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Ja, **Maja Grisonic,** ovime izjavljujem da je moj **doktorski** rad pod naslovom **Salt exploitation and trade in the Eastern Adriatic in Classical Antiquity** rezultat mojega vlastitog rada, da se temelji na mojim istraživanjima te da se oslanja na izvore i radove navedene u bilješkama i popisu literature. Ni jedan dio mojega rada nije napisan na nedopušten način, odnosno nije prepisan iz necitiranih radova i ne krši bilo čija autorska prava.

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Introduction

Salt archaeology is a well established topic of study since the 18th century. The first systematic study of salt archaeology was written by Jacques Nenquin in 1961, in his book *Salt: a study in economic prehistory*, upon which all subsequent works were created (Harding 2013). Archaeology of salt has recenty been the subject of a fundamental book (Brigand, Weller 2015). In the last two decades studies about salt in human history acquired a very dynamic role. Quite a few scientific congresses on salt have been organized worldwide, resulting in important publications (Weller 2002; Fíguls, Weller 2003; Morère Molinero 2006; Monah *et al*. 2007; Weller *et al*. 2008; Alexianu *et al*. 2011; Nikolov, Bacvarov 2012; Plata Montero 2022).

In Europe prehistoric salt production has been object of numerous projects (Chapman, Monah 2007; Gaydarska, Chapman 2007; Weller *et al*. 2011; Harding, Kavruk 2013; Harding 2013; Alessandri, Attema 2022; the project *NeoSal : Exploitation du sel dans la vallée d'Añana, Pays basque*, https://www.resefe.fr/en/node/4788). On the other hand, due to the extremely fragmentary evidences that coastal solar evaporation saltpans,[1] which were the principal source of salt in Classical Antiquity, leave in the archaeological record, the studies on material culture about salt exploitation, consumption and trade in Classical Mediterranean are still at their beginnings, although more and more numerous archaeological remains of ancient saltworks are gradually emerging in different parts of the Mediterranean (Işik, Atik Korkmaz 2012; Grossi *et al*. 2015; Guarnieri *et al*. 2019; Bechor *et al*. 2020; Koncani Uhač 2020) and the Iberian Atlantic coast (Castro Carrera 2006; Currás 2017; Castro Carrera *et al*. 2022; Brochado *et al*. 2022). While the archaeological studies on the topic are still struggling to take off, a key publication about salt in the Greek and Roman world (Carusi 2008) has provided an overall knowledge on the matter, becoming a starting point for all further studies.

This work aims to contribute to the economic history of the eastern Adriatic region in Classical Antiquity, trying to fill the gap of knowledge of an economic branch that had enormous importance in the area in all following historical periods. In the Eastern Adriatic, salt production and trade in the Middle Ages and in the Modern period have been studied by multiple eminent scholars, including Milena Gecić (1955), Zlatko Herkov (1971), Jean-Claude Hocquet (1978-

[1] In the text the terms *saltpans, saltworks, salinas, salterns* are used as synonyms.

1979; 2012, just to cite his principal works), Tomislav Raukar (1970; 1977; 1981), Ante Usmiani (1984), Ivan Erceg (1977; 1981), Josip Kolanović (1995), Šime Peričić (2001; 2005), Stanko Piplović (2003), Serđo Dokoza (2015), Bruno Brakus (2019) and others. However, very little about salt exploitation in Classical Antiquity is known. The only researcher who has attempted to study the history of salt in this area in this period is Marin Zaninović (1991). Considering that salt production was one of the most important sources of income of this region in later historical periods, it is very possible that it held a primary importance already in Classical Antiquity, if not even earlier. It is reasonable to assume that in many cases there was a continuity of exploitation of salt production spots from Classical Antiquity (sometimes even from Prehistory) to the Middle Ages. This has been demonstrated at several saltpan sites, where at least two different chronological phases can be detected (see Ch. 3 and 4). Due to the historical importance of salt in this region, this gap of knowledge in Classical Antiquity also represents a large gap in our understanding of the economy of ancient *Histria* and *Dalmatia* as a whole (Grisonic 2022).

This work summarizes the available information on salt production on the eastern Adriatic coast in Classical Antiquity, providing new perspectives and contributions that originate from personal field research, both on land and underwater. Field investigations were partially included in the project "Saltpans as Anthropogenic Landscape Intervention, a New multidisciplinary Approach for Studying Sea-level changes", started in 2018 by the Croatian Geological Survey (HGI) and the University of Haifa, in collaboration with the Universities of Zadar, Zagreb and Padova. The project now benefits from the contributions of additional scholars from other international institutions (Bechor *et al*. 2020; 2023). Because of the still low anthropization of large parts of the Croatian shore, many archaeological remains of historical saltpans, both under water and on the coast, survive to the present day, which makes the Croatian shore an exceptional location for studying the history of salt production in the Mediterranean. This is the reason why this work focuses on salt exploitation. The data that might hint to salt trade in the Eastern Adriatic in Classical Antiquity are so scarce that allow us only to make rudimentary assumptions and wider comparisons with later periods, when these matters can be partially elucidated thanks to the help of archival documents.

This work is divided in four chapters: the first one, *Salt and its history*, introduces the topic and contains general information about the types and uses of salt, salt sources, the history and symbolism of salt through different periods of human history, with a particular focus on the eastern Adriatic region. It is a derivative and non-original chapter, which does not present the records in an exhaustive and systematic way, but it is useful to provide a context.

The second chapter, entitled *Salt production and trade in the Mediterranean in Classical Antiquity*, is a review of the available information on this subject, but is also raises new questions and brings new perspectives about the interpretation of ancient literary sources. The description of antique salt-making sites discovered in the Mediterranean provides useful comparisons for the next two chapters of the work, which are the core of the thesis.

The third chapter, *Salt production in Classical Antiquity in the Eastern Adriatic*, presents the methodology used to identify ancient salt-making sites, gives a review of the ethno-historical data that can be obtained from still-working saltpans in Slovenia (Piran: Sečovlje and Strunjan) and Croatia (Pag, Nin and Ston). The chapter further discusses the toponymy of salt on the Eastern Adriatic, the written sources (both literary and epigraphic) and it presents the locations of salt production, which occurred next to urban settlements, Roman villas and fish-processing sites. The chapter ends with the discussion on the functioning and typology of saltpans through various historical periods: firstly, the data collected on the still-working saltpans that continue to produce salt in the traditional way, followed by the description of saltpans in the medieval period, several of which I have personally surveyed along the Croatian coast. Lastly, the so-far known main elements that constituted the saltpans in Classical Antiquity are presented. I believe that with the progress of the archaeological research, these data will soon be integrated with many more material evidences.

The fourth and last chapter, *Case studies and Catalogue*, presents a detailed description of the survey campaigns conducted on four sites that have been chosen for field investigations as part of the above-mentioned project "Saltpans as Anthropogenic Landscape Intervention". Furthermore, the chapter presents the presumed sites of ancient saltpans along the eastern Adriatic shore that have been researched by other institutions. Other possible saltpan sites, which I have identified based on aerial photography, toponymy, archival documents and the presence of nearby archaeological remains that can be linked with productive activities, are listed in the last part of the chapter.

Although the study is focused on the period of Classical Antiquity, it presents copious data that are useful to the history of salt in this region in a wider diachronic perspective, towards where the continuation of the work will be directed.

1.

SALT AND ITS HISTORY

1.1. What is salt and how it is produced

Common salt or sodium chloride (NaCl) is a mineral, which concentrates or crystallizes from an aqueous solution – the oceans, seas and salt lakes. Therefore, it is defined as an evaporite mineral (Harding 2021).

Both humans and animals need to consume salt, which provides them the sodium (Na^+) that is necessary for proper physiological processes: sodium regulates the fluid balance of the body and supports the functioning of internal organs. Flavoring food with salt could be a biological adaptation (Harding 2021). **Humans** get their amount of salt through eating meat, eggs and fish. The diets that comprise cereals, vegetables and boiled meat (typical of agricultural societies) need an extra salt intake, while diets based on raw or roasted meat, fish or insects (typical of hunter-gatherer societies) do not require additional salt (Tašić 2000: 36).

The recommended **daily intake of salt** is very debated, ranging from 1.5 to 15 g per day (see Harding 2013: 14). Given that at all times humans probably consumed much greater quantities of salt than it is actually needed, these very inconsistent data still cause huge problems in calculating the amounts of salt required and produced in different historical periods. The consumption of too abundant or too low amounts of salt can lead to various deseases.

Even some **plants** need a certain amount of sodium at trace levels for growing, as *Atriplex spp* (commonly known as saltbush, because it retains salt in its leaves), *Kochia childsii*, millet and others. Studies have shown that sodium is also beneficial to other plant species (see Maathuis 2014).

In pre-industrial societies, salt has another crucial role – that of **preserving food**. Before the invention of the refrigerator, salt was one of the most widespread conservants, because of its antibacterial properties (Harding 2021). Nowadays, most salt is factory-produced and employed for de-icing roads, because it lowers the freezing point of water to -18 ºC (Hocquet *et al*. 2001: 13). Salt is hygroscopic (it absorbs water), it softens hard (calcareous) waters and it is also employed for producing caustic soda (used to make soaps, detergents and to unblock drains), glass, as a fertilizer in agriculture, in cement production and so on (Hocquet *et al*. 2001; Harding 2013). Only one third of the world's production of salt originates from the sea, the rest is obtained from mining.

1.1.1. Various types of salt

Sea salt

Seawater typically contains 3.1 to 3.5 % of salts, which means that 1 l of water contains 31-35 g of salts: in other words, its salinity is 31 to 35 ‰ and the remaining percentages of water need to be removed to finally obtain the grains of salt (Harding 2013; 2021). Oceanic waters have an average of 3 % of salts (Weller 2015: 68). The saltiest open sea in the world is the Red Sea, where salinity reaches 4 %. The average salinity of the Mediterranean and the Adriatic Seas is 3.5 %, but due to climate change it can now reach 3.9 % in the Adriatic Sea (https://www.irb.hr/Novosti/Jadran-nikad-slaniji). Due to the influx of fresh water from some of Europe's biggest rivers, the Black Sea contains only 1.8 % of salts. The salinity of the Baltic Sea is less than 1 %, that is why the Scandinavian countries historically imported salt from other regions, because extracting salt on their shores would not have been very profitable (Harding 2021: 15).

Salt is extracted from seawater by evaporation. Depending on local and weather conditions, seawater contains various percentages of different dissolved salts, mostly the ions of sodium (Na) and chlorine (Cl), but there are also other minerals and impurities that cause a bitter taste: sulphur (S), magnesium (Mg), calcium (Ca) and potassium (K), as well as algae and sediments. Saltwater needs to be farmed in successive pans, evaporated and purified from the undesired salts that decrease the quality of the final product. In the saltpans this is obtained progressively: in every succession of pans, the least soluble salts precipitate first. The first minerals that precipitate in very small quantities are iron oxide (FeO) and calcium carbonate ($CaCO_3$), then it is the turn of calcium sulfate ($CaCO_4$), also known as gypsum. The most difficult minerals to eliminate at the end of the process are mainly magnesium chloride ($MgCl_2$), magnesium sulfate ($MgSO_4$) and potassium chloride (KCl), which, if incorporated in the final salt, would give it a bitter taste (Harding 2021: 13-14). At the same time when the so-called “bad salts” gradually precipitate, seawater progressively condenses to saturation, which happens in the crystallization pans. Saturation occurs when the concentration of sodium cloride or common salt (NaCl) reaches 25.6 %: it can no longer be kept in a dissolved state, so it crystallizes and precipitates at the bottom of the salt basins, from where it can be harvested (Rumora 1997).

