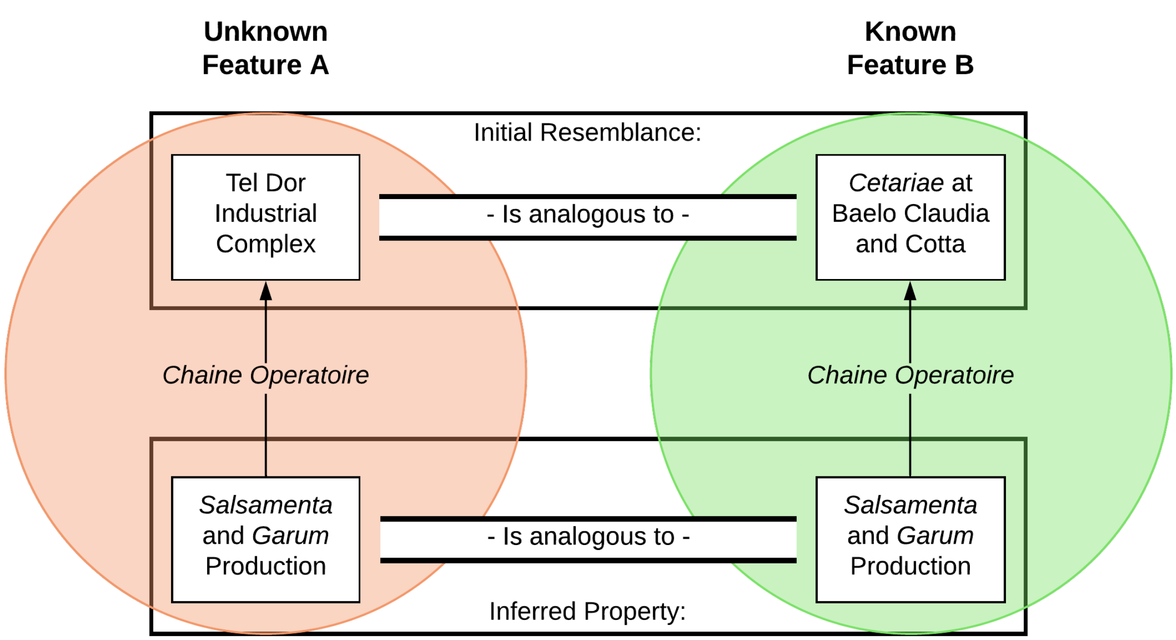

Figure 22: Diagram of the analogy, showing the proper situation of relevant archaeological form datasets and relevant production function datasets within the model. Note how the chaîne opératoire defines the relationship between the form and function of each feature.

archaeological correlates of gestures, and what parts of the *chaîne opératoire* are interpreted from preserved material or adopted from relevant textual evidence.

When developing a *chaîne opératoire* from the archaeological record, certain considerations must be made to account for uncertainties arising from these limitations. First, any archaeologically derived *chaîne opératoire* must remain flexible to incorporate new data as it becomes available. A modern ethnographer, or in this case a technographer, has access to audio and video recording equipment that helps capture an entire *chaîne opératoire* in real time; the relationship between physical and abstract components is readily observed. Even with advances in cyber-archaeological techniques (such as photogrammetric modelling of excavations and material, GIS databases, and virtual reconstruction), the most meticulous excavations reveal only an incomplete picture of the past. Archaeologists cannot (or certainly *should not*) be in the business of making archaeological laws, as this assumes a cultural and social consistency across space and time that is simply not realistic. Modelled operational sequences, therefore, should not be viewed as true for every instance of that process in the record.

Second, a *chaîne opératoire* should either be specific to the location and time period under investigation or generalized for the purposes of comparing material evidence from a specific location and time period in order to determine discrepancies between what material is expected and what material is present. This consideration may seem obvious – for example, it is nonsensical to use the *chaîne opératoire* of a modern Boeing 747, made with titanium in an automated factory, to accurately represent the production process of the 1903 Wright Flyer, made with wood by hand. Nevertheless, the deeper one looks into the past the more tempting this becomes due to an increased lack of data. Ethnographic data is useful in this case but should not be considered an exact replica of the ancient *chaîne opératoire*.

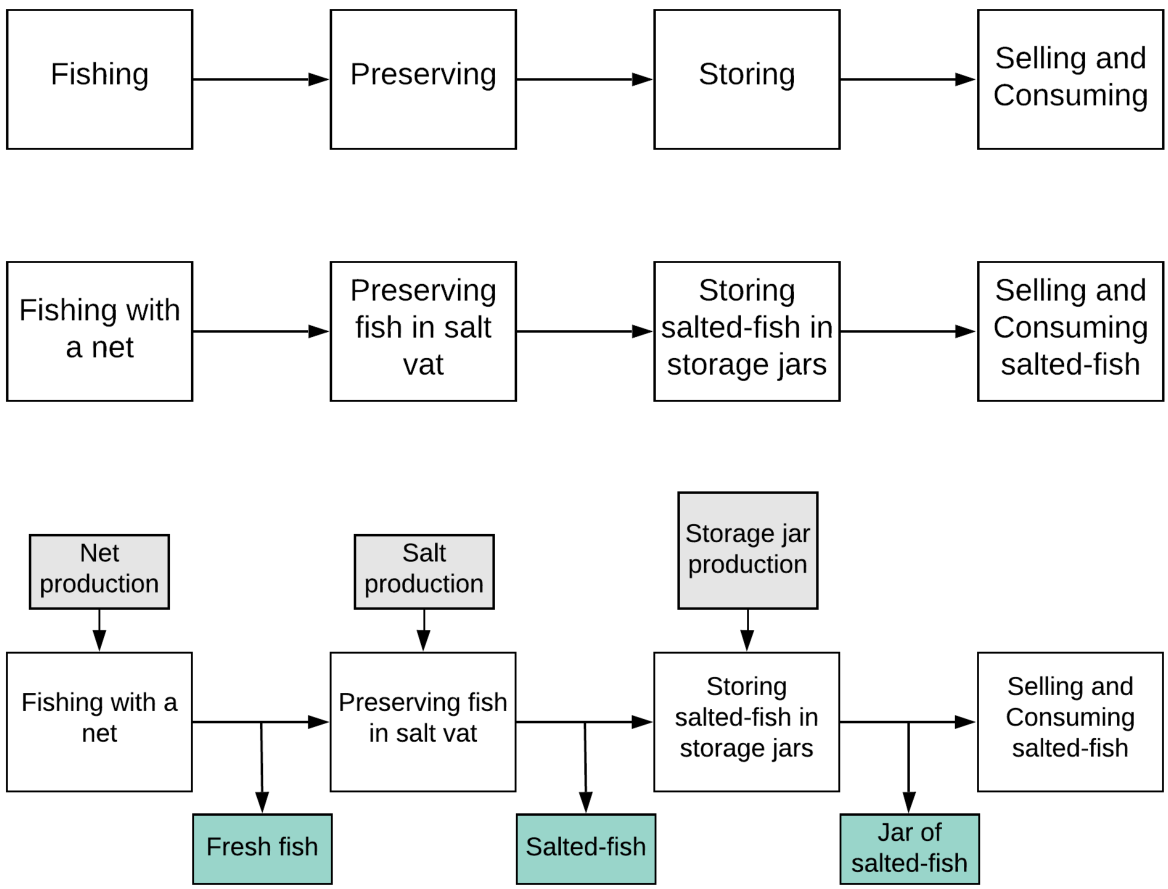

Figure 23: A generalized chaîne opératoire showing the gestures required for fish-processing (top), with matter and objects specified (middle), and with parallel chaîne opératoires (gray) and the resulting product of each gesture (blue) added.

Below, I synthesize textual, archaeological, and experimental evidence to produce *chaîne opératoire* models for murex-purple dye production and *salsamenta* production. Since the goal of this paper is to support a reinterpretation of the Dor industrial complex, I include the *chaîne opératoire* for purple dye production to show that the archaeological correlates – the architectural features, tools, and materials – required for Dor to be a "Purple Dye Factory" have not been found. In contrast, archaeological correlates for the *salsamenta chaîne opératoire* are evident at Dor, further supporting the analogy proposed in this essay.

Chaîne Opératoire for Roman *Murex*-Purple Dye Production from c. 100 BCE – c. 300 CE

This type of purple dye, also known as “Tyrian purple” or “*murex* purple” has a long history of production in antiquity across the Mediterranean world. The invention of the dye is a hotly debated topic, but present historiographic research indicates the production process is likely Minoan in origin and initially developed around the 15th century B.C (Kalaitzaki et al. 2017: 106).[3] Nevertheless, the Phoenicians are most commonly associated with the production and trade of purple dye in antiquity (for more on this, see Alberti 2008; Cooksey 2013; Reese 2010; Ruscillo 2005; Stieglitz 1994). Cloth dyed in the royal purple has been considered a sign of wealth and prestige for many different cultures, with the cost of purple-dye pigment often fetching more than its weight in gold, and cloth dyed in it costing even more (McCord 1969: 379-81). Under the Romans, the dye became so popular that emperors eventual imposed regulations on who could and could not produce, sell, and wear the color, with one story going so far as to say the Emperor Caligula had a visiting vassal king murdered for appearing at the colosseum wearing a robe of fine purple (Cooksey 2013: 174).

Murex purple is so named because the dyeing compound that gives the substance its unique color is found naturally in the hypobranchial glands of certain sea snails – most famously those in the family *Muricidae*. Recipes for the production of *murex* purple, although incomplete, have survived from antiquity, providing experimental archaeologists with a base from which to begin recreating this elusive color. The most extensively cited recipe for production comes from

[3] The name “Tyrian Purple” has led some (Huheey and Ruggieri 1977: 196; Jensen 1963: 104; Ziderman 1990: 98) to erroneously name Tyre as the origin of the dye. While some of the clearest and most thoroughly documented evidence does come from the Lebanese coast around Tyre and Sidon, the oldest evidence of a dyeing industry (involving export of product) using *murex* snail comes from Palaikastro, Karoumes, and Kommos – Minoan sites on the island of Crete (Alberti 2008: 76; Cakirlar and Becks 2009: 97; Viviers 1999: 225).

the elder Pliny’s *Naturalis Historia*, and provides step-by-step instructions on how to acquire *murex* snails, extract the dye precursors, and process the dye so that it could be used on fabric on-site, or dried and shipped as a powdered pigment that could be rehydrated and used elsewhere.