If the weather is sunny and there is no wind another crystallization can occur at the surface of the crystallization pools: it is the tiny crust of the renowned **flower of salt**, which, due to its infrequency and most demanding harvesting and drying techniques, is much more expensive than common kitchen salt and has more minerals. The crystals of kitchen salt are cubic, while those of flower of salt are pyramidal. Flower of salt is not used for cooking, but for final seasoning of food, to which gives an additional gourmet touch.

T. 1 Chemical compounds of the Adriatic seawater (Rumora 1997)		
NaCl	sodium chloride	27.99 g/l
$MgCl_2$	magnesium chloride	3.36 g/l
$MgSO_4$	magnesium sulfate	2.33 g/l
$CaSO_4$	calcium sulfate	1.28 g/l
KCl	potassium chloride	0.76 g/l
$CaCO_3$	calcium carbonate	0.12 g/l

Salt from salt lakes

Salt lakes generally contain much larger amounts of salts than the seas and oceans. The Dead Sea contains about 340 g/l or 34 % of salt. Other known salt lakes are for instance the Salt Lake (Tuz Gölü) in Anatolia and the Great Salt Lake in Utah, USA. The salt lakes in Arab countries, which can be found next to the coast or in the depressions under salty mountains, are called *sebkhas*. In some salt lakes salt can be picked up around their shores, without the need of eliminating impurities.

Rock salt (halite)

Halite is the mineralogical name of sodium chloride (NaCl), which occurs as cubic crystals (Fig. 1). It is colorless when it is pure, and it colors in blue, green, yellow or red, when it gets in touch with other evaporitic salts, as potassium chloride, copper and iron oxides (Hocquet *et al*. 2001: 21).

Rock salt or halite forms through evaporation over different geological eras. It is contained in the diapirs or dome-like structures, which due to their lower density, arise from paleo seawater deposits towards the earth's surface (Harding 2021).

Like other rocks, rock salt can be extracted from open-air quarries or underground mines (Gouletquer, Weller 2015: 15). The extracted rock salt can then be traded in blocks of specific shape, or washed and transformed into brine, to eliminate the impurities and obtain the salt in grains. In Europe, the biggest rock salt deposits are found in the area of northern England, the Netherlands, Germany (Bad Reichenhall) and Poland. Other extensive deposits are located in the Carpathians, in the Austrian Alps (Hallstatt, Dürrnberg near Hallein, Hall), France, Spain, western Sicily (Realmonte), Bosnia-Herzegovina (Tuzla) and others. Present Croatia and Slovenia do not have any rock salt deposits.

Fig. 1 Halite (Rémi Bornet, https://www.le-comptoir-geologique.com, accessed 23/03/2022).

Table/cooking salt with added iodine

In present-day grocery stores, it is the iodized and refined table salt that is most commonly sold. Table or cooking salt is typically mined from underground deposits and it is processed to remove other minerals. Sea salt is less processed than table salt and retains trace minerals. It generally contains less iodine than table salt. As iodine can be assumed only through diet, the World Health Organization recommends to add 20 to 40 mg of iodine per kg of salt to help prevent iodine deficiency, which causes thyroid and brain disorders and mental retardation (WHO 1998). Salt was selected for this purpose because it is widespread and regularly consumed by most people in the world and because salt iodization is very cheap. Since 1993, when salt iodization started to be applied worldwide, the iodine deficiency disorders have greatly diminished (https://apps.who.int/nutrition/topics/idd/en/index.html). Iodization of sea salt is compulsory or recommended: in Pag this has been performed since 1954 (Rumora 1997).

Ancient salt was not processed and did not have iodine, it was more concentrated and therefore it tasted differently than the salt we are normally used to, although nowadays many unrefined salts can be bought: they are usually more expensive than the most common iodized salt (Harding 2013).

1.1.2. Salt sources

Salt can form spontaneously in nature, like rock salt and salt that naturally forms through evaporation in coastal or inland ponds and lakes. However, the majority of salt is acquired through human action. Spontaneously formed salt is believed to have been exploited from the earliest periods of humanity, while men started to artificially produce salt probably as early as in the Mesolithic period (Harding 2013; Weller 2015). In Pliny the Elder's encyclopedic work, the natural (*sal nativus*) and artificial (*sal facticius*) salts are clearly distinguished (*Nat. Hist*. XXXI, 70-92).

There are two major ways of obtaining salt through human action: by the **evaporation of saline liquids** – brine or seawater, or by **mining and quarrying**.

Natural saline waters – seawater, salt lakes and springs – need to be **concentrated** in order to obtain salt through evaporation (Gouletquer, Weller 2015: 15). This means that highly-concentrated brine needs to be obtained and gradually evaporated, to finally collect the salt crystals. **Brine** is defined as a high-concentrated solution of salt, most commonly sodium chloride, in water, and is one of the crucial elements of salt-making (Harding 2021: 13). The liquid evaporates thanks to the heat and as a result the salt crystals are left on the water surface or they stick to solid surfaces. This can occur naturally by insolation and it is what happens in the saltpans, coastal lagoons and salt lakes. Another way of obtaining brine is by artificially heating it (see below).

Salt production techniques adapt to local climate and possibilities (Gouletquer, Weller 2015: 13). As ethnographic examples have shown, salt crystals can also be obtained by burning **halophyte plants** that grow on saline soils (like the *Salicornia europaea*/common glasswort) or plants that directly contain sodium chloride (sea grasses on tidal salt marhes), washing their ashes and gathering salt grains from ashes and charcoals (see Hocquet *et al*. 2001: 25-32; Harding 2013: 28; Gouletquer, Weller 2015: 16). This manner of obtaining salt leaves significant quantities of charcoal and ashes in the archaeological record (Weller 2015: 73). Aristotle (*Meteorol*., II. III, 35-40) attests a method of obtaining salt from rushes and reeds in Umbria. Additionally, salt can also be obtained through **lixiviation**, a process of filtration or leaching of salty sand, earth and clays, which causes the separation of soluble and insoluble substances (Harding 2013; 2021). Salty mud, salt plants and seaweeds are washed with fresh water or with lightly concentrated brine: the insoluble parts are removed after boiling and the result is concentrated brine that can be further evaporated to obtain salt in grains (Gouletquer, Weller 2015: 15).

The boiling of brine and the extraction of rock salt are more easibly identifiable, as they leave distinct **traces in the archaeological record**. Other methods of obtaining salt can de discerned from ethnographic parallels and written sources. The preservation of the remains of saltpans, in addition built with perishable materials, is conditioned by more recent human activities, the changing landscape and sea level, as well as the preservation potentials of the natural environment where they were built.

Natural salt evaporation ponds on coastal rocks

This is probably the most ancient and easiest way of gathering salt (Balen-Letunić 2006). Pliny (*Nat. Hist.*, XXXI, 74) and Isidore of Seville (XVI, 2, 3) talk about this type of salt, obtained from the sea foam, which dries in natural ponds along the coast (Zaninović 1991: 259). On Malta and the neighboring islands, rectangular or rounded salt pools (salting yards) and channels are hollowed on coastal rocks (Fig. 2). It is thought that on the Malthese archipelago salt was already harvested from coastal rocks starting from the 5th millennium BC, and probably in a more structured way since the appearance of the megalithic temples of Malta in the second half of the 3rd millennium BC (Hocquet *et al*. 2001: 41).

Fig. 2 Xwejni Bay saltpans on the island of Gozo, Maltese archipelago (courtesy of Tena Festini).

Salt springs, streams and rivers

Inland salt-water springs originate from underground deposits of rock salt. As all underground water they are pressed upwards (Harding 2021). The brine from salt springs (Fig. 3) can vary in salinity from day to day, depending on the rainfall, sun and the depth of the rock salt deposit (Harding 2013). As an example, the salt springs of Hallstatt have one of the biggest concentration of salt, reaching the 25 %. The brine from the salt springs frequently contains not only sodium chloride, but also other salts with healing properties. The impurities contained in the brine from inland sources are less frequent than in the brine obtained in coastal saltpans: in some cases the boiling of inland brine is enough to eliminate the undesired salts (Harding 2013).

Fig 3. Rock salt outcrops and salty river in Berca, Romania (Daniel García-Castellanos, https://i.stack.imgur.com/BNpMX.jpg, accessed 23/03/2022).

In inland Spain, salt was produced in saltpans that have the same plan and technology of coastal saltworks, using the water from inland salty sources and streams. They were built in valleys or disposed on terraces and insolation played the main role in obtaining the grains of salt. Salt production was complementary to other agricultural activities, mainly oliviculture (Hocquet *et al*. 2001: 33-38; Plata Montero 2006). Nowadays, most of these inland saltpans are abandoned, although numerous Spanish researches and organizations are trying to raise awareness on this important activity and preserve its historical landscape (see for instance the articles published in the journal El Alfolí).

Fig. 4 Salinas de Añana (courtesy of Tiago Brochado and Miguel Costa).

One of the oldest (from ca 7000 BC) and most picturesque salt factories in the world are **Salinas de Añana** in the Basque Country, Spain (Fig. 4). The rainwater that falls on the diapir of solid salt under the Valle Salado de Añana firstly crosses the upper rock strata and then the salt layers, emerging again to the surface in the form of hypersaline springs. There is no need for drilling or pumping, because four of the many salt springs in the Añana Valley supply brine continuously, providing an average flow of about 2 liters per second, with a salt concentration of around 210 grams per liter. The brine is channeled from the springs to the brine storage wells by a complex network of wooden canals (mainly hollowed pine trunks, Fig. 5), and then the brine is poured in the pools of the saltpans, in order to fill them for 2 to 4 cm. The saltpans of Añana are composed of horizontal evaporation platforms of different dimensions, built on scenographic terraces. Thanks to the action of the sun and wind, the brine quickly evaporates and salt can be collected already after four hours (Plata Montero 2006: 90-112; https://vallesalado.com/Como-se-produce-la-Sal-de-Anana).

Fig. 5 Salinas de Añana: brine storage well and brine channels (courtesy of Alberto Plata and Noelia Tofé).

In the Balkans, an important salt production site is **Tuzla**, located in northeastern Bosnia-Herzegovina (Fig. 6), where the rock salt layer reaches 160 m of thickness (Rumora 1997). It was exploited from Prehistory up to present. The first industrial facility for salt extraction was constructed in 1885, when the deeper rock salt layers were reached (see Banović 2010). In earlier periods, salt was obtained by evaporation of brine from underwater salt springs (Balen-Letunić 2006). In the Early Neolithic, in Gornja (= upper) Tuzla, members of the Starčevo culture (6200-5500 BC) produced cone-shaped pots used in the process of obtaining salt (Čović 1961; Tašić 2000: 36; Tašić 2012: 215). In Roman times, this area was included in the Roman province of *Dalmatia* and the settlement of *Salinae* developed (Pašalić 1960: 75; Zaninović 1991: 258). It was destroyed in the 6th century by the Avars and Slavs (Croatian Encyclopedia). In the 10th century, in his work *De administrando imperio*, the Eastern Roman Emperor Constantine VII Porphyrogenitus still refers to Tuzla with the toponym *Salinae* (Skok 1971; Banović 2010). In ancient Croatian language, Tuzla was called *Soli* (= salts), while from the beginning of the 16th century, the Ottomans renamed it *Tuzla*, which means salt mine in Turkish (*tuz* = salt).

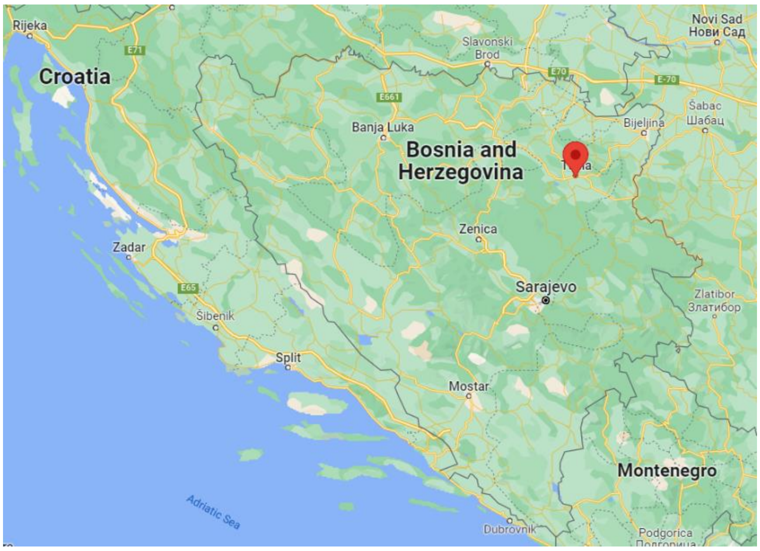

Fig. 6 Location of Tuzla (Google Maps).

In the interior parts of present Croatia, salty wells called *šokoti* (from Hungarian *sokut*) were dug in order to extract salt water (Balen-Letunić 2006). The oldest written evidence of this practice dates back to the 14th century (Herak 1971: 116).

Brine from salty springs has been used to produce salt from the Mesolithic period (Harding 2013; Weller 2015) onwards. An interesting example of this practice in the 1st century AD is found in Tacitus (*Ann.*, XIII, 57), who described the collection of brine from salty springs and the following process of obtaining salt grains once the brine got in contact with a burning pile, performed by two Germanic populations (Balen-Letunić 2006).

Salt mines and quarries

Salt mines are located in many sites across Europe. At present they are set much deeper than in ancient times, when salt rock was primarily worked from the surface. Deep mining is attested at Halstatt and was later developed by the Romans.

Rock salt is very hard and its extraction is very challenging still today (Harding 2021: 7). In prehistoric times, hard stones and later bronze/iron hammers and picks were probably used for this difficult operation. When a piece of rock salt was obtained, it was crumbled and dissolved in water and evaporated, in order to remove the unwanted minerals in the salt, which precipitate at different stages in the evaporation process.

Fig. 7 Rock salt piercing using a wooden trough and consequent extraction of rock salt in Băile Figa near Beclean, northern Transylvania, Romania (Buzea 2018: 69, 111).

Experimental archaeology in Romania has shown that salt can also be extracted from salt rock using wooden troughs (Buzea 2018; Harding 2021: 8-12, Fig. 7). Channels of wooden troughs were built to bring fresh water to the site, the water was let dropping from a perforated trough onto the rock salt surface for some hours and depressions were obtained where salt dissolved, which could be used for fragmenting the salt rock. For the moment this technique is known only in the Carpathians, in central and northern Transylvania and the Maramureş region in northern Romania and western Ukraine.

One of the most impressive prehistoric salt mining sites is **Hallstatt** in Austria, located at the lakeside near the well-known Iron Age necropolis, after which the Hallstatt period was named (ca 1200 - 700 BC). The mining area with tunnels and shafts cut deep in the Plassen mountain comprises various parts, which belong to different chronological phases from the Bronze Age to the early Iron Age (Kern *et al*. 2009; Harding 2013: 71-72; 2021, Fig. 8). The salt rock blocks were removed and then further processed dissolving salt in the water and evaporating it (during the Middle Ages, this was done in underground salt ponds). The production and distribution of salt was the base of the prosperity of the local Halstatt population, which is manifested through grave goods, often very luxurious items from the Mediterranean, Graeco-Etruscan world.

Fig. 8 Hallstatt, Austria (Hartl et al*. 2015).*

Very important is also the **Cardona** salt mine, located in Catalonia, about 80 km northwest of Barcelona. Cardona is a more than 140 m high salt mountain (Fig. 9), a tip of a 2 km deep diapir, where numerous salt mining tools from the Neolithic period were recovered (Weller 2002; 2015: 75-76). At that time, rock salt was being removed from the open quarry and then probably shaped into standard forms to be stored and exchanged. Salt mining continued through all historical periods until 1990. The Cardona mountain is now converted into a cultural park.

Fig. 9 Muntanya de Sal in Cardona (https://www.likealocalguide.com/barcelona, accessed 05/03/2022).

Saltpans

Traditional saltpans (salt-pans/salt pans), saltworks (salt-works/salt works), salterns or salinas/salines (sing. salina) are intertidal facilities, where, during high tide, seawater is channeled into a system of shallow pools (basins), usually lined in mud. The water flows in low gradient between successive basins of different evaporation grades, regulated by sluice gates. In every succession of pools, thanks to the sun and winds, the brine reaches a higher concentration, until the crystallization phase, when salt can be harvested (Trakadas 2015: 17-19; Bechor *et al*. 2020). About 17 kg of seawater are required to achieve, at the end of the evaporation process, 1 kg of salt (Moinier 1985: 77; Marzano 2013: 124).

Fig. 10 Salines de Guérande on the Atlantic coast (http://www.vjoncheray.fr, accessed 23/03/2022).

The most suitable environments for salt production are coastal lagoons and salt marshes, also located more internally from the sea, as it is the case with the saltpans in Guérande, not far from the estuary of the Loire River, close to Nantes in western France (Fig. 10).

Flattened alluvial zones, close to the estuary of rivers, contain the most suitable substratum for salt production, made of clayish and loamy waterproof soil (Hocquet *et al*. 2001: 42). Many saltpans are located at the deltas of big rivers, like the Po, Rhône, Loire, Ebro, Tago, Nil and others. Smaller saltpans can be arranged in shallow, flat coves and lagoons, close to Mediterranean marshes and streams of mostly seasonal character, where loamy and clay sediments accumulate as well, as it is the case of numerous saltpans on the eastern Adriatic coast. On the Dalmatian coast,[2] shallow, mostly northwest-, but also southeast-oriented flat and

[2] The term “Dalmatian coast” refers to a coast characterized by the ingression of the rising postglacial sea into a relief of coast-parallel anticlines (ridges) and synclines (valleys) from a young orogenesis and it is named after the landscape of Dalmatia. This coastal landscape of the eastern Adriatic Sea extends for 400 km from the city of

muddy coves, which are the result of Holocene marine ingression into marly sandstone valleys (tectonic synclines), bounded by karstic ridges (tectonic anticlines), were being systematically chosen for the implantation of saltpans, like the saltpans of Pag, the biggest in Croatia (Fig. 11). The deposits of mud and clay found at these locations supply the raw materials needed to construct the salt basins and, together with wooden planks and poles, the embankments of saltworks (Fig. 12). Saltpans need to be repaired every year after the salt harvest.

Fig. 11 Saltpans of Pag (M. Grisonic).

Salt obtained in present-day saltpans is threatened by the pollution of the seas and the air (Hocquet *et al*. 2001: 8). At the same time, due to unprofitability and the conversion of large parts of the coasts for touristic purposes, saltpans themselves constitute an endangered landscape in Europe. The Mediterranean has still quite numerous saltpans, although many were abandoned in the last decades. In Mediterranean Spain, salt is produced in Cabo de Gata (Almería) in eastern Andalucía, in San Pedro del Pinatar (Murcia), in Torrevieja close to Alicante, in Torredad (Tarragona) at the estuary of the Ebro River and in the saltpans of Es

Rijeka in the north to Dubrovnik in the south, with numerous islands that are up to 60 km long and only a few km wide (Kelletat 2019).

Trenc on Mallorca. In southern France, salt is mainly produced in the Camargue region, at the delta of the Rhône River: the best known are the saltpans of Aigues-Mortes and those of Giraud. Further west along the French Mediterranean coast, there are also the saltpans of Gruissan and those of La Palme close to Narbonne. In Italy, the still-functioning saltpans are those of Cervia and Margherita di Savoia on the western Adriatic coast, Trapani-Marsala in Sicily and Sant'Antioco in Sardinia.

Fig. 12 Examples of embankments on saltpans: the abandoned saltworks of Dinjiška, island of Pag (a) and the still-functioning traditional saltpans in Sečovlje, Piran, Slovenia (b) (M. Grisonic).

On the Slovenian coast, salt is being produced in Strunjan and Sečovlje (Piran). The three still-functioning saltpans in Croatia are those of Pag and Nin in northern Dalmatia and Ston in southern Dalmatia. Montenegro is currently the only Mediterranean country that does not produce sea nor any other type of salt. Albania's saltworks are located in the Narta lagoon (Vlorë), in the southwestern part of the country. In Greece, saltpans are active in Messolonghi on the Ionian Sea, Kitros, Aggelochori and Nea Kessani in the northern Aegean Sea and in Kalloni and Polichnitos on the Lesbos Island. In Turkey, sea salt is produced only in İzmir Çamaltı and Balıkesir Ayvalık saltworks, in NW and W parts of Anatolia. The majority of Turkish salt is obtained from salty lakes and salt rock. The eastern and southern Mediterranean are also rich in saltpans, as well as Malta and Cyprus.

According to ancient authors, **saltpans** were used on the Italian Peninsula and other parts of the Mediterranean **in historic times**. The demographic increase and consequent growth of the demand for salt in central Italy's early city-states between the Bronze Age and the Roman period probably led to the intensification of salt production and the adoption of saltpans, to replace the previously employed briquetage technique of salt production. This hypothesis is currently being researched by scholars from the Groningen Institute of Archaeology, in the framework of a new interdisciplinary research project "Salt and Power, Early States, Rome and Resource Control" (Alessandri, Attema 2022).

Fig. 13 Salt harvest in Cervia in 1909 (courtesy of Nino Giunchi).

Briquetage technique and iron/lead pans

In Prehistory and Protohistory, brine of both seawater and inland salty sources was evaporated using the briquetage technique (concentrating and boiling brine in single-use raw ceramic vessels, which were then broken to extract salt cakes, Fig. 14, 15).