Interest in the historical significance of purple pigment and dye – as a luxury trade export in its own right and as symbol of prestige when used to color textiles, garments, and even architecture – within anthropological archaeology (e.g., Franklin 1984; Gleba, Berghe, and Cenciaioli 2017; Kremer 2017; Lowe 2017; Pons 2016) and recent investigations into the unique chemical qualities of 6-6’ dibromoindigotin – the dyeing compound found in some *murex* hypobranchial glands – in chemistry (e.g., Cooksey 2017; Głowacki et al. 2012; Karapanagiotis et al. 2013; Margariti et al. 2013; McGovern and Michel 1990; Meiers 2017; Valles-Regino et al. 2016; Verri et al. 2019) has placed the dye industry in the spotlight of archaeological interpretation at coastal sites around the Mediterranean (e.g., Cakirlar and Becks 2009; Houby-Nielsen 2017; Kalaitzaki et al. 2017; Karmon and Spanier 1988; Macdonald 2017; Wilson 2004). However, the resulting influx of *murex* purple dye facility discoveries published in archaeological literature necessitates the need for a standardized method of identifying purple dye production sites in the archaeological record.

Natalie Susmann (2015) proposes such a standard, using evidence from historical accounts (namely Pliny, *Hist. 6*), experimental archaeological studies of *murex* dye production (see McGovern and Michel 1990; Michel and McGovern 1987, 1990), and archaeological evidence from sites on the Mediterranean coast spanning the Bronze Age through the Roman period (sites and citations in Susmann 2015: 97-100). Susmann’s criteria, summarized in Table 2, helps archaeologists determine the likelihood that a site was used for dye production.

Table 2: Necessary evidence for dye production facilities, and which datasets can provide evidence for each category. Tools and residue are marked 'F' to signify that they might indicate production but are not always feasible to collect during an excavation. A lack of tool or residue evidence alone is not sufficient to determine that a site was not used for purple dye production (Susmann 2015: 91, Table 1).

Necessary Evidence for Dye Production	Textual Data	Experimental/Scientific Studies	Archaeological Evidence
Snails			
Large amounts of shells in a midden/concentrated context			x
Confirmation of *murex* snail species	x	x	x
Dye Production Process			
Vein extraction	x	x	
Dye mixing	x	x	
Heating	x	x	x
Specific production location (reference to location or particular environment)	x	x	x
Evidence of residue	x	x	F
Dye Production Equipment			
Pits, vats, and channels	x	x	x
Extraction tools	x	x	F
Light and oxygen controls	x	x	x

Susmann's investigative criteria is essentially the archaeological indicators of the main gestures required to produce purple fabric from marine snails. As such, I use the archaeological correlates that she identifies to form the *chaîne opératoire* for *murex*-dye production presented below. Roman period murex-purple dye production can be separated into seven steps: (1) identifying murex snail habitats; (2) baiting and catching the snails; (3) removing the hypobranchial gland; (4) soaking the gland in an alkaline solution; (5) reducing the solution over artificial heat to form a dye; (6) soaking the cloth or wool in the dye solution; and (7) exposing the dyed fabric to sunlight. The description that follows will provide citations (textual, archaeological, and contemporary) for each step in the process and note those steps which have not yet been positively identified due to their absence in the textual or archaeological record.

1. Identifying Murex Snail Habitats

The first step in the complicated process of *murex*-dye production is finding and capturing the right sea snails. While most snails in the *Muricidae* family possess the hypobranchial gland necessary to produce 6-6' dibromoindigotin, three were preferred in antiquity for their ability to produce certain unique and desirable shades of blue, red, and purple. *Hexaplex trunculus*, also known as the banded-dye *murex*, was sought after for its ability to create the strongest and longest lasting dye and are most commonly found at depths ranging from 1 to 30m. *Bolinus brandaris*, or the spiny-dye *murex*, produces a redder dye due to it possessing more natural dibromoindigotin and can be found in deeper waters – from 5 to 150m below the sea surface. *Stramonita haemastoma*, also called the rock-*murex* or the red-mouth *murex*, produces a very weak but deep purple dye and was often mixed with either *Hexaplex* or *Bolinus* snails to create a stronger, yet darker dye; this snail only lives in the intertidal zone.[4]

2. Capturing the Snails

According to Pliny the Elder (*Nat. Hist.* 9.61.132) and modern *murex*-fishing practices, *murex* snails are carnivorous and therefore able to be baited into baskets left idle on the seafloor. These baited baskets are the first, although perhaps least likely, archaeological indicators indicating the possible presence of a *murex*-purple dye facility. Unfortunately, they were often made of material (e.g., reeds) that quickly decompose and rarely survives in indicative quantities in the archaeological record. Sometimes the snails were kept alive or bred in *piscinae*, but special care had to be taken as the snails are cannibalistic, making large breeding operations difficult (Ruscillo 2005: 102).

[4] For more on the sea snails, their physiology, and the dyes that each species can produce, see Macdonald (2017: 13-22).

3. Hypobranchial Gland Removal

Dibromoindigotin was collected either by cutting open the shells and removing the hypobranchial glands by hand, or by crushing the shells whole and then soaking the whole snail. Pliny (*Nat. Hist.,* 9.60) elaborates, saying, "It is a great point to take the fish alive; for when it dies, it spits out this juice. From the larger ones it is extracted after taking off the shell; but the small fish are crushed alive, together with the shells, upon which they eject this secretion." In the archaeological record, this gesture would result in massive[5] middens of crushed *murex* shells or *murex* shells with evidence of being worked by tools. The presence of huge quantities of worked shells is even more to be expected when we consider a modern attempt found that the production of only 1.4 g of pigment required some 12,000 snails (Friedländer 1909; Wolk and Frimer 2010: 5473)! Additional material indicators include iron tools (Vitruvius, *De Arch.*, 7.13.3) and a workspace that is protected from the sun, as Dibromoindigotin is photosensitive and regulating the amount of sunlight exposure is essential for producing the desired color (Michel and McGovern 1987: 140).

4. Soaking the Glands in an Alkaline Solution

The glands or crushed shells were then soaked in an alkaline solution (such as salt water) for no more than three days to reduce the chemical compounds into a usable pigment (Koren 2013: 54; Ruscillo 2005). Archaeological evidence reveals that soaking occurred both in temporary containers – as seen from purple-stained ceramic sherds at Sarepta, Tel Akko, Tel Keisa, Tel Shigmona (Alberti 2008: 82) – as well as permanent vats like those found in Area D5 at Tel Dor (Nitschke, Martin, and Shalev 2011: 136-7). In either case, the vessel had to be coverable so as to protect the mixture from direct sunlight, but not airtight in order to allow produced gases to escape.

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[5] For example, the *murex* midden near the dye-works at Aperlae, Turkey covers a total area of 1600 m^2, and contains hundreds of thousands of shells, both fragmented and whole (see Hohlfelder and Vann 2000).

5. Reducing the Solution over Artificial Heat

During this initial stage of reduction, the meat of the *murex* snail begins to decompose, and a colony of bacteria is formed within the solution. When exposed to the correct environment, these bacteria break down the pigment and make it water-soluble. Results from contemporary experiments (Michel and McGovern 1987, 1990) indicate that this stage requires the solution be kept in an anaerobic environment else the dye will oxidize, rendering it useless. Additional experiments (Koren 2013: 48-54) have found that solutions at 45-50° C and a pH level of 9 form the ideal conditions for this reduction process to occur. Additionally, this stage requires the solution be kept in an anaerobic environment else oxidation occurs and ruins the dye. Pliny's account disagrees, arguing that the solution be boiled rather than merely heating it:

> It is then set to boil in vessels of lead, and every hundred amphorae ought to be boiled down to five hundred pounds of dye, by the application of a moderate heat; for which purpose the vessel is placed at the end of a long funnel, which communicates with the furnace; while thus boiling, the liquor is skimmed from time to time, and with it the flesh, which necessarily adheres to the veins.
>
> (Pliny, *Nat. Hist.* 9.62)

This may, however, have been due to difficulties in accurately measuring the temperature of the solution without thermometers, and so by saying "boiling," Pliny merely meant artificial heating in general rather than describing the solution be brought to boiling point. Heating the vessels over a simple fire was likely the most common method, as it was cheap and relatively easy to maintain. On the other hand, Pliny describes the use of a furnace from which a funnel would draw hot air to heat the reduction vessel. In either case, a method of heating the solution was required to reduce the pigment into a usable dye.

Pliny also describes the use of lead vessels for heating and reducing the pigment. The reason for this is still a mystery; it could be to avoid unwanted reactions between the pigment and the vessel, or perhaps lead vessels heated more uniformly than other vessels and therefore produced a better dye. Nevertheless, the presence of lead vessels in a possible dye-works context is a strong indicator of *murex*-dye production.

Modern attempts to reproduce the dye also indicate that the reduction stage requires an anaerobic environment and vessels allowing for precise oxygen control (Koren 2013: 51; Michel and McGovern 1990: 99; Sukenik et al. 2017: 777).

6. Soaking the Fabric in the Dye

The penultimate step in the process is soaking the cloth or wool in the now reduced and heated, alkaline dyeing solution. The duration of soaking results in different colors dyed into the fabric, as does the temperature at which the solution is kept during soaking. A five-hour soak at around 50° C has been found to produce the classic "Tyrian Purple," a rich shade of amethyst (Koren 2005: 141), while other times and temperatures produce colors ranging from sky blue, to deep red, to the blackish red/purple called *oxyblatta* (Latin: ox blood), or "Imperial/Royal Purple," by the Romans. Soaking must still be carried out in a low light until the last step in the process.

7. Exposing the Fabric to Sunlight

After the material is soaked under the desired conditions for the correct duration, it is finally exposed to direct sunlight. As long as the pigment, dye, and now dyed fabric were kept out of direct sunlight, the substance appeared a light-yellow color even after varied durations of soaking. Exposing the dyed material to sunlight begins a catalyst reaction in the dye that produces first a greenish color, then shades of light to dark blue, before finally finishing in the final color dictated by the variables discussed at every step above: (1) the type of snail used, (2) the duration and temperature of pigment reduction, (3) the duration and temperature at which the material was soaked, and (4) the duration in which the dyed material was exposed to sunlight throughout the process, especially at the very end. Although no drying racks survive in the archaeological record, the Romans likely dried dyed material in the sun on some sort of temporary wooden frames.