In coastal Europe, this technique was mostly used in areas of less favorable athmospheric conditions of northern, western and central Europe. Findings of big mounds of these pottery vessels and connected heating structures are common on the eastern British coast, on the coasts of Netherlands, Belgium and western France (Harding 2013).

More and more numerous finds of briquetage along the Mediterranean shores point to the fact that this technique was also used in the area that from the Graeco-Roman period on started to produce salt in saltpans.

Fig. 14 The briquetage technique of obtaining salt: reconstruction of a kiln discovered in Pont-Rémy, Somme, northern France in 1994

(© Cyrille Chaidron, Inrap, https://www.inrap.fr/dossiers/Archeologie-du-Sel, accessed 23/03/2022).

An evolution of the briquetage technique were the medieval and modern iron or lead salting pans, placed over a fire. They became common in central Europe in the Early Modern period (Agricola, *De re metallica*, 1556). Unlike the single-use briquetage vessels, iron or lead salting pans could be reused over and over. Lead pans were probably used for this purpose already in Classical Antiquity (Harding 2013).

Fig. 15 Reconstruction of the briquetage technique of salt production: evaporation of brine in the briquetage ceramic vessels to obtain the salt ingots (a) and dried salt ingots extracted from broken ceramic vessels (b) (© Cyrille Chaidron, Inrap, https://www.inrap.fr/dossiers/Archeologie-du-Sel, accessed 23/03/2022).

1.2. Various uses of salt

In ancient literary sources, the knowledge and use of salt were considered fundamental elements of civilization (Zaninović 1991: 255-256; Traina 1992: 363; Carusi 2008: 247; 2018, Grisonic 2022). From Prehistory on, salt represented the **main food condiment**. Additionally, it was of prime importance in the **preservation of food**, allowing medium- and long-distance trade of products. Another main purpose of salt was in **animal husbandry**; it was added to livestock feed and used in the preparation of cheese (Zaninović 1991: 257; Marzano 2013: 123; Moinier, Weller 2015: 220-223). Salt was one of the principal ingredients employed for the preparation of the beloved fish sauces of ancient cuisine. It was used as a medicine, in mummification, in the textile and tanning industry, in metallurgical processes and since Prehistory it served as a commodity in bartering. The manufacture of salt ingots from prehistorical times on demonstrates that salt was often used as a currency (Carusi 2008: 41-43; Marzano 2013: 123).

Salt is bactericidal and allows the preservation of organic remains, such as wood, but also leather and textiles, as it is the case of the salt mines of Hallstatt, where numerous Iron Age organic objects were recovered (Harding 2013). Salt is an antibacterial element, which heals wounds and infections.

Salt as the main food condiment

The question of when humans started to flavor food with salt remains open and hardly demonstrable. The oldest evidence for artificially produced salt dates to the Mesolithic period (Harding 2013; Weller 2015), but it is believed that long before that men, as other mammals, searched for salt that naturally formed in nature, to which they were biologically attracted to.

The oldest written evidence of salt consumption is provided on Babylonian clay tablets (Moinier, Weller 2015: 153-154). In the Greco-Roman world salt was the main food condiment (as it is today), flavoring all kind of foodstuffs and stimulating appetite (Carusi 2008: 21). The Homeric heroes could not eat meat without adding salt to it. In ancient Rome, the basic meal was composed of bread and salt (Carusi 2008: 23; Moinier, Weller 2015: 157).

In many Slavic cultures, the peasants used to greet the visitors by offering them bread and salt (in Croatian *kruh i sol*): bread was intended as the basic nourishment, and salt had the symbolic meaning of good health (Harding 2013).

Salt for the preservation of food

Apicius (*De re coquinaria*), Athenaeus (Δειπνοσοφισταί), Cato (*De agri cultura*) and Columella (*De re rustica*) wrote recipes where salt was employed for the preparation and preservation of food (Moinier, Weller 2015: 165-167). Due to their bactericidal properties, salt (*sal*/ἅλς) and brine (*muria*/ἅλμη) were used for the conservation of meat (Cat., *Agr*., 162, 1), fish and cheese (*Agr*., 88), vegetables and some kinds of fruits, like pears and plums (Col., XII, 4-10). Every foodstuff preserved under salt or brine was called *salsamentum*, in Greek τάριχος: yet most of the time these two words indicated salted fish, especially τάριχος, showing that in the Greek world salted meat was almost inexistent, while in the Roman world meat preserved in salt was more frequent (Carusi 2008: 25).

The Sequani tribe exploited the salty sources in Franche-Comté (eastern France) and exported salted pork to Rome and other markets (Strab., IV, 3, 2, C 192). Nevertheless, one of the main producers of salted pork was northern Italy, where it was preserved in salt inside clay silos (Moinier, Weller 2015: 201). Salt was also important for the production of ham and sausages.

The principal foodstuff preserved under salt was salted fish (Roman *salsamentum* or Greek τάριχος "par excellence") and various kinds of fish sauces known from ancient written sources (*garum, liquamen, muria, allec/hallex*), which were used as condiments. They were consumed in all periods of Classical Antiquity at all social levels (Carusi 2008: 26). The most renowned ancient fish sauce was the *garum*, obtained from the fermentation of blood and viscera of mackerel, tuna, bigger *clupeidae* and *sparidae* (Grainger 2014: 42). Salt needed to be added in the process to avoid putrefaction (Carusi 2008: 26). *Liquamen* was a sauce made from small whole-fish, also used for cooking (Grainger 2014: 38). *Muria,* for which Pliny says that Dalmatia was known (*Nat. His.*, XXXI, 93-95), was a sauce cleared from fermenting viscera, made from tuna, mackerel or by mixing various types of fish to obtain a sauce of poorer quality compared to *garum* (Borzić 2011: 72, n. 24; Grainger 2014). *Muria* and *garum* made from tunas were most likely secondary products to the salted fish (Grainger 2014: 43). Finally, *allec* or *hallex* was a fish paste made with small *clupeidae* and *sparidae* (Grainger 2014: 37). Salted fish and derived fish sauces were produced in fish processing workshops known as *cetariae*, which spread all over the Mediterranean basin over the 1st century BC - 3rd century AD.

Salt was employed for the **conservation of oil and olives**, as attested by Cato (*Agr*., 7, 4 and 117) and Columella (*Rust.*, XII, 49). If salt is added, oil does not alter and can be used to develop make-up and pharmaceutical products (Moinier, Weller 2015: 212-213). In **cheese making**, rock salt was to be preferred over sea salt, allowing a longer preservation (Varr., *De re rust*., II, 11, 5).

Salt in animal husbandry and transhumance

During the Early Neolithic, when sheep, goats, pigs, cattle and horses were domesticated and habituated to a sedentary life, salt needed to be added to their diet (Tašić 2000: 36). Domestic herbivores need big quantities of salt for the proper functioning of their physiological processes, while carnivores intake the needed amount of salt by eating meat, eggs and fish. Estimates of the yearly amount of salt that various animals need to ingest are very different (see Alexianu *et al*. 2015: 56). We can use Zaninović's data as an example of how much greater quantities of salt domestic animals need in comparison to humans: according to him, a human needs daily 12-15 g of salt, a horse needs 50 g and a cow nearly 100 g (Zaninović 1991: 257). It seems that in the past much greater amounts of salt were consumed than truly needed. An example is Cato the Elder's remark (*Agr*. 58) that one slave needed yearly 8.7 kg of salt (1 *modius*), while according to Aristotle (*Hist. an*., VIII, 10, 596a) a sheep needed almost 40 kg of salt per year (Giovannini 1985: 376). For this reason salt was so precious for the farming populations, mainly living in the interior, who did not have a direct access to marine salt. They exploited the salty sources and mines, but as the populations developed and the number of individuals grew, they needed to import it from more or less distant places, which produced salt for exportation.

The importance of adding salt to fodder to achieve better milk and dairy products was known in Classical Antiquity, as well as the use of salt in veterinary practice (Arist., *Hist. animal.*, VIII, 10-12; Cat., *Agr*., LIV, 2; Col. *Rust.*, VI, 2, 7; Plin., *Nat. Hist.*, XXXI, 41, 88). When salt was not given to animals as part of their diet, they would search for salty pools, rocks or sodium-rich vegetation (Harding 2021). Sodium is very important for nursing young animals and prevents the roundworms (Alexianu *et al*. 2015: 56).

From Prehistory on, in numerous places of the world, the **seasonal activity of animal husbandry was completed by that of salt production** (an example in Moldova: Ursulescu 1995: 491). It has been supposed that salt exploitation originated because of the needs in animal husbandry (Gouletquer *et al.* 1994b: 123; Montagnari Kokelj 2007: 166). Nuria Morère (2002: 184-185) has postulated that in prehistoric Spain animal husbandry and transhumance trails, along with the presence of nearby settlements and/or salting or purple-dye industries, as well as toponymy and prestigious objects indicating the existence of important trade connections and local élites, can be indirect indicators of salt exploitation.

Salt for the need of humans and animals was traded along the so-called "**salt routes**", the most famous of which is the *via Salaria*, the most ancient Roman road, which, from Ostia and the mouth of the Tiber led into the internal Sabina Region (Varr., *De re rust*., I, 143). Animals and shepherds traveled along Roman roads (*viae publicae*) and **transhumance paths** (*calles*), which could traverse shorter distances or dozens of miles. Pastures were either public or private, with several laws regulating their use (Pasquinucci 2002: 204).

Anthropological and archaeological studies have shown that in many cases the **same transhumance paths have been used from Prehistory until the Modern period**. An example is the 19th century "long distance" year-round transhumance from Transylvania to the Friuli Plain in northeastern Italy, an activity that can be traced back to the Roman period and hypothesized for earlier periods too (Montagnari Kokelj 2007: 166). In the Roman era, animal husbandry was a fundamental branch in the economy of the northern Adriatic region, with tradesmen operating as far as the province of *Dacia* (Verzár Bass 1987: 268). These links are proven by several inscriptions; one of them, from *Apulum* (present Alba-Iulia) in *Dacia* (*CIL* III 1209), belongs to a man who lived in the 3rd century AD and was *conductor pascui, salinarum* and merchant at the same time, showing the correlation of pastoralism and salt production and trade (Tsigarida 2012: 317).

Salt in Greek and Roman religion

In the ancient world salt was a gift of the gods and a guarantor of the purity of human intentions during oblations and religious sacrifices, allowing a privileged relationship with the deities. It symbolized communion and mediation (Moinier 2012: 16). Men considered divine all the things that are of common interest and that pertained to their needs, such as water, light, the seasons, the earth (Plut., *Mor.*, 685a-b). According to Plutarch, salt was another fundamental necessity, because it stimulated the appetite and provided the body with the indispensable nourishment supply. Secondly, salt was divine because it was a preservative agent, which impeded the rot of bodies and therefore it opposed to death, similarly to the soul, the divine element present in every human being (Plut., *Mor.*, 685b-c). Lastly, salt was considered divine because it stimulated sexuality, improving the reproductive performances of men and animals and was thus comparable to the gods, who were the principle of everything (Plut., *Mor.*, 685d-f). The myth of **Aphrodite/Venus**, the goddess of beauty, sensual love and fertility, who was born from the salty foam/salt, the result of the crystallization of Uranus's sperm, which spread in the sea after he had been emasculated, together with her epithet *haligenes* – who shaped out of salt (Hes., *Th.*, 176-206) – would allude to the generating power of salt (Plut., *Mor.*, 685d-f; Carusi 2008: 19-20).

In the Greek world, temples built next to the sources of salt are a constant: most of the time, they were dedicated to Aphrodite or Artemis, but also to Athena and Apollo. Important temples dedicated to Aphrodite arose near the saltpans of Corinth and at Eryx (temple of Venus Erycina), above the saltworks of Drépane, present Trapani (Moinier 2012: 33). Temples of **Artemis** were built in a marshy area of Trezene on the Peloponnese (Eur., *Hipp.*, 228-229; Pau., II, 30, 7; see Carusi 2008: 60, n. 37) and next to the salty lake of Kition on Cyprus, where salt spontaneously formed (Plin., *Nat. Hist.*, XXXI, 74; see Carusi 2008: 96-98). Salt was also collected from the properties of the Artemision of Ephesus, as attested on the inscription on a silver sheet found inside the temple and dated to the end of the 7th - beginning of the 6th century BC (*I. Ephesos* Ia 1) and on the properties of the temple of Athena Polias in the 1st century BC Priene (*IP* 111; see Carusi 2008: 81-85, 192-195, 232-233, 236-237).

In addition, salt was important in the cult of **Heracles/Hercules**, to whom the shepherds and breeders were devoted. According to the myth, Heracles, a hero who had become a shepherd, murdered Eryx, son of Aphrodite and master of the saltpans, which appears as a transmission

(Moinier 2012: 36). On the Italian Peninsula, Hercules has been considered the patron and dispenser of salt (*Hercules salarius*) that brought benefit and growth to herds (Giovannini 1985). The close connection between Aphrodite and Heracles in the Italian *emporia* has been described by Torelli (1993), who stressed the role of milestones that the sanctuaries of these two deities assumed along the transhumance paths and next to the cattle markets, especially on the main axis of the *via Salaria*. Salt warehouses must have constituted the essential annexes of the sanctuaries of Hercules and Aphrodite, which were erected near the saltworks (in *Herculaneum*, a temple dedicated to Hercules was built near the saltworks) or in strategic positions, where the storage of salt had to be ensured for cattle breeding and pastoralism. These places of worship represented real neuralgic joints along the pastoral circuits and were built preferably at the crossroads of major roads or transhumance paths, or along transition zones, at the limit of two territories or two cultural and economic areas (Torelli 1993). An example is the great sanctuary of *Hercules Victor* at *Tibur*, located next to a *forum pecuarium*, at the point where the transhumance path becomes a mountain trail towards the region of the Marsi and Eques (Coarelli 1987: 85-86). Numerous temples of Hercules in the Roman provinces followed the transhumance routes, showing the tight connection between cattle breeding, pastoralism, salt production and trade (Placido 1993; Gros 1995).

Salt was used during libations and religious rites as a medium. It was scattered over the altar and the sacrificial victim together with the grains of barley. It could be used instead of lustral water (ThesCRA II, 20). The Vestals used coarse salt (*sal durus*) and/or salt obtained from boiling brine (*sal coctus*) to prepare the sacred brine (*muria* or *muries*) (Ser., *Egl*., VIII, 82). This was cooked in the oven and used to salt the *mola salsa* (Plin., *Nat. Hist.*, XXXI, 89; Ov., *Fast*., I, 335), a toasted spelt flour that was spread on the heads of the animals destined for sacrifice (v. *immolare*), as well as on the sacrificial knife and on the altar. It was believed that it acted as a medium to free the victim from its physicality (Arvanitis 2010: 66, n. 7). The Vestals delivered the *mola salsa* to the people three times a year, to be employed in the sacrifices during the Lupercalia (February 15th), Vestalia (June 9th) and the Ides of September (Arvanitis 2010: 90). Additionally, salt was used in purification rites of homes and graves (Ov., *Fast*., II, 23-24; 538).

Medical and cosmetic uses of salt

Salt is antibacterial and it is still used to cure rheumatism and arthritis. It disinfects wounds and heals infections (Harding 2013; 2021). Hippocrates (c. 460 - c. 370 BC) described the medical properties of salt and its use for treating sores (Morand 2017: 200-201). In the 1st and 2nd centuries AD, the two doctors Dioscorides (*De materia medica*) and Galen (*De temperamentis*) explained the link between salt and medicine (Morand 2017: 203; Hoët-van Cauwenberghe *et al*. 2020).

Pliny explicated that salt was applied to cure bites, burns, pustules and eye, mouth and throat troubles. Salt from Tragasai (NW Anatolia) and the Tatta Lake (present Tuz Gölü in central Anatolia) were the best to cure eye diseases, while skin illnesses like the psoriasis could be healed with the salt from Thebes (Plin., *Nat. Hist.*, XXXI, 84-87, 98-105). Many sicknesses could be healed using a combination of salt, brine or specific fish sauces mixed with honey, but also oil, vinegar and other substances (see Moinier, Weller 2015: 205- 208). Salt was ingested to expel intestinal worms. Theophrastus in the 3rd century BC (*Hist. Plant.*, IX, 18, 10) and Plutarch in the 1st century AD (*Symp.*, V, 10, 2 and 4) enumerated salt and salty waters among the criteria to increase sexual excitement and child conception (Moinier, Weller 2015: 209). Ancient authors and Bible verses witness the use of salt or salted water to scrub the skin of the newborn, to purify the baby (Soran., *Gyn*., II, 13; Val. Fl., III, 422-423; ThesCRA II, 75; Moinier, Weller 2015: 210-211; Husquin 2020). Salt was also used to prepare toothpastes and to relieve dental pain, as well as eyewashes (Moinier, Weller 2015: 215-217).

In Classical Antiquity, salt was added to oil or honey to prepare cosmetic products and perfumes (Moinier, Weller 2015: 212-215). Ancient authors testify the wide use of *Dunaliella salina*, a

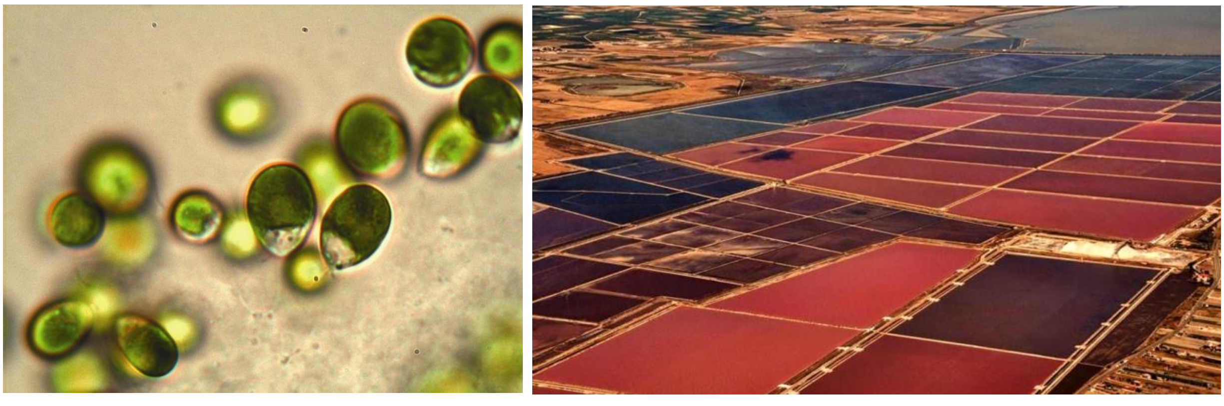

Fig. 16 Light microscopy photo of Dunaliella salina *(Lamers 2011: 12) and the saltpans of Margherita di Savoia (Matteo Nuzziello, https://www.foggiatoday.it, accessed 11/04/2022).*

halophile unicellular green micro-alga found in hypersaline environments, including salt evaporation ponds, which provides glycerol that was used as a solvent in the perfume industry, an activity that was widespread in the Roman world, even at the lower social scale (Longhurst 2007). It is due to the presence of *Dunaliella salina* that the salt evaporation ponds color in pink, orange-red or yellow (Fig. 16). This green alga has large amounts of a carotenoid pigment called β-carotene, which protects it from UV radiation and turns its color in pink-red. Consequently, the crustaceans who eat the *Dunaliella salina* (the brine shrimp *Artemia salina*) and the birds (like pink flamingos) who feed on these algae and tiny shrimps, ingest large concentrations of carotenoids and appear therefore pink or red.

Not just salt, but also brine holds many therapeutic properties. Salty hot springs and baths all over the globe stimulated health tourism to cure various diseases and improve the fertility of women. One of these examples were the Swiss salty thermal baths of Bex-les-Bains, which during the Belle Époque attracted mainly wealthy female customers from all Europe (Cirafici 2020). Today, peasants in Romania still collect salty water from inland salt sources to use it for medical purposes, as well as in food conservation and preparation of cheese (Alexianu *et al*. 2011: 7-23; 2015). Salt dissolved into hot water, combined or less with natural herbs, provides an excellent bath for the feet and salt compresses are applied to wounded or aching areas of the body (Alexianu *et al*. 2015: 56).

Finally, halotherapy or salt therapy is an alternative form of medicine, which consists of breathing salt particles to improve breathing. It is a traditional remedy being used to treat asthma, caugh and other respiratory problems (Crisan-Dabija *et al*. 2021). It can be done in any salt-enriched environment, using home devices, halo-chambers or naturally occurring salt environments, such as salt mines. The Wieliczka salt mines in Krakow County (Poland), exploited from the 13th century until 2007 and now a UNESCO World Heritage Site, are also known for the research and clinical resort for pulmonic patients. Currently, numerous programs are being organized to heal patients suffering Long COVID.

In contrast to all the healing and therapeutic properties of salt, it is recognized that excessive intakes of salt cause various diseases, which have been recently summarized by Lecerf (2020).

Other uses of salt

In Classical Antiquity, salt was precious for the fabrication of **purple-dye** (Machebœuf 2007), which could had been a complementary product of the fish processing workshops. As Pliny states (*Nat. Hist.*, IX, 133), the glands of marine snails *Murex trunculus* and *Murex brandaris* were left macerating in salt for three days and then the purple-dye was extracted. Salt was also used for fixing colors needed for dyeing fabrics and wool (Moinier, Weller 2015: 239).

Cato refers that salt also served in the **preparation of Greek wine** (*Agr*., 105), to facilitate its preservation and trade. Wines from Cos and Rhodes were softened with seawater. Salting wine later became a common practice to correct its mistakes when the winemaking conditions were mediocre (Moinier, Weller 2015: 233-237).

Like nowadays, salt was used in **water softening**. Blocks of salt were thrown in the water to eliminate impurities like calcium, magnesium and other metals, making it potable (Vitr., *De arh.*, VIII, 7, 15).