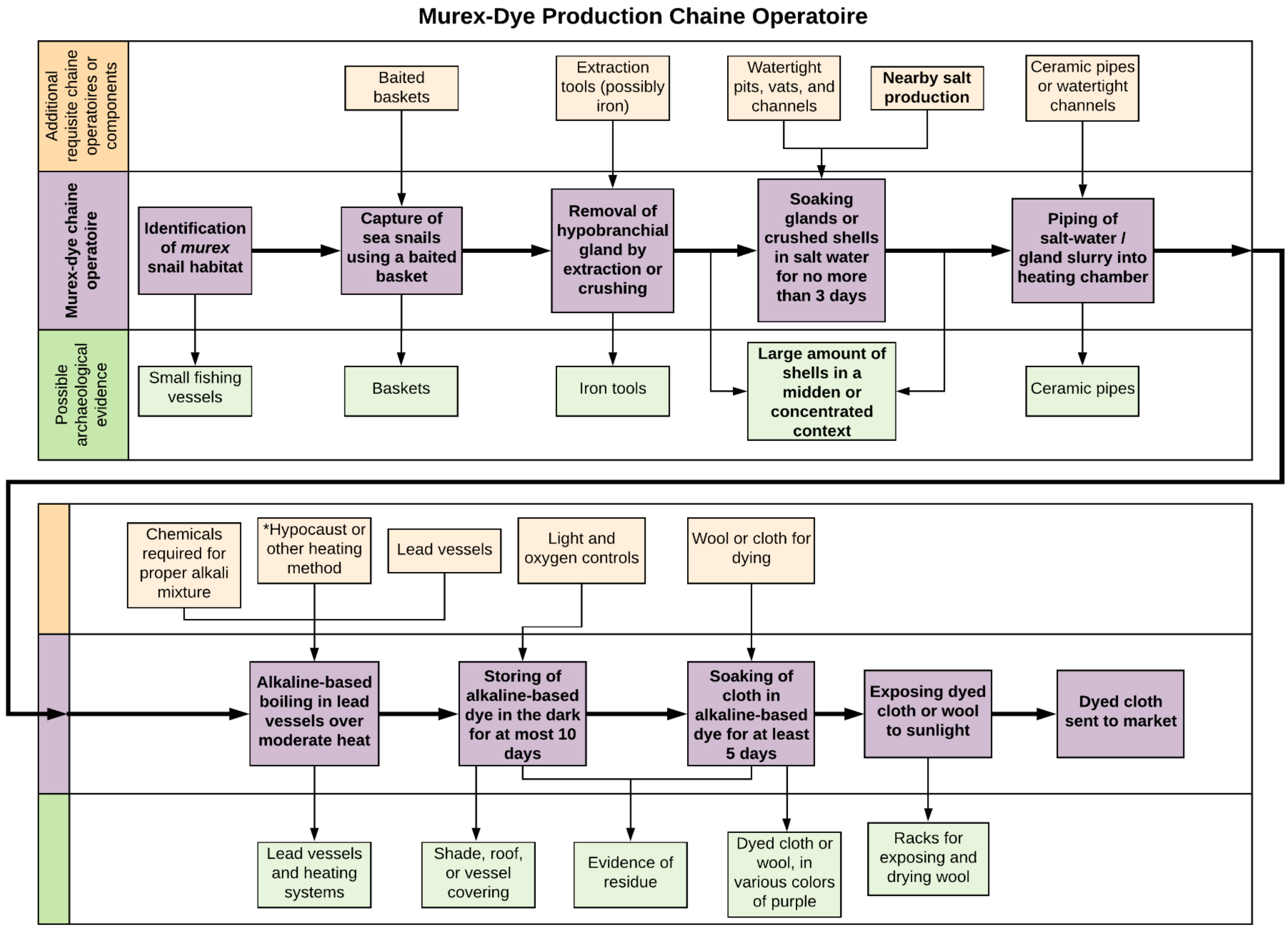

Figure 24: A chaîne opératoire model of *murex*-dye production (purple) during the Roman period, after archaeological and textual evidence (Pliny, Hist. Nat, 9). Note parallel chaîne opératoires or technological components (yellow, above) and possible archaeological correlates of each gesture (green, below).

It is no surprise that *murex*-purple clothing fetched an incredibly high price throughout antiquity. The number of snails required for even the smallest quantity of dye would have taken weeks of human-hours to gather and process. Dye-workers needed to have a specific knowledge of each step to produce the desired color, especially since they were unable to check the color before it was exposed to sunlight. Lastly, the photosensitive properties of the dye make it incredibly unique among natural dyes, and it is no surprise that the Romans believed the "Royal Purple" first came to them from the gods.

***Chaîne Opératoire* for *Salsamenta* Production from c. 100 BCE – c. 300 CE**

Salsamenta, or salted fish, was a staple of Roman cuisine. Fish spoils rapidly but salting the meat can slow or even halt spoilage indefinitely (depending on the ratio of salt to fish) if done soon after the fish are caught (see Hall 1997: 54-61). *Salsamenta* likely rose to prominence as a way to transport fish to inland regions of the empire, in addition to preserving large catches of in-season, migratory fish (e.g., blue fin tuna, Atlantic mackerel, sardines, anchovies, etc.) for sale and consumption throughout the year (Marzano 2013: 89-90).

The following *chaîne opératoire* is presented in such a way as to highlight the archaeological correlates of steps in the production process (see Figure 24). Roman period fish-salting can be separated into eight steps: (1) identifying fish migration channels; (2) catching the fish; (4) washing the fish in fresh water; (5) butchering the fish; (6) transporting the fish meat and viscera (heart, gills, stomach, intestines, etc.) to nearby *cetariae*; (7) layering the fish meat and salt in vats or jars, alternating layers until the vat or vessel is full; and (8) draining the brine liquid; and (8) storing the salted fish in amphorae for transport.[6] As step 7 deals with the production of *garum*, a significant commodity in the Roman Empire, it will be explored in

[6] The packing and sale of *salsamenta* (steps 7 and 8), although of great importance, will not be considered here as it is not represented in the material evidence at Dor beyond the presence of storage jar sherds that have not yet been thoroughly examined.

detail in the following section on fish sauces. The general process itself is not complex, but each gesture has slight variations at different fish-processing locations and warrants a brief discussion.

1. Identify Fish Migration Channels

Textual evidence from the Roman period, particularly works by Pliny the Elder, Strabon, Athenaeus, and Columella (for a list of fish treatises from the early empire, see Corcoran 1964), indicate that the Romans possessed an extensive knowledge of edible marine life – fish, eels, mollusks, even sharks and whales (for supporting archaeological evidence of the latter in fish-salting contexts, see Ponsich 1970: 211; 1988: 138; Ponsich and Tarradell 1965: 39, 101) – including their preferred habitats and migration patterns. Columella, writing c. 60-65 CE, considered a knowledge of fish migration to be of the utmost importance for success in the fishing business (McCann et al. 1987: 144). Capitalizing on that knowledge required an elevated viewpoint in order to observe migratory schools from above.

In addition to the textual evidence, fishing and fish-processing facilities at Cotta (Bekker-Nielsen 2005a: 67; see Fig. 36 in Ponsich and Tarradell 1965), Boca do Rio (near a major tunny migration route through the Straight of Gibraltar, see Fig. 16 in Trakadas 2015: 15), and Kouass (on the northern coast of Morocco, see Trakadas 2015: 66) exhibit evidence suggesting fishermen stood atop the tops of cliffs, bluffs, and towers built near the water for the express purpose of observing schools of fish and directing fishermen. Strabon (c. 64 BCE – c. 24 CE) also writes (5.2.6, 5.2.8, 11.2.4) about similar watchtowers used by fisherman on the sea of Azov (Bekker-Nielsen 2005a: 138), and on the Italian peninsula at Cosa and Populonia (Bekker-Nielsen 2005a: 158). The presence of natural or artificial lookouts near fishing grounds is so ubiquitous in the literature and material record that it is considered a primary indicator of commercial fishing (Bekker-Nielsen 2005a: 133).

2. Catching the fish

Fishing occurred across the Roman empire in both fresh and saltwater and at different levels of organization and size. The smallest operations were single fishermen, working from the shore or a small boat, and catching enough to feed their families (Bekker-Nielsen 2010: 25-26; Marzano 2013: 16), while the largest were multi-team commercial enterprises that caught, salted, and exported fish in large quantities. Accordingly, tools used to catch marine life – fishing hooks and lines, nets and net weights , baited baskets and traps, spears and harpoons, and watercraft of all sizes (for these and additional methods employed by Greek and Roman fisherman, see Bekker-Nielsen and Bernal Casasola 2010; Oleson 2008: 207-10) – come in many forms based on the number of people involved, the type of animal being fished, and the method being used. As previously discussed, p*iscinae* were commonly used for storing and breeding fish: larger pools and extensive pool networks have been found in association with major fishing operations, and single ponds are commonplace in *villae* and *villae maritimae* contexts for private use (see Higginbotham 1997). Larger operations tend to be more visible in the archaeological record, leading to a disproportionate representation of massive fishery sites and city-dominating salting "factories" in the academic literature.

3. Washing the Fish in Fresh Water

Evidence that the Romans washed their recently caught fish with fresh water only survives in ancient texts; however, some form of fresh water supply structure (see Bernal-Casasola 2005: 1422; Curtis 1991: 178; Trakadas 2015: 69) has been identified at most *cetariae* around the Mediterranean (Sánchez López 2018: 87). Some scholars (e.g., Botte 2009: 102-4) argue that fisherman used readily available salt water for cleaning fish and salting vats, with fresh water being supplied for consumption by the workers. Regardless of its possible use, the evidence is clear from the Cotta *cetaria* that fresh water – from cisterns, wells, and water channels – was a necessary component of the fish-processing process.