Small amounts of salt are still used to **fertilize lands** (Zaninović 1991: 257). This practice was known in Classical Antiquity and ancient authors were aware that palm trees like to grow on salty lands. On the contrary, hypersaline soils were known to be unfertile (Moinier, Weller 2015: 244) and salt seems to have been used to definitively ruin the soil of certain enemy cities, after they had been conquered. According to a historiographical tradition, in 146 BC Romans spread salt over the destroyed Carthage. Burgeon (2020) has convincingly argued that in fact this never happened in Carthage.

Salt was used for the treatment of **precious metals** (Zaninović 1991: 257; Carusi 2008: 29-30). Yellow earth mixed with some salt was used as a "medicine for gold", to make it look shiny and beautiful. Starting from the 6th century BC, salt was also used to separate gold from silver (see Penkova 2012).

In the **tanning industry** salt was used to make ropes, which were obtained from the hide of a slaughtered ox (Hom, *Il.*, III, 375; Cat., *Agr.*, 63 and 135, 3-4; Moinier, Weller 2015: 223-227). In addition, salt was used to eliminate the residues of leather: it absorbed its humidity and prevented the development of microbes. Significant quantities of salt must have been used to fabricate the leather for the tents of the Roman army (see Moinier, Weller 2015: 226-231).

1.2.1. Appendix. Symbolism of salt through the ages

Salt has always symbolized purity, incorruptibility, eternity, immortality, but also friendship and hospitality, and only sometimes it had a negative connotation, that is, it was a symbol of infertility, because the excessive salinity made the earth sterile and it was seen as a curse.

Symbolism of salt for the Greeks and Romans

For Homer salt is a substance of the gods (*Il*., IX, 214) and Plato (*Tim*., 25) specifies that salt is favorite to the gods (Zaninović 1991: 255). It was used in sacrifices as a medium to free the victim from its physicality and allowed a privileged relationship with the gods (Arvanitis 2010; Moinier 2012). The tradition of employing salt for this purpose has roots far back in time in the Eastern Mediterranean (Moinier 2012: 17).

Salt was considered a symbol of communion and true friendship (Plut., *Mor*., 684e). When salt was shared between two individuals or parties, it created indissoluble connections. For both Greeks and Romans, salt was considered one of the basic features of civilization: people that did not know salt were considered uncivilized[3] and barbarian (Hom., *Od*., XI, 122-137; XXII, 269-284; [Arist.] *Mir*., 138; Varr., *Rust*. I, 7, 8; Tac., *Ann*., XIII, 57; App., *Hisp*., LIV, 227).

Salt was also a metaphor indicating all the things that give pleasure in life (Plin., *Nat. Hist.*, XXXI, 88). By some ancient authors it was considered a metaphor for feminine beauty (Lucr., IV, 1162; Catull., 86) and wit (Cic, *Fam*., IX, 15, 2; Quint., *Inst*., VI, 3, 89).

Salt played an important role in several myths and it was considered magical, being also used in spells and magic rituals. Several incantatory formulas that had to be pronounced with salt in the mouth for them to be effective are known from classical works and ancient papyri (Moinier 2012: 58-59).

[3] There are still some people that consume very small amounts of salt (less than 2 g per day), for instance the Amazon's Yanomamo Indians, the largest relatively isolated tribe in South America (Oliver *et al*. 1975), the Xingu Indians of Brazil and rural populations in Kenya and Papua New Guinea (see Mancilha Carvalho *et al*. 1989).

Symbolism of salt in Christian religion

A comprehensive study of the symbolism of salt in Judeo-Christian religion was provided by Latham (1982). Salt was a consecrated substance, a mineral that connected men to God, which is visible in various passages of the Old Testament (Zaninović 1991: 255).

The Book of Genesis (XIX, 23-26) describes the story of **Lot's wife** who after the destruction of Sodom and Gomorrah was transformed into a pillar of salt, because she disobeyed God's warning not to look back at Sodom, while Lot and their daughters escaped. In this case, salt maybe represents the wisdom that Lot's wife lacked (Moinier 2012: 60). On the other hand, the transformation into a pillar of salt could be explained by a more concrete fact. The toponym *Sodom* probably derives from *Sadeh Adom*, meaning red field or field of blood, which, given that the area is known for salt deposits, can be interpreted as salt ponds that turned into red color by the action of the alga *Dunaliella salina* (Fig. 16; Nenquin 1961: 142-143). This can be the indirect evidence of salt exploitation in the area in Biblical times.

In the New Testament, Christ has been defined "heavenly salt" or just "salt" (Latham 1982: 205). Christ said to his disciples: "***Vos estis sal terrae***" (Matthew, V, 13). In other words, salt was to food what disciples were to men. This means that the mission of the disciples was to be like salt, to flavor the earth with faith and to save the world, like salt is vital for the majority of living beings. If they would not take their mission seriously, they would lose their savor and be useless (Latham 1982: 205).

In liturgy, salt symbolized wisdom and conferred immortality. During **baptism**, the rite that admits the person to be part of the Christian Church, a grain of salt was put on the mouth of the baptized, in the sign of fidelity to Christ (Latham 1982: 241). At the same time, this might have a pagan origin, when the babies were purified with salt or salty water (ThesCRA II, 75). The practice of putting salt on the mouth of the baptized was supressed in 1969, when the Roman Catholic Church updated its liturgy (Latham 1982). In the Last Supper, Leonardo da Vinci depicted an overturned salt pot under the elbow of Judas, thus underlining the broken covenant with Christ.

Salt was being employed also for exorcisms, consecrations of churches and bell blessings (Monier 2012: 61).

Symbolism of salt in popular beliefs

The use of salt to ward off evil spirits has persisted in popular beliefs. It can be found in German literature, where the use of the word *Salz* (salt) scares away devils and witches (Moinier 2012: 61). Salt is present in many superstitions: it was thrown at the four coins of the pasture to protect cattle from curses, in the house to protect it from evil spirits and in the fire to drive away storms. A still known superstition says that if salt is spilled on the table it brings bad luck, but this can be reversed if a pinch of salt is thrown over the shoulder.

Slavic people likewise believed that salt was an apotropaic means of defense against the evil. In the Neretva Valley in Croatia, baptismal water, laurel put on the windows, blessed salt and a special plant called "kućepazitelj" (caretaker) were warding off all evil from the house (Babić, Vekić 2010). According to locals, in Kali on the island of Ugljan (Croatia), fishermen threw a handful of salt towards local "štrige" (witches). If the fishermen would not catch any fish for a couple of days in a row, they would throw salt in the sea (Mrkonja 2016: 13-14).

1.3. History of salt through the ages

The history of salt, its production and consumption have been widely studied by distinguished scholars (Nenquin 1961; Mollat 1968; Hocquet 1978-1979; 1989; 2019; Bergier 1982; Adshead 1992; Hocquet *et al*. 2001; Kurlansky 2002; Harding 2013; 2021). Because of its vital importance for humans and animals and as a means for the preservation of foodstuffs, for which it acted as a guarantor of their commerce and exchange, salt has been defined as the "**white gold**". This chapter presents a survey of the history of salt in Prehistory, Middle Ages, the Modern and Contemporary periods, focused on the eastern Adriatic region, in order to highlight the similarities and the differences of salt production and trade between the different periods of human history and better understand the specificity of this branch of the ancient economy in Classical Antiquity, which will be presented in the following two chapters.

1.3.1. Salt in Prehistory

The oldest traces of exploitation of salty sources in Europe and the world date back to the Mesolithic period (see Weller 2015). The shortage of naturally available salt resources during specific periods in Prehistory implied that salt acquired an important social and economic role (Harding 2013; Weller 2015: 77-78). This can be discerned by the concentration of settlements around the salt sources, rich grave goods and other valuable objects that attest long-distance contacts and exchange networks with other cultures. There is a connection between the salty sources and the distribution of greenstone alpine axes, which in the 5th millennium BC Western Europe are considered symbols of wealth and power (Weller 2015: 77). Likely, in the Carpathian-Balkan region, the oldest copper and gold objects appear within salt exchange networks.

In several French sites, various wooden wells and wattles have been found, constructed around salty springs. The oldest of these structures dates to 5600 BC (see Weller 2015: 70). Similar structures are known for much later periods too. For example in Inowrocław, Poland, in the Roman Iron Age salt-processing site, several brine wells were found, up to 4.5 m deep, with their sides covered with braided wooden rods and poles. The remains of a wooden ladder were found in one well (Bednarczyk *et al*. 2015: 114, 116).

The most important Neolithic and Chalcolithic (5500 - 4200 BC) salt production site in Europe is Provadia-Solnitsata in Bulgaria (Fig. 17), a tell with numerous salt-extracting installations that lies over a salt diapir (Nikolov 2012; Harding 2013). Salt caused the fortune of this important settlement, as attested by the rich grave goods that show long-distance contacts with other cultures.

Fig. 17 Provadia-Solnitsata (AFP, http://decouvertes-archeologiques.blogspot.com, accessed 22/03/2022).

The most prosperous civilization of Europe's Early Iron Age was the **Hallstatt culture** (c. 800-450 BC), which established upon the mining of rock salt that started in the Bronze Age. The rich necropolis of its inhabitants with burial objects from Greece, Italy and other parts of Europe testifies the widespread trading connections that the Hallstatt culture had, exporting salt and other goods in all these regions (Zaninović 1991: 256). Another important Bronze and Early Iron Age salt production center was Halle in German Saxony, where the **Hallesche Kultur** (c. 800-400 BC) developed. In Halle, Lorraine and the Seille Valley in France huge quantities of Iron Age broken pottery for salt production (briquetage, Fig. 18) were observed and studied since the 18th century (see the bibliography in Harding 2013: 18). Similar founds, although

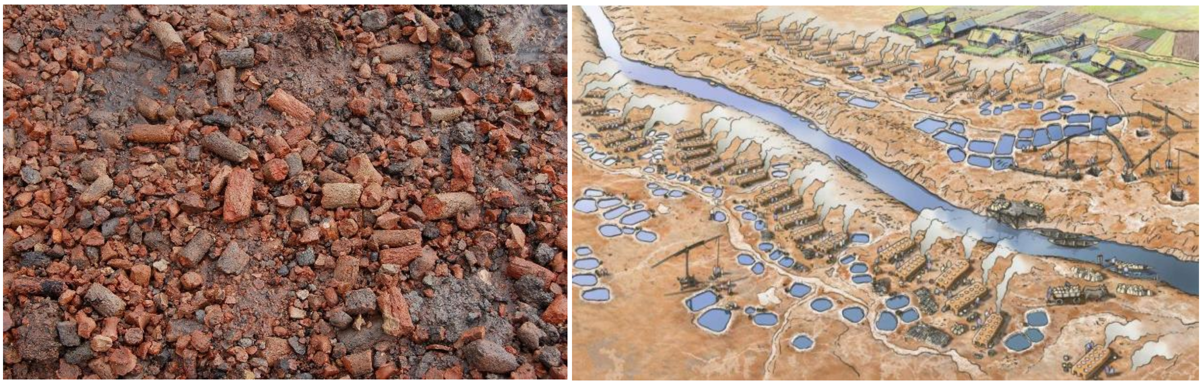

Fig. 18 The briquetage fragments in the Seille Valley (a) (© Laurent Olivier, Projet Briquetage de la Seille) and drawing of the Iron Age salt production in the Seille Valley (b) (courtesy of Patrick Siebert, https://autour-de-vic-sur-seille.over-blog.com/2018/10/le-briquetage-de-la-seille.html).

quantitatively less developed, were found in the "Red Hills" or "salting mounds" on the eastern British coast, most of which continued their activity in Roman times (Lane, Morris 2001).