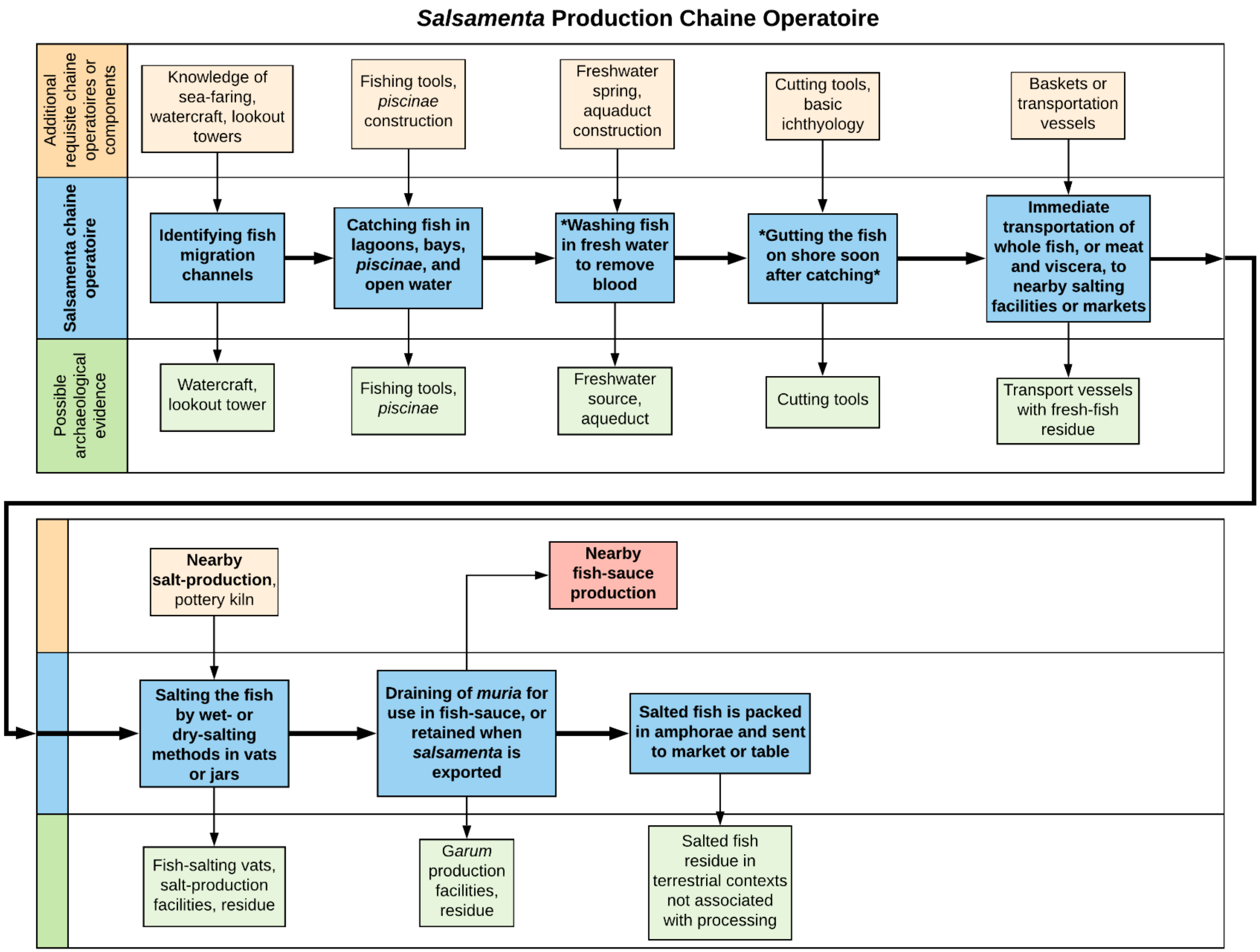

Figure 25: A chaîne opératoire model of salsamenta (salted fish) production (blue) during the Roman period, after archaeological and textual evidence. Note parallel chaîne opératoires or technological components (yellow and orange, above) and possible archaeological correlates of each gesture (green, below).

4. Gutting the Fish

Ancient texts and bone remains indicate that fish were salted both whole and in pieces (see footnote 1 in Curtis 1991: 6). Thus, “gutting” as a gesture has been marked in Figure 24 with an asterisk because it is not a necessary step in producing *salsamenta* (nor fish sauce, more on that later) but was commonly practiced when a certain type of *salsamenta* was desired. Additionally, evidence of gutting or cutting the head off of freshly caught fish is, unsurprisingly, practically nonexistent in the archaeological record. Knives used for cutting fish have likely survived in the archaeological record but positively identifying them is impossible without specific contexts or epigraphic descriptions that distinguish them from other kitchen or industrial cutting tools. Likewise, it would be difficult to determine from fish bones *in situ* whether a fish skull was removed from the skeleton prior to or during the consumption of the fish.

5. Immediate Transportation of Fish to a *Cetaria*

As today, fishing in antiquity was a time-sensitive activity; without refrigeration, fish would, depending on the species, spoil within a few hours of capture unless it was heavily salted to prevent biodegradation (for an experimental analysis of fish spoilage and tradition fish-processing techniques, see Holma and Maalekuu 2013). Additionally, modern studies disagree about whether gutting and washing increases the amount of time before a fish begins to spoil (Hall 1997). Thus, in all cases fishermen needed to transport the whole fish or the meat and viscera to a salting facility almost immediately or risk losing their catch, an interpretation supported by Manilius in the *Astronomica* (5.656-81) (see Curtis 1991: 9). This pressure led to the construction of fish-processing facilities directly adjacent to fisheries or open fishing areas, often on the coast itself but never further inland than could be travelled by foot or horseback before the fish spoiled.

6. Salting the fish

Evidence for the salting process itself is based on experimental archaeology aimed at recreating authentic Roman *salsamenta* (García Vargas et al. 2018; Holma and Maalekuu 2013); a modern analogy from the production of *Lona ilish*, a salted fish product popular in India (Majumdar and Basu 2010); and textual evidence from the works of Columella, Pliny, Galen, Manilius, and Oppian (summarized in Trakadas 2015: 10-12). Like today, two types of salting occurred in antiquity: wet-salting, where the fish is placed in salt water ("brining") with or without added wine-vinegar ("pickling"); and dry-salting, where the fish is thoroughly washed and dried prior to being rubbed or packed in salt (Thurmond 2006: 227-229). Dry-salting can be further classified by the ratio of salt to fish: "slack-salting" (10-20% salt-to-fish by weight), which could preserve the fish for 1-3 weeks; and "hard-salting" (at least 30% salt-to-fish by weight), which could preserve the fish indefinitely (Thurmond 2006: 227).

Although any of the above methods could have (and likely were) used during the Roman period, textual evidence seems to indicate that hard-salting was preferred due to the need to indefinitely preserve the fish:

> Plautus describes stockfish so tough it had to be soaked in water for days and Columella's salting description is for a "hard cure". Pliny describes *melandrya*, salted pelamydes or young tunny, so hard that it is like wood. It would seem that hard salting was preferred, and this would also ensure that *salsamenta* could be stored for some time and shipped over long distances.
>
> (Trakadas 2015: 11)

Hard-salting involved layering fish meat in a vessel with salt, where it was then packed down with weight from above and left to desiccate. There is no consensus in the present scholarship on the ratio of fish to salt used as it likely differed among facilities, and from region to region based on climate (preserving in hotter, dryer climates would require less salt than in cooler, wetter areas); however, a modern study by García Vargas et al. (2014) on *garum* production found that as much as 50% salt-to-fish by weight could be used and still produce the liquid byproduct, called *muria*, necessary to make some fish sauces. More salt resulted in an almost inedible product that produced little to no *muria*. Packing could have taken place in large salting vats, as was the case at Baelo Claudia and Cotta, or in pits and even *dolia,* as was likely in smaller facilities in the Black Sea region (Bekker-Nielsen 2005a: 37, 71) and even well-established *cetariae* in the northwest Maghreb (Trakadas 2015: 41, 73, 128) and France (Benoit 1959: 103).

Fish Sauces and Other Byproducts of *Salsamenta* Production

Fish-salting facilities also produced a number of secondary commodities in addition to *salsamenta*, namely fermented fish sauces and the pickled remains of the fish-salting process. These products, all made by fermenting the viscera (flesh, organs, bones, blood, etc.) left over from fish-salting activities, can be grouped generally into four categories: *garum*, *liquamen*, *muria*, and *allec*.[7]

The term *garum* (the Latin form of Greek *γαρός*, *garos*), although initially used for fish sauces generally, became the term for fish sauce of higher quality and presumably better taste by the end of the 1st c. CE (Pliny, *Nat. Hist.*, 31.93; see Curtis 1991, 9-10). Pliny also mentions a specific sauce of the highest quality, "*garum sociorum*," which was made from mackerel processed in the *cetariae* of the Spanish provinces (Carannante, Giardino, and Savarese 2011: 73). On the other hand, the Latin word *liquamen* (which does not have a Greek root) is mostly absent in literature from the early empire but became the term for fish sauce of secondary quality (Columella, *On Agriculture*, 6.2.7, 9.14.3, 9.14.17) and then, by the mid-3rd c. C.E.,

[7] The terms *garum*, *liquamen*, and *muria* are used somewhat interchangeably in Roman literature, with *garum* used more frequently in the early empire, and *liquamen* favored in later works. Scholars do not know to what specific product each term referred, however, the specific definitions given here were done so for the sole purpose of simplifying the variety of fish products into four categories that match their most common usage in modern academic literature. For more information about this semantic problem, see Grainger (2012: 1-2).

synonymous with fish sauce in general (see Grainger 2012: 2). The word *muria* is rarer in all periods and was used for any remaining liquids from fish-salting that were incorporated into fish sauces or merely used as a condiment in its own right (Curtis 2009: 713S; Grainger 2012: 7). Lastly, *allec* (also *allex*, *alic*, *halex*) was the lowest quality byproduct of fish sauce production – a mix of the solids, blood, salt, and spices leftover from the production of other sauces.

The production of various types of fish sauces was not a discrete industrial process per se, but rather a by-product of fish-processing in general. From Pliny (*Nat. Hist.*, 31.93-5), we know that basic fish sauce required fish viscera, salt, and time. All of these are necessary (or in the case of fish viscera, *produced*) in abundance during fish-salting. Additionally, excavations of *cetariae* across the Roman empire, especially those in the Spanish provinces like Baelo Claudia, attest to the simultaneous production of *salsamenta* and *garum*: "The discovery of abandoned salting vats which still contain half-processed *garum* is also worth noting. The excavation of *cetariae* C.I. XI and XII has resulted in the discovery of basal layers of sediment (4-8 cm deep) largely consisting of the bony remains of the fish being salted" (Bernal-Casasola, Expósito, and Díaz 2018: 340). It is therefore logical to treat the *chaîne opératoire* for fish sauce as an extension of the *chaîne opératoire* for *salsamenta*, as has been done in both Figure 24 and Figure 25.

The most complete fish sauce recipe comes from the *Geoponica*, an encyclopedic agricultural volume compiled around 900 CE, almost a millennium after *garum* became a staple in Roman cuisine. The author describes four different methods for producing different qualities or styles (e.g., Bithynian) of fish sauce:

> The so-called liquamen is made thus. Fish entrails are put in a container and salted; and little fish, especially sand-smelt or small red mullet or mendole or anchovy, or any small enough, are all similarly salted; and left to pickle in the sun, stirring frequently. When the heat has pickled them, the *garos* [*garum*] is got from them thus: a deep close-woven basket is inserted into the centre of the vessel containing these fish, and the *garos* [*garum*] flows into the basket. This, then, is

how the *liquamen* [*garum*] is obtained by filtering through the basket; the residue makes *alix* [*allec*].

The Bithynians make it thus. Take small or large mendole, or if none, anchovy or scad, or mackerel, or also *alix* [*allec*], and a mixture of all of these, and put them in a baker's bowl of the kind in which dough is kneaded; and to one *modios* [approximately 8 liters] of fish knead in six Italian pints of salt so that it is well mixed with the fish, and leaving it overnight put it in an earthenware vessel and leave it uncovered in the sun for two or three months, occasionally stirring with a stick, then take it, cover, and store. Some add two pints of wine to each pint of fish.

If you want to use the *garon* [*garum*] at once, that is, not by ageing in the sun but by cooking, make it thus. Into pure brine, which you have tested by floating an egg in it (if it sinks, the brine is not salty enough in a new bowl, put the fish; add oregano; place over a sufficient fire, until it boils, that is, until it begins to reduce a little. Some also adding grape syrup. Then cool and filter it; filter a second and a third time until it runs clear; cover and store.

A rather high-quality *garos* [*garum*], called *haimation*, is made thus. Take tunny entrails with the gills, fluid, and blood, sprinkle with sufficient salt, leave in a vessel for two months at the most; then pierce the jar, and the *garos* [*garum*] called *haimation* flows out.

Geoponica 20.46:1-6

From the above text, analyses of fish bones from excavations (see Arndt et al. 2003; Botte 2009; Desse-Berset and Desse 2000; Étienne and Mayet 2002; Van Neer and Ervynck 2004), and ethnographic evidence from modern fish sauce production (e.g., nouc-mam, nampla, budu, etc.; see Curtis 2009; Lopetcharat et al. 2001), we can make two observations: (1) The fish sauce *chaîne opératoire* is comprised of seven general steps; and (2) internal variations within each of the seven steps occurred as a result of recipe variations between facilities, and even within a single fish-processing facility.

The seven steps of the basic *chaîne opératoire* for fish-sauce production (Figure 25) are as follows: (1) Placing fish viscera in a container or vat; (2) adding salt to the mixture, with a salt-viscera ratio of 1:8-1:2 (depending on the desired result); (3) fermenting in either direct sunlight for approximately 2-3 months, or over artificial heat (e.g., fire or hypocaust system) for a few hours; (4) periodically stirring and adding additional salt to ensure the mixture properly

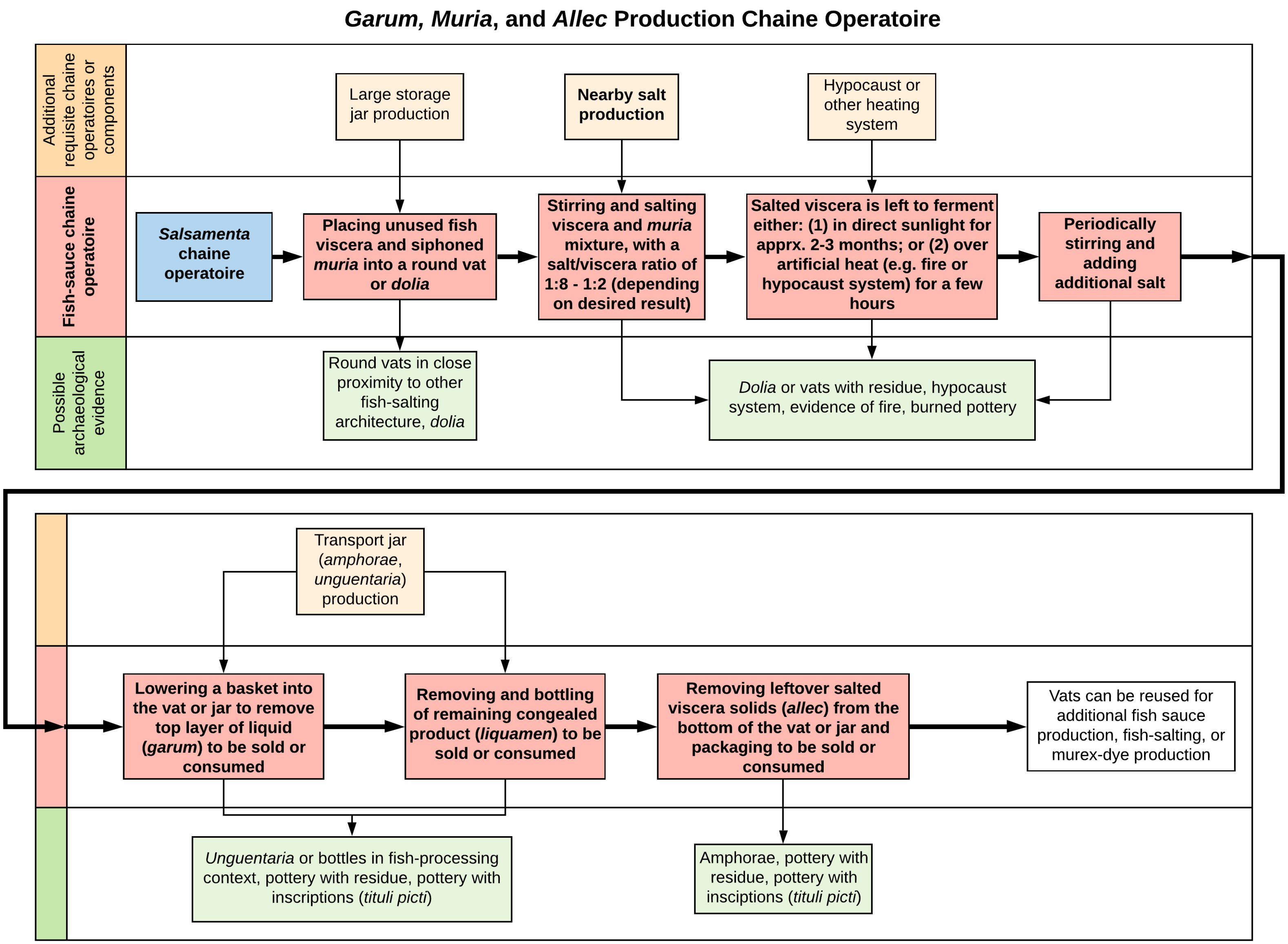

Figure 26: A chaîne opératoire model of fish sauce production (orange) during the Roman period, after archaeological and textual evidence. Note parallel chaîne opératoires or technological components (yellow, above) and possible archaeological correlates of each gesture (green, below).

autolyzes and to prevent bacterial growth; (5) removing the top layer of liquid (*garum*) with a basket, perforated jug, or other similar filter and bottling; (6) removing and bottling the remaining liquid product (*liquamen*); and (7) removing the leftover salted viscera solids (*allec*) from the bottom of the container or vat and packaging in a storage jar.

Salt Production in Antiquity

It is likely that salt production via saltwater evaporation occurred at Dor since salt-works are often found in close proximity to fish-processing operations across the Mediterranean region (Bekker-Nielsen 2005a: 154-6; Busana 2018: 8) and it was more cost effective to produce salt locally (if possible) rather than transport the heavy material over long distance. With that said, there were many methods in antiquity for producing salt, and one or more of them could be conducted at the same location simultaneously. Annalisa Marzano (2013: 123-37) has an extensive chapter on the subject, including citations to archaeological indicators of each type of production. Since salt production was ubiquitous across the Roman Mediterranean, and regional variations have been identified throughout the archaeological record, it is beyond the scope of this section to describe each in detail (for those interested, see Marzano's chapter and the citations therein). A very brief description of the most common types of salt-production processes is given here.

Each of the methods outlined in Figure 26 (with the exception of salt mining) follows the same basic chain of operations.[8] First, a saltwater source (brackish lagoon, saltwater spring, the sea) is identified and collected in a low energy environment apart from the source (in *salinae* or salt pans, rock-cut pools, or naturally in beach sand). The input of saltwater into the

[8] It is unlikely that salt was mined near Dor in antiquity. The nearest exposed terrestrial salt outcrop is at Mount Sdom on the shores of the Dead Sea, over 175 km to the southeast (Folle 2007: 11).

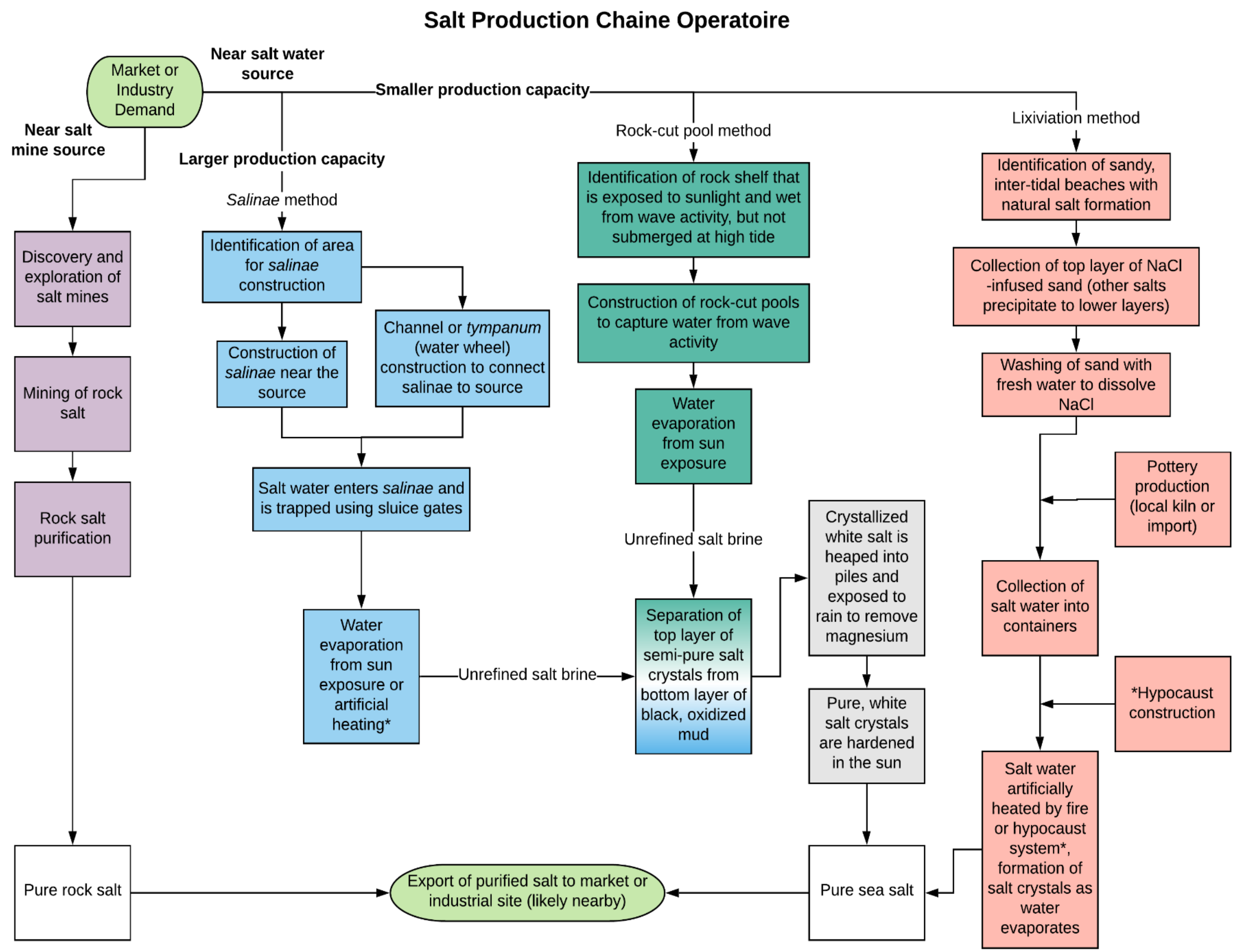

Figure 27: A chaîne opératoire model of salt production during the Roman period. Salt mining (purple), salinae (blue), rock-cut pool (green), and lixiviation (red) methods are presented (after Marzano 2013, 123-37).

collection vessels must be regulated (using sluice gates or natural tidal and wave action) to allow for the water to dry and the salt to be removed before more water is added. The saltwater is then left to evaporate under natural forces (sunlight, wind) or artificial ones (fire, hypocaust system) until unrefined salt crystals remain. The salt crystals are then washed free of impurities, such as magnesium, naturally (by being left in the rain) or manually (by hand using a regulated, slow supply of fresh water). The purified salt crystals are then dried further, using the same methods described before. Lastly, the pure salt is collected and sent to locations nearby where it can be used in other industries or sold to consumers.