In the Seille Valley, most briquetage waste can be dated to the 8th - 6th centuries BC and the 2nd - 1st centuries BC, the industrial production of salt dating to the second period (Olivier 2000; 2015; Harding 2013: 75; Riddiford *et al*. 2016). On the western French coast, salt was produced with the briquetage technique starting from the Iron Age and it continued in the Gallo-Roman period, reaching "industrial" levels (Daire 2003; Harding 2013: 75-79).

Briquetage

In Prehistory, as well as in most recent times, salt that formed from simple evaporation of marine water in natural ponds along the coast was collected and used for local needs. This system of salt collection is also known as ***fabrication naturelle du sel*** (Morère 2002: 184), which does not leave any archaeological trace and the only fact that could indicate it is the proximity of a salty source, lake or a flooding land. On the contrary, the term ***fabrication ignigène*** indicates the artificial technique of obtaining salt by fire, which speeds the crystallization (Morère 2002: 184). The latter leaves tangible remains of the so-called ***éléments de briquetages,*** or simply ***briquetage(s)***,[4] comprising coarse fired clay vessels, clay vertical supports and fragments of kilns for boiling brine or for drying salt, usually preserved in large accumulations in the archaeological record. These are the remains of briquetage workshops (*atelier de briquetages à sel* or *atelier de bouilleur de sel* in French), where marine or geologic brine (*saumure*) was boiled in ceramic clay vessels or salt molds (*moules à sel*), sustained by bricks or vertical pedestals of the same material, put over a hearth (Fig. 14, 15). These workshops usually had one or more kilns and annexed structures (tanks or basins) to store the brine, which was let to evaporate (Gouletquer *et al*. 1994a: 10). The briquetage workshops are sometimes hard to identify because they were very different from one another: sometimes they had complex kilns, while in others a fire was lit on a clay floor, above which the brine was

[4] The term *briquetage* appears for the first time in the 18th century (Artézé de La Sauvagère 1740) to designate the huge quantity of archaeological remains connected to salt production by the evaporation of brine, discovered for the first time in Marsal in Moselle, northeastern France. The finds, mainly fragments of intentionally broken clay vessels and furnaces, lay spread over an area of more than 10 km in length, with an estimated volume of 3.5 million m^3 (Olivier 2000). The term *briquetage* is frequently used today to designate only the ceramic vessels that held the brine, although it actually indicates the entire construction of the hearth and the upper superstructures (bars/walls) that held the coarse ceramic vessels for brine evaporation (Harding 2021: 17).

boiled in clay vessels, supported by clay pedestals of various forms (see Daire 2003; Montagnari Kokelj 2007: 174).

The common denominator of the clay vessels for salt production (salt molds) is an open, more or less conical form, a coarse fabric of local provenance, including smooth inner and rough outer walls, with frequent fingerprints (Montagnari Kokelj 2007: 177). These vessels appear highly fragmented in the archaeological deposits, because they were broken in order to extract the salt cakes or ingots (*pains du sel*, Fig. 15). They were used both as molds for the salt cakes and as crystallizers of salt and contain two to twenty times more chlorine compared to other kitchen vessels (Weller 2015: 72). In addition, different containers could have been used for different stages of brine evaporation, for storage, for the drying into transportable salt cakes of several weights and for the transportation of salty water from the source to the workshop (Morère 2002: 185, 187).

In Europe, Early Neolithic societies extracted salt from natural sources since the 6th millennium BC (Weller 2015). It has been estimated that the preparation of salt cakes in more or less standardized forms in specific salt molds probably dates already in the Early Neolithic, before the briquetage. In these early periods, salt cakes could have been obtained by the fabrication of salt scoops, rolled up in leaves and dried on the ashes, which caused their hardening (see the bibliography in Montagnari Kokelj 2007: 176). Studies in Romania and eastern France have shown that salty water was spilled over a pyre covered by a plant mantle that slowed down the falling water, and salt crystallized as soon as it got in contact with the coal (Weller 2015: 75). In AD 58, two Germanic tribes used a similar technique of obtaining salt, as described by Tacitus (*Ann.*, XIII, 57).

During the Chalcolithic period, in the middle of the 5th millennium BC, big accumulations of fragmented salt molds start to appear around salty sources in Romania and Bulgaria, although annexed combustion structures have not yet been found (Weller 2015: 71-73; Sordoillet *et al*. 2018). In Western Europe, the briquetage workshops appear in the Bronze Age and become largely widespread during the Iron Age (Gouletquer *et al*. 1994b: 129; Harding 2013: 73), when the development of more complex societies causes an increase in salt production and trade and salt acquires socio-economic and pre-monetary values (Montagnari Kokelj 2007: 176). Iron Age furnaces for salt production could have complex superstructures (Harding 2013). As ethnographic examples have shown, salt cakes or ingots were hardened naturally or artificially, and were stored, exchanged or traded as a unit of standardized form and weight (Gouletquer, Weller 2015). They had different chemical compositions, colors, shapes and packaging, indicating different provenances and different producing groups.

In the eastern Adriatic area, briquetage remains have been found so far in two geographic regions: Trieste and northern Istria (in present Italy and Slovenia) and in the Podvelebit Littoral, in the Kvarner region (Croatia).

Prehistoric salt production in the area of Trieste and northern Istria

Montagnari Kokelj (2007: 166-169, 184) suggests that the intensive use of many caves, located at a maximum distance of 8-10 km from the sea in the Trieste Karst in northeastern Italy, could be connected to prehistoric marine salt exploitation. She assumes that during the Neolithic salt that formed from simple evaporation of marine water in natural ponds along the coast was collected and used for local needs. This area and the neighboring area of Koper in present Slovenia (Fig. 19) were probably producing salt in a sporadic and uncontrolled way since the Neolithic period. Later, during the Middle Bronze Age, salt harvest might have acquired a more systematic nature (Càssola Guida, Montagnari Kokelj 2006; Montagnari Kokelj 2007; Montagnari Kokelj *et al*. 2015).

Fig. 19 Satellite image of the area of presumed prehistoric salt production (Google Earth).

At the beginning of the 2nd millennium BC, fortified structures called *castellieri* started to appear on the hilltops in the Karst, Istria and parts of Dalmatia, substantially changing the settlement pattern in the area and generating more developed exchange and trade relationships (Montagnari Kokelj 2007: 175). These fortified structures on hilltops gave the name to the Castellieri culture, which lasted until the second half of the 1st millennium BC. The *castelliere* of Elleri, overseeing the Noghere Valley from south and located less than 1 km from the coast of the Bay of Muggia, preserves hundreds of broken ceramic fragments, which have been identified as briquetage vessels and pedestals (Càssola Guida, Montagnari Kokelj 2006: 328-330; Montagnari Kokelj 2007: 175-184, Fig. 20).

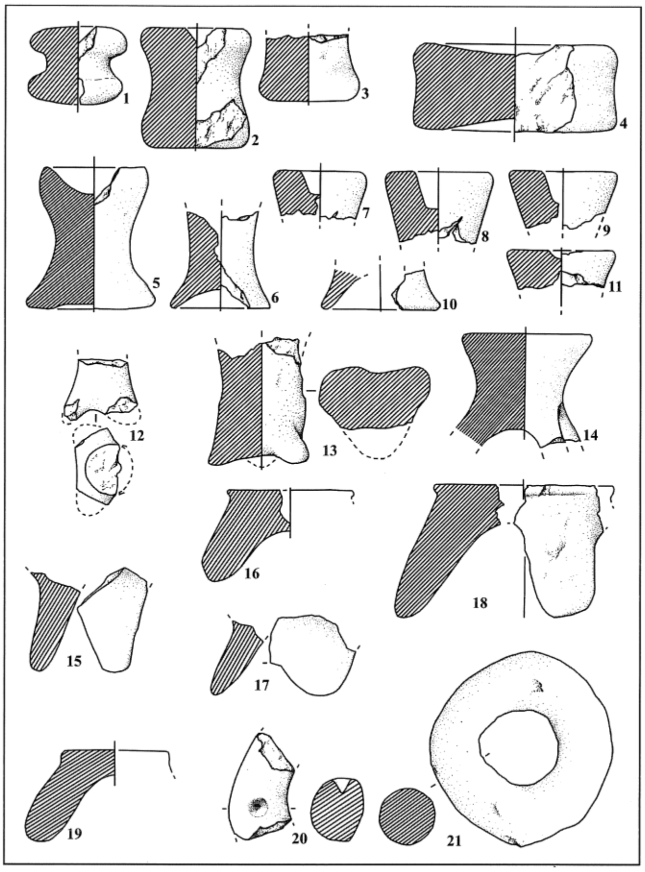

Fig. 20 Briquetage pedestals from the castelliere of Elleri, Muggia (Montagnari Kokelj 2007: 179).

It has been supposed that salt was also produced in Stramare, close to the mouth of Rio Ospo, on the terrace above the Roman remains on the shore (Càssola Guida, Montagnari Kokelj 2006: 330-331; Montagnari Kokelj 2007: 175, 177). Stramare might have been an open-air site, where the preliminary concentration of brine was obtained and then transported to the *castelliere* of Elleri for further processing. Elleri was one of the most significant hillforts in the Karst, inhabited from the Middle Bronze Age to the Late Iron Age, with reoccupations during the Roman and Medieval periods (Montagnari Kokelj 2007: 182).

Prehistoric salt production in the Podvelebit Littoral

Quite a few briquetage terracotta pedestals, either with a three-horned or a spool-like ending, about 20-25 cm long, have been found on four coastal sites on the Podvelebit Littoral in the Kvarner region, in between Rijeka and Starigrad Paklenica (Forenbaher 2013, Fig. 21). Briquetage pedestals were recovered as surface finds on the coastal hillforts of Prizna and Silna Gromila (Tribanj), on the seabed of Sveti Juraj and under an abandoned fuel station close to Karlobag (see Domines Peter, Parica 2021: 146, map 3). These sites are situated on the rough coastline under the large mountain range of Velebit.[5] They can be dated to the Late Bronze Age and in the Early Iron Age.

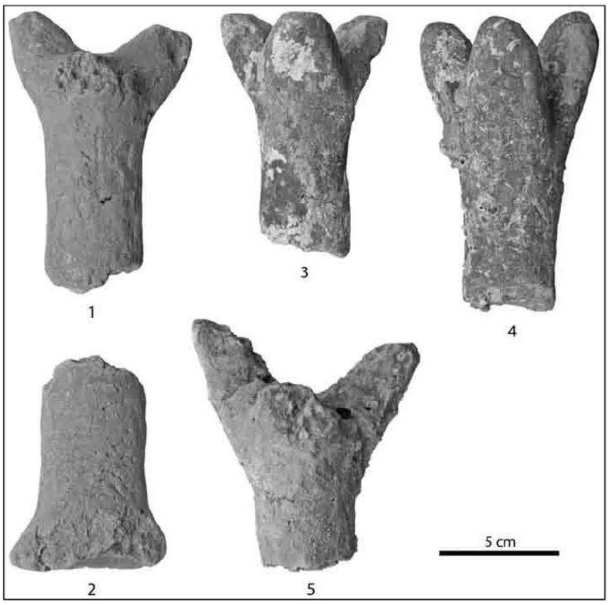

Fig. 21 Fragments of briquetage pedestals from Prizna (1, 2), Sveti Juraj (3, 4) and Silna Gromila (5) (Forenbaher 2013: 181).

The site of Sveti Juraj – Lisac Islet, about 7 km south of Senj, was recently inspected and studied (Domines Peter, Parica 2021). Not only a considerable amount of briquetage pedestals, but also numerous fragments of ceramic vessels that served for salt production have been recovered from the submerged site. The approximately 9 m wide embankment (built over an


Fig. 22 The islet of Lisac seen from the Gradina hill (M. Grisonic).

[5] Velebit is the mountain range in the Croatian Kvarner region that runs parallel to the Velebit Channel, in between the Adriatic Sea and the Lika plateau in the hinterland. It runs approximately 160 km from the Vratnik passage above Senj in the NW to the canyon of the Zrmanja River (close to Obrovac) in the SE. The highest mountain is Vaganski vrh (1758 m), above Starigrad Paklenica. Velebit is part of the Dinaric Alps, the mountain range of southern Europe (Enciclopedia della geografia De Agostini, Novara 1996: 1264).

ancient tombolo?), which was connecting the mainland with the islet of Lisac, is nowadays located on the seabed of the about 80 m wide and 2.9 m deep strait (Fig. 22, 23). Next to the embankment, towards the NE and along the eastern coast of the Lisac Islet, there is a 50 x 8 m artificial plateau, located at 3-4 m depth. The surface layer of the plateau is covered with fragmented briquetage pillars and numerous and highly fragmented thin-walled, flat-bottomed ceramic vessels, with internal reddish coating (Fig. 24), identified as salt molds of uniform shape (Domines Peter, Parica 2021). The briquetage pedestals have a circular cross-section and according to the researchers, the three-horned ending was placed upwards to hold the salt molds for brine evaporation, while the spool-like endings (widened and concave, Fig. 21.2) were the bases of the pillars, which were put over a hearth (Forenbaher 2013; Domines Peter, Parica 2021). The analogy of other thick-walled ceramic containers recovered on the site and the radiocarbon dating of an animal bone found in the submerged artificial plateau, as well as the depth at which the finds are located, show that salt production and other anthropic activities took place here in the 10^{th}-9^{th} centuries BC (Domines Peter, Parica 2021). This site shows great potential for further multidisciplinary underwater researches. The seabed under the mainland coast, just across the prehistoric salt production site (Fig. 23), preserves big concentrations of Roman pottery and building material, which can be connected to the settlement of *Lopsica* (Plin., *Nat. Hist*., III, 140). This *oppidum* of the *Lopsi*, a Liburnian peregrine community (*civitas*), is believed to be located just above, on the Gradina hill and on the coast of Sveti Juraj. As Ἀλουψοί (Aloupsoi), it appears for the first time in the Pseudo-Scylax's Periplus from the 4^{th} century BC. The whole area was most likely included in a larger

Fig. 23 Sveti Juraj: view from the islet of Lisac (M. Grisonic).

fortification system, which included neighboring hillforts. The coastal settlement of *Lopsica* gained the municipal status under Emperor Tiberius (Glavičić 2013).

Fig. 24 Concentration of briquetage pedestals and small reddish sherds (remains of salt molds) on the seabed in front of the Lisac Islet (M. Grisonic, 2019).

The archaeologists of the Croatian Conservation Institute discovered a second underwater site with briquetage remains, in Brkinac Cove north of Karlobag, underneath the abandoned fuel station (Mihajlović 2014; 2015). Two 2 x 2 m archaeological probes were dug, at 7.5 and 8 m depth. Three-horned briquetage pedestals (Fig. 25a) and huge quantities of extremely fragmented thin-walled reddish pottery were found, representing the 99% of the material recovered in the probes. Again, this type of ceramic that can also be seen in the profile on land has been identified as salt molds (Fig. 25b). The whole site is estimated to spread over 5000 m^2. Thanks to the presence of diagnostic ceramic artifacts, this site may be dated to the Late Bronze and the Early Iron Age.

Late Bronze Age indigenous communities developed with continuity into the Iron Age. From the 9^{th} century BC until the end of the 1^{st} century BC, the northern and central eastern Adriatic coast was inhabited by the **Liburnians/Liburni**, who were skillful sailors and merchants. The Liburni that lived on the rough coast open on the Velebit Channel under the Velebit mountain range were intensively trading wood, cattle, fish, probably salt and other goods with the Japodes and other farming populations living on the other side of the mountains (Zaninović 1981: 192; Čače 1985: 486; Starac 2006). An important branch of the Liburnian economy was sheep breeding, for which they needed considerable amounts of salt (Čače 1985: 488-489; Kurilić 2008: 21). The Liburni probably continued and further developed previously established trade ties between the coastal and internal Bronze Age populations.

Fig. 25 Three-horned briquetage pedestals from the site north of Karlobag (a) and profile with fragments of probable salt molds (b) (courtesy of Igor Mihajlović and Pavle Dugonjić, HRZ).

In a yet not better defined period of central Italy's early city-states (*Roma*, *Veii*, *Cerveteri*, *Tarquinia*, *Satricum*) between the Bronze Age and the Roman Kingdom, following the increase of the population, salt started to be obtained by evaporation in artificially built saltpans at the mouth of the Tiber, supplying the growing demand for salt. The previous briquetage salt production technique, slower, less efficient, time and resource (firing wood) consuming, was abandoned (see Alessandri, Attema 2022). Similar situations most likely occurred in other areas of the Mediterranean as well. Gradually, the knowledge of salt production in artificially built saltpans, together maybe with specialized salt workers, probably spread also in the Liburnian territories.

On the Podvelebit Littoral there was no space for the organization of saltworks. It is possible that the old briquetage salt production technique continued on these coasts for a while, but, due to the changing relative sea level,[6] probably not at the same Late Bronze/Early Iron Age salt production locations, until the imports of salt produced in artificially built saltpans prevailed. The closest saltpans that most likely started to be exploited in the Liburnian period probably arose in the flat shallow bays of the neighboring islands of Krk, Rab and Pag, where the presence of saltworks is documented in medieval archival documents. Traces of Late Iron Age salt production in Croatia must yet be found.

1.3.2. Salt in Classical Antiquity: an introduction

Because of its nature, salt is invisible in the archaeological record. Ancient literary sources and inscriptions provide scarce information about salt production and trade in the Classical world. In this picture, archaeological investigations carried on ancient salt production sites can bring the most promising data for the reconstruction of the places and techniques of this primordial economic activity.

Salt was produced by urban settlements, villas, fish-salting facilities and in the Greek world also by civic sanctuaries (Ch. 1.2; Carusi 2008). The majority of Roman villas likely had their own saltpans, from where they extracted salt for their own needs and in some cases for trade also. Salt exploitation and the making of fish sauces were closely related, because the surplus of freshly caught fish needed substantial quantities of salt. Fish processing workshops leave important material remains and allow us to postulate hypotheses on the quantities of salt produced in the ancient world.

The biggest amounts of salt were produced in coastal solar evaporation saltpans: it is generally thought that the techniques employed have remained substantially unchanged over the centuries, which the archaeological excavations will hopefully prove. Material evidence of saltpans from Classical Antiquity is gradually emerging all over the Mediterranean and Iberian Atlantic coasts. All this will be discussed in Chapters 2, 3 and 4.

[6] Relative sea level change is a constant process and it is the result of eustatic, tectonic, glacio- and hydro-isostatic factors. It is a consequence of global, regional and local phenomena (Radić Rossi 2017). According to the studies of Lambeck *et al*. (2004: 1593, fig. 12), in the last 4000 years sea level has risen 2.5 m in this area. In the last 2000 years, sea level has risen 0.75 m in the northern Adriatic area, 1 m in the area comprised between southern Istria and Šibenik and 1.25 m in the southern Adriatic. If altered relative sea level values are obtained, they are interpreted as results of vertical tectonic movements (Radić Rossi 2017: 569, fig. 12; Radić Rossi *et al.* 2018: 240-242, fig. 12).

1.3.3. Salt in the Middle Ages

In Europe, for the period of the Early Middle Ages (5^{th} century - AD 1000), very few archaeological remains (from mining deposits and inland salty sources) and written documents reveal something about salt and saltpans, mainly texts and accounting books from abbeys. Additionally, salt exploitation and trade can be assumed through the toponyms that survive along the roads and on the places, where salt was produced and sold. During the Early Middle Ages, emperors and kings donated the right over salt exploitation to feudal lords and mostly abbeys, for whom it was one of the main sources of revenue (Bergier 1982: 50). The salt workers were local peasants to whom this hard labor was imposed as a corvée.

In Western Europe, during the 11^{th} - 12^{th} centuries, big landowners – bishops, dukes and earls – donated large parts of the salty sources first to the Benedictine and later to the Cistercian monasteries (Hocquet 2019: 270). In this period, **tenants** obtained long lease contracts (emphyteusis) over maritime saltpans, usually exploiting two neighboring salt fields. They had to pay a tax to enjoy all the rights of property. At the end of the 13^{th} century, they entrusted the exploitation of their properties to **sharecroppers**, who paid them a rent equal to a third of the harvest. At the end of the 13^{th} century, the big landlords tried to reclaim their ancient properties, by buying them back from the monasteries (Hocquet 2019: 271).

From the 12^{th} century, salt trade became **one of the driving forces in European economy**. Salt trade was much more profitable for the merchants than for the salt workers. In big cities, like Venice, Lübeck, Krakow, Munich, and in smaller centers, salt made the fortune of the mercantile patriciate. Salt owners sought to impose the **monopoly** on salt supplies to the cities and to the seigneuries, which were under their influence (Hocquet 2019: 272).

It was especially from the 13^{th} century, a period of urban renaissance and demographic growth that the economic progress led to the development of industries, the intensification of trade and the increase in the production of certain products, including salt. It is in this period that salt trade started to be considered as a public good. The States, seigneuries, communes and princes developed it in the form of monopoly, to avoid shortages and speculations (Bergier 1982: 52-53; Hocquet 2019). Monopoly was most of the time incapable of managing salt production and its transportation, which would have required many investments, workers and the existence of a skilled administration. Therefore, it was applied only at strategic points: in the warehouses, where the stocks of salt were managed by public officials and distributed to farming companies

(Hocquet 2019). From the 13th century, Venetian and Genoese ships traded with salt in the Mediterranean. The two city-states and later maritime republics of Venice and Genoa