I include salt production here because salt was an essential ingredient for *murex*-purple dye, salted-fish, and every type of fish sauce. It is important to note that long-distance salt trade did occur in antiquity – Plutarch (*Mor*. 685d) references "ships carrying salt" in a section on Mediterranean trade practices (Carusi 2018, 488). Nevertheless, salt readily forms today on the *kurkar* ridges of Dor without human intervention, and it is safe to assume that the Romans exploited such a necessary and readily available resource in their time.

REINTERPRETING THE FUNCTION OF THE INDUSTRIAL COMPLEX

The analysis by analogy that I propose above requires that I prove formal similarities exist between the features at Tel Dor and the features at Roman fish-processing plants elsewhere in the Mediterranean. This is the *initial resemblance*. I have provided a detailed description of the features at Tel Dor, the eight *cetariae* at Baelo Claudia, and the single, yet complex *cetaria* at Cotta. Next, I posit that the Dor industrial complex performed the same function – *salsamenta* production – as the *cetariae* in the western Mediterranean with which it shares formal similarities. This is the *inferred property*. To test this hypothesis, I have shown that the *chaîne opératoire* for *salsamenta* and fish sauce production accounts for the physical characteristics of fish-processing plants. The final step in my argument is to present the analogy in its entirety. To this end, the following section proceeds one-by-one through the six feature classes at the Dor industrial complex. For each, I will endeavor to meet three objectives: (1) Note the formal analogues of each feature class using the features at Baelo Claudia and Cotta; (2) connect each feature class with its associated step or steps in the fish-processing *chaîne opératoire*; and (3) address discrepancies between features at Dor and features that one expects to find at a purple dye factory.

For reference, the following excerpt summarizes Raban's justification for interpreting the industrial area as a "Purple Dye Factory."

> One possible use [for the rock-cut pools] could have been as hatching pools for the larvae of the gray mullet (*Mugil cephalus* and *Mugil capito*). This fish, very popular in the eastern Mediterranean… is adapted to life both in salt and in fresh water… Consequently, an appropriate mixture of fresh and sea water may have been used by the inhabitant of ancient Dor in order to create artificially controlled hatching pools for the gray mullet. The problem is that even the present-day fisher research center at Dor has not been able to achieve optimum conditions for this… Among the rather detailed descriptions of the sophisticated Roman agriculture there is no reference to such a process, or to any other procedure using mixed salt and fresh water for fish ponds. In any case, the shallow basins and the barely inundated benches would be unsuitable for marine creatures.
>
> **Another alternative may have been the harvesting of *murex* shells for the manufacture of purple dye, known to have taken place at Dor.** These shells and probable residues of the pigment were found elsewhere at the site, in Area D1 by A. Gilboa. However, what we know of the technique of purple dye manufacture in antiquity does not fit with this type of large open basins, implying a complicated operation of alternate rinsing of either wool fibers or cloth with fresh and sea water. The ancient sources do mention the need for ponds for keeping the harvested *murex* alive and perhaps their hatching and raising in captivity. The accounts of Aristoteles, Strabo, and Columella attest to their intimate knowledge of the complete ethology of the mollusks and the fact that they were kept alive in ponds otherwise used for salting, pickling, or even hatching fish. Yet none of these sources refers to fresh water. Fresh water may have been used in this context, in ample quantities, for washing the natural grease from wool fibers before the dying process.
>
> **All in all we prefer the interpretation that the function of the industrial complex was connected with purple dyeing rather than other alternatives such as the tanning of hides or processing of salted fish.**
>
> (Raban 1995: 301, emphasis added)

Rock-Cut Pools: Hatching *Piscinae*, Salt Pans, or Washing Basins

In light of the present evidence, there are four likely possibilities for the function of the rock-cut pools in the industrial area: (1) the pools were used as *piscinae* to hatch fish (such as the grey mullet, *à la* Raban) and the larvae were not kept in these pools after achieving a certain size (*contra* Raban), but were moved to larger and deeper pools nearby, perhaps those to the immediate north; (2) the pools were not used for aquaculture purposes but rather for the local production and collection of naturally occurring sea-salt by either the rock-cut pool method or the lixiviation method; (3) the pools were simply used for washing (in both salt and fresh water) the whole or fileted fish prior to salting; or (4) similar to Raban's interpretation, the pools were used to store the *murex* shellfish during seasons when fish-processing was either not viable or less economically productive due to weather or the migratory routes of more desirable species of fish. While all are possible and not necessarily mutually exclusive, correlative evidence from other *piscinae* support the first interpretation more fully.

The rock-cut pools pose a challenge for interpretation, as we see in Raban's report above. The pools dimensions are abnormal compared with the larger assemblage of Roman *piscinae* in the Mediterranean region. While the surface area of the pools is not out of the ordinary for a small fish-pond installation (see Higginbotham 1997; Marzano 2013: 213-33), the depth of the pools – no more than .60 meters according to the DEM used above to date the pools, and only .30 meters according to Raban's fieldnotes due to sand-cover at the time (see also Raban 1981: 298) – is too shallow for fish to survive for more than a couple days (see Davaras 1974: 91; Leatham and Hood 1959: 265). Therefore, it is unlikely that the two rock-cut pools on the western side of the facility were used as traditional *piscinae* for the keeping of live adult fish before processing.

Due to this problem, Raban argues that the pools were likely used as washing basins, possibly for wool or other clothes, as a part of a complicated process of preparing the wool for dyeing. Fulling, the industrial process of finishing woolen products by removing natural oils, was a common enough activity during Roman times (see Cleland, Davies, and Llewellyn-Jones 2007); the process is attested to in texts from the time period and the vats and channels of Roman *fullonicae* survive in the archaeological record at such places as Pompei (see Carratelli 1993) and Ostia (see Flohr 2017). Fulling involved submerging the wool in an alkaline solution (to dissolve fats and pollutants) and then repeatedly compressing (usually with ones feet) the wool until such time as the oils had been removed into the liquid (De Feo and De Gisi 2013: 600). While the Romans could have certainly used saltwater as the alkaline solution in this process, there is no evidence that this ever occurred. In fact, both the textual and archaeological records indicate that the Romans preferred to wash their garments in water mixed with *urine* – often from camels, but also from other animals and even from humans (see Bradley 2002: 30-2, 36-41; De Feo and De Gisi 2013: 599, 600, 605; Flohr 2006: 195-6; 2017). Also absent from the literature is any other example of a Roman *fullonica* being located so close to the sea – in this case, within the intertidal zone!

The Romans are known to have used small compartments or separate tanks to segregate fish by species or size (for example, see Higginbotham 1997: 140-51, figs. 55-61, 153-4, figs. 162-3, and 166, fig. 72). This practice protects smaller fish from larger predators, even those in their own species (see section on cannibalism in Shepherd and Bromage 1992), until they had grown to a sufficient size. Additionally, while textual evidence is missing regarding the intentional creation of brackish environments for breeding and local attempts at producing an ideal brackish breeding environment have been unsuccessful (cf. Raban's argument above), Geoffrey Kron (2008c) notes that smaller tanks built by the Romans have been found elsewhere that appear to have been built for this express purpose, saying, "they [the ponds] are often furnished with aqueducts supplying fresh water so as to create the brackish conditions which promote the development of the fry of the popular euryhaline [able to tolerate a wide range of salinity] species which were generally farmed" (182). If Kron's assessment is accurate, it helps explain the reason for the freshwater channel that Raban found entering the northernmost rock-cut pool, while also addressing the size discrepancy that has made these pools difficult to interpret.

The formal evidence from Baelo Claudia and Cotta would suggest that *piscinae*, salt pools, and tanks for keeping *muricidae* are related yet non-essential features in the fish-salting and *garum* production *chaîne opératoire*. It is again worth noting that neither Baelo Claudia nor Cotta, with some of the largest and most complex *cetariae* in the Mediterranean world, have dedicated *piscinae* near the salting facilities. It is not necessary for a facility to possess its own nursery ponds or *piscinae* – fishing provides the same matter (fish) and may require less energy and fewer tools to do so.[9] Nor is using rock-cut pools a requirement for washing fish; this was done in the plastered courtyards and smaller plastered basins in the *cetariae* of Baelo Claudia. Additionally, any type of large, open basin or even basket would be sufficient for this purpose. Nor does salt production, an essential part of any fish-saltery, require a set of dedicated pools for evaporating sea water or washing salt-infused sand. Thus, while each of the aforementioned possibilities could be correct given the present data, at this time we cannot identify with certainty for what purpose or purposes the pools served.

One final note about the size and shape of the rock-cut pools. In each of the above interpretations (including Raban's) the pools do not seem to conform to any common style found elsewhere in the Roman or other periods: as *piscinae* the pools are oddly shallow (though this may be due to erosion and cementation), as washing pits in a *fullonica* they are unnecessarily

[9] The Romans were prolific fishermen (see Bekker-Nielsen 2005b, 2010; Marzano 2018), and the wealth of fishing equipment unearthed at Baelo Claudia suggests that that the entire fish-salting operation there could have been supported by the catch of local fisherman (see Bernal-Casasola 2010).

wide, as salt pans they are unusually deep for their width. A possible explanation for this is that the Romans adopted the quarry-cuts of past periods into their architecture and added what features they needed – channels, sluice gate notches, walking paths around the circumference of each pond, etc. – in order to make the rock-cuts usable for their intended Roman function.

It is well documented that this part of the *kurkar* coast rock was widely used throughout the occupation of Dor as a quarry for building stones (see "Introduction" in Stern 1995: 1-12). Raban also notes in his final assessment that, "[the pools were] established in an area of quarrying that predated its earliest phase. This can be deduced from the fact that the rock-cut channel had to be cut diagonally through the corner of a group of partly hewn blocks, a leftover from the last use of the quarry." The *piscinae at* Akhziv (see Spier 1993) is a local, albeit more complex, example of this type of quarry reuse, supporting the claim that the Romans made minor modifications to contemporary and ancient coastal quarries to make them function as basic *piscinae* (Marzano 2013: 229). In any case, wave erosion and calcareous cementation have largely removed or covered any details hinting at their use in the Roman period. Their function was undoubtedly linked to the consistent circulation of saltwater that still occurs within them, but more data is needed to make a confident hypothesis.

Water Channels: Saltwater Mixing and Freshwater Sources

The water channels should be separated into separate systems and analyzed independently: (1) a three-channel saltwater system and (2) a two-channel freshwater system. The two systems do converge at the rock-cut pools, but one of the two freshwater channels travels through the central building prior to this. I suggest that the function of this freshwater channel is much more closely related to, and indicative of, the activities occurring in the central structure rather than in the rock-cut pools. To this end, I interpret the saltwater channels as

Raban does – facilitating the controlled circulation of water into and out of the pools in tandem with the rise and fall of daily tides. The main function of the freshwater channels, however, was to bring freshwater from the River Dalia to the central complex for the purpose of processing fish and making *garum* and other fish sauces.

Raban (1995: 298) argues that the saltwater channels function in the same way today as they would have during Roman times. While it is difficult to fathom any other function the saltwater channels might have served, for this to be true, sea-level during Roman times must have been equivalent to the present sea-level. If sea-level was lower, water would not reach the bottom of the channels and fill the pools at high tide. If sea-level was higher, the walls of the pools would not be able contain the water within them. Whether or not the pools were used for holding living creatures, uncontained water defeats the purpose of building a pool. Current paleo sea-level research on the Israeli coast (see Sivan et al. 2004; Sivan et al. 2001; Toker et al. 2012) has determined that Roman sea-levels were within ±0.25 m of their current levels, supporting Raban's hypothesis.

Conversely, the freshwater channels are, along with wells and cisterns, one of the archaeological correlates of the third step in the *salsamenta chaîne opératoire*: washing the fish. Freshwater is also necessary for cleaning the basins in between batches of *salsamenta*, as well as for the workers to drink. As I have mentioned above, the *cetaria* at Cotta and Baelo Claudia C.I. IV both have immediate access to freshwater. At least 23 other *cetariae* in the western Mediterranean exhibit similar freshwater features (see Sánchez López 2018: 85, Table 1), and multiple additional experimental sources attest to the need for freshwater in the *salsamenta* and *garum* production process. The channel flowing through the central structure likely performed this function in tandem with the "large rectangular space… covered with heavy plaster which continues over the side walls… apparently a water tank" described by Raban (1995: 300). This rectangular feature, while not a traditional cistern *per se*, parallels some of the larger vats at

Baelo Claudia (e.g., P6 in XII) that have been interpreted as temporary freshwater storage tubs. As such, the freshwater channels at Dor fit the fish-processing interpretation.

Concerning the murex-purple dye *chaine opératoire*, it needs to be mentioned that (aside from the need for drinking water) freshwater is not a necessary component of the process. The hypobranchial glands of the *murex* snail needed to be soaked in an alkaline solution, as the dye itself is *not* soluble in water (Sukenik et al. 2017: 777). While additives such as ash or fermented urine could be added to freshwater to make an alkaline solution, Koren (2013: 58) explains that freshwater is not necessary from a chemical standpoint, and the immediately present sea could supply more than enough water. This is certainly not to say that the freshwater channels indicate purple dye was not produced; the presence of a dedicated sources of freshwater more closely resembles analogous fish-processing facilities than those facilities that produced just purple dye (e.g., Tel Shiqmona; see Karmon and Spanier 1988; Sukenik et al. 2017).

Rectangular Vats: Fish-Salting

The three rectangular vats at Tel Dor are analogous to the vats at Baelo Claudia and Cotta in both dimension and special distribution, and are one of the primary indicators that fish-processing occurred at Dor. Within the framework of the *salsamenta chaîne opératoire*, whole fish or fish pieces would be layered with salt into these vats and then left in the sun to desiccate. In light of residual evidence from some of the vats at Baelo Claudia, it is also likely that the facility workers fermented fish sauce in these vats when they were not making *salsamenta*.

First, the rectangular vats are poorly suited for purple dye production, and analogous vats in purple dye contexts exhibit notable differences. Dye vats tend to have a smaller open surface area in order to facilitate control over oxygen intake during soaking and reduction. This also protects the dye from being exposed to the sun – the photosensitive properties of the dye dictate that it be kept out of direct sunlight until the final step in the dyeing process. An example of positively identified dye vats come from Persian strata in Area D of Tel Dor (on the tel proper). These vats are circular, measuring 0.9 m in diameter and 1 m deep (Nitschke, Martin, and Shalev 2011: 136-7; Stern and Sharon 1987: 213, Plate 26). At Tel Shiqmona, another local dye site in Israel, Sukenik et al. found "pottery sherds indicat[ing] large vessels with coarse wall, which are adapted to purple dyeing, a process that requires a vessel with a narrow orifice, which can be closed to allow control over oxygen intake during the dyeing process" (2017: 783). The rectangular vats do not fit this morphology, as they are wide-mouthed and would be difficult to adequately cover.

With an average surface area of 4.4 × 3.6 m, all three vats are larger than any at Cotta or Baelo Claudia, with the exception of vat P6 in *cetaria* C.I. XII at 3 × 6 m (see Figure 2). This is not necessarily an abnormality, however, as the vats at Cotta generally exhibit larger average surface areas than those at Baelo Claudia. As I mentioned in my analysis of Cotta above, this is likely due to the additional space available when the *cetaria* is not built within city walls. This is the case at Dor; the industrial area is in a part of the coast with only the ocean to the west and the Tel to east that limit the building space.

The larger surface area might also have been an intentional decision on the part of the Romans to compensate for the shallower depths of the vats. During my 2018 and 2019 survey, sand cover prevented me from accurately measuring the depth of the vats. Nevertheless, the highest point of these features (part of the wall rim of the westernmost vat) is only 2.1 m above modern sea-level. If we assume that the base of the vat lies above sea-level to prevent

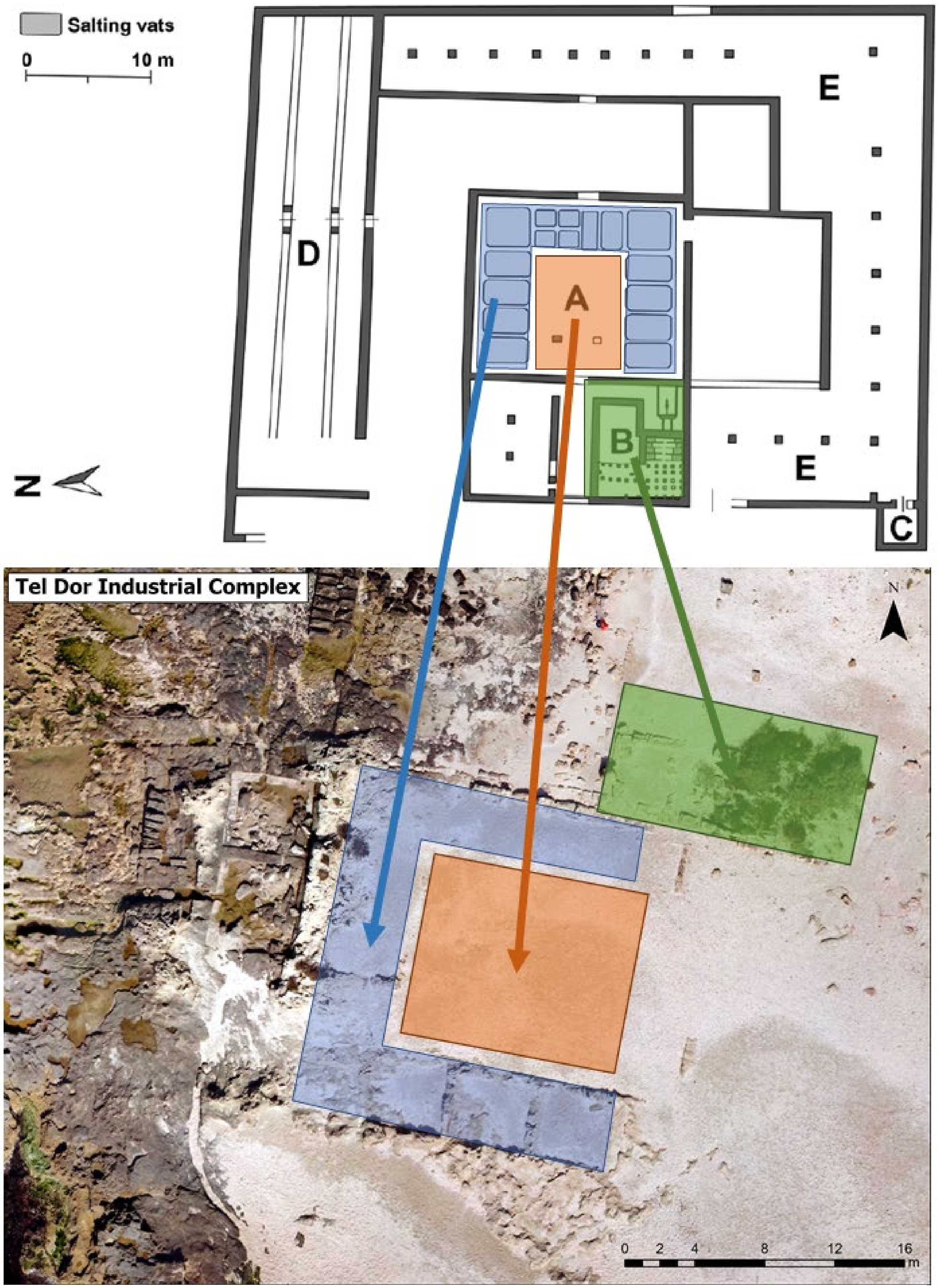

Figure 28: Spatial comparison of Cotta (top) and Tel Dor (bottom) with plastered preparation area (orange), salting vats (blue) and adjacent structures (green) shown (Cotta plan from Marzano 2013: 103, Fig. 18).

saltwater from leaking into the system from the saltwater table, then the vat has an absolute maximum depth of 2.1 m, and likely closer to 1.8 m (the additional 0.3 m accounts for tidal changes in the saltwater table, see Vunsh et al. 2018). Therefore, the cumulative volume of these three vats is, at maximum, roughly 85 m^3, well within the expected range established by Baelo Claudia for a fish-processing facility. Even with the addition of two more vats to the north (those appearing in Raban's top plan) with estimated dimensions of 2 × 2 × 1.6 m, and the possibly three oval basins to the west (discussed below) measuring 4.3 × 2.8 × 1.3 m, the total capacity of the Dor facility is around 140 m^3, well under the 258 m^3 at Cotta and above the 106 m^3 of C.I. XII at Baelo Claudia.

In addition to sharing similar dimensions, the rectangular vats at Dor are spatially distributed around the site in a manner that is almost identical to Cotta (see Figure 27). The salting vats (and sand-covered) salting vats at Dor are distributed in a U-shape around an open, central plastered preparation area. The multiphase structure to the northeast is also immediately adjacent to the salting area. This distribution also fits the model set in Baelo Claudia, where the salting vats are always adjacent to or surround a central preparation area.

Oval Basins: Additional Fish-Salting or *Garum* Production

The oval basin feature class from Dor does not parallel any of the features at Baelo Claudia or Cotta. There are no round features at Cotta, and the round vats in C.I. VI at Baelo Claudia are deep (2.5 m), and nearly circular. The oval basins at Dor are shallower (a minimum of 0.3 m) and more closely resemble rectangles with rounded corners than circles. In this case, turning to the fish-processing *chaîne opératoire* can prove useful. Two interpretations, which are not mutually exclusive, situate this feature class within the *salsamenta* and *garum chaîne opératoires*: (1) the basins were used as fish-salting vats but do not conform to the more common rectangular shape, in which case an additional analogue is needed; or (2) they were used as containers for the fermentation stage of *garum* production.

To address the first, Wilson (1999: 42) notes that vats in *cetariae* at Sullecthum (Tunisia), Neapolis (Tunisia), and Lixus (Morocco) also fit this rounded rectangle style. In particular, four vats at Sullecthum (Figure 28) exhibit a surprisingly similar shape to the oval basins at Dor. These vats are plastered and sunk into the ground so that their rim is at floor level, and also functioned as salting vats. It is notably that they are almost half the size and over twice the depth as the basins at Dor. However, like the rectangular pools discussed above, this discrepancy may be a result of the nearby sea (in this case, only 10 m away at high tide) limiting the depth to which these vats could be dug.

The second interpretation – that they were used to ferment *garum* – is more likely as it accounts for the discrepancies in the shape and size. In his analysis of the abnormally large,

Figure 29: Oval salting vats at Sullecthum (Salakta, Tunisia). Note the rounded corners but generally rectangular shape. Scale: 1m (Wilson 1999: 41, Fig. 15).

round vats at *cetaria* C.I. VI in Baelo Claudia, Curtis (1991: 52) argues that circular vats (and by extension oval or rounded corner vats) would be particularly well suited for preparing fish sauces, as stirring the mixture would be easier without corners. Stirring, although a minor action, is an essential step in the *garum chaîne opératoire* as it ensures the mixture properly autolyzes, and equally distributes salt to halt the growth of harmful bacteria.

Interpreting the basins as *garum* production vessels also accounts for their smaller size and shallower depth compared to the neighboring rectangular vats. *Garum* was often fermented in open jars (e.g., *dolia*) or common cooking vessels (Carannante, Giardino, and Savarese 2011: 73; Corcoran 1963: 206; Wilkins 2005: 29) in addition to permanent vats (as was found in C.I. X and XII at Baelo Claudia, Expósito, Bernal-Casasola, and Rodriguez 2018: 290). Ponsich and Tarradell (1965: 55-68) interpret the four smaller vats at Cotta as *garum* vats for similar reasons. For the same reasons I mentioned above regarding the rectangular vats, the dimensions of the oval basins are poorly suited for the production of purple dye. Considering the present evidence, I prefer the interpretation that the basins held fermenting fish sauces.

Central Building: Additional Processing Features

The central building at the Dor industrial complex presents a complicated array of features that are difficult to interpret individually without continuing excavations. At present, sand and vegetation completely cover all of the features that Raban (1995: 296-301; Raban and Galili 1985b: 341-3) describes, save for part of a plastered floor in the west room of the building. Nevertheless, as a complete dataset the structure parallels the factory buildings at each of the *cetariae* in Baelo Claudia and Cotta. The plastered features indicate the function of the structure is closely related to the movement of liquids: freshwater (from the aforementioned

Dalia channel) for washing the fish prior to salting, *garum* and other fish sauces, or even murex dye solutions. As this building is complex and multi-phased, all three interpretations are possible – either for different time phases or the same phase – but *salsamenta* and *garum* production is more favorable.

According to presently available data from Raban's publications, the plastered features in the central building are the only evidence that purple dyeing could have occurred at the industrial complex. Many of the plastered basins that Raban describes are small and sheltered from sunlight under a roof. Their size would also be more conducive to covering when needed, and he correctly observes that the entire system of channels implies not just the presence of liquid, but its *movement* from one stage of production to the next – indicative of both the purple dye and fish sauce *chaîne opératoires*. After extracting the hypobranchial glands in one basin via crushing, workers could add an alkaline solution to the crushed shells and siphon away useful material into a new basin for soaking. After soaking, the solution (minus the glands) could then be separated further and prepared for heating.

Nevertheless, a dye interpretation does not account for the absence of two indicative archaeological correlates from Susmann's criteria (Table 2): (1) purple dye residue and (2) a method for heating the dye solution. As I previously mentioned in my description of the industrial complex above, the "large purple spot" that Raban discovered in one of the southern rooms did not contain any 6-6' dibromoindigotin; in fact, a personal communication with K. Raveh cited by Lanigan (1989: 50) claims that the purple was not contemporaneous with the structure, but rather modern purple paint. Additionally, Raban's excavations did not turn up any formal heating mechanism akin to the hypocaust present at Cotta. It is possible that the dye was heated over a fire – some of the cooking pot sherds found in one of the southeast rooms are burned (A. Ratzlaff, pers. comms.) – but this does not positively indicate dye production as there are many reasons for pottery to have burn marks.

In light of this and its spatial relationship with the other five feature classes, the most likely function of the structure is fish-processing – particularly fish sauce production – not purple dyeing. Like purple dye, fish sauce requires separation of product and byproduct at different steps in the *chaîne opératoire*. First, high quality *garum* is drawn off the top of lower quality *liquamen*. Then, the *liquamen* (liquid) is separated from the *allec* (solid) and both are packaged separately. Raban's description of some of the plastered features seems to allude to this process:

> The basin was drained through a curbed ashlar-built U-shaped plastered channel, 0.30 m wide on its western side, around the rock-cut ledge and the western wall of the earlier structure, to the norther side of the leveled bedrock. Over the northern wall of the basin and adjacent to it from the outside, there was a series of ashlar-built basins and dividing slab-covered channels that brought fresh water for use in some kind of sieving process. There were some stone-cut grilles and pierced architectural members that demand further study in order to establish their exact function.
>
> (Raban 1995: 300)

Further investigation of the central building is certainly needed to develop a more feature-specific interpretation within the structure, but the structure itself certainly parallels the *cetariae* facilities at Baelo Claudia and Cotta.

Central Courtyard: Preparation Area

Finally, the central courtyard is analogous to the preparation areas of all of the *cetariae* at Baelo Claudia and Cotta. The courtyard is plastered (whether or not with *opus signinum* is unclear from Raban's notes), surrounded by salting vats (see Figure 27), and void of additional architectural features. Fisherman could bring their catch from either the North Bay or the Love Bay, clean the fish with the freshwater at the central building or saltwater in the rock-cut pools, and then gut the fish in the preparation area. The plastered courtyard could then be cleaned with readily available fresh or saltwater, where its natural slope would channel the water into the sea through the opening between the rectangular vats and the *kurkar* wall.[10] This space convincingly mirrors similar spaces in identified *cetariae*.

CONCLUSIONS

The objective of this paper is to firmly support the hypothesis that the Roman period coastal industrial complex at Tel Dor was, in form and function, a fish-processing facility that produced *salsamenta* and various fish sauces. I have endeavored to do so by presenting an argument by analogy that compares the form and function of six feature classes at Tel Dor – rock-cut pools, water channels, rectangular vats, oval basins, a multi-phase structure, and a central courtyard – with the form and function of analogous features elsewhere in the Roman Mediterranean. The argument by analogy follows the style of an "if, and, then" statement: (1) *If* the form of the features at Dor are analogous to the form of features at other fish-processing sites, (2) *and* the form of those features is a result of their function, (3) *then* the function of the features at Dor are likely to be analogous to the function of the features at other fish-processing sites.

I began by presenting the Tel Dor *form* dataset – a description of the dimensions and physical characteristics of the six feature classes according to Avner Raban's excavations from 1981-1984 and my own surveys from 2018-2019. Following that, I set up the analogy with a comparative *form* dataset – a summary of the dimensions and physical characteristics of nine Roman fish-processing sites at Baelo Claudia (Spain) and Cotta (Morocco), as well as a rock-cut *piscinae* at Caesarea Maritima (Israel) – and noted the parallels between the two form datasets. This fulfills requirement (1) above.

[10] Although not necessarily indicative of the courtyard surface beneath it, the modern sand surface exhibits a gentle slope to the southwest towards the Love Bay.

I then proceeded by constructing a *chaîne opératoire* model for murex-purple dye production (the original interpretation of the function of the Dor complex), and *salsamenta* and *garum* production (the new interpretation advocated for here). The *chaîne opératoire* model is well-suited for this type of analysis because it identifies specific features required for each step in the production process (function). This is the relationship between the form of a feature and its function. I determined that in both *chaîne opératoire*s, the form of specific required features is a direct result of their function, thus fulfilling requirement (2).

Finally, I compared the features at Tel Dor with the archaeological correlates that I expect to find at either a purple dyeing or a fish-processing facility. The features at the Tel Dor industrial complex more closely resemble those of the *salsamenta* and *garum* production *chaîne opératoire*. The features do not, however, match what is expected for a complex that produces murex-purple dye. In light of this, I argue that my initial hypothesis is accurate: the industrial complex was indeed a Roman period fish-processing facility.

The argument made here has a significant implication. To date, there are no documented *cetariae* in the eastern Mediterranean (excluding the Black Sea). Compared with the ubiquity of fish-processing installations in the western and central Mediterranean, this dearth of evidence is surprising. Additional data is required to determine the production capacity of the Dor fish-processing facility, but if it is of the same magnitude as the *cetariae* at Baelo Claudia, Cotta, and other well-documented sites, then Tel Dor would be the first documented example of a *cetaria* in the eastern Mediterranean.

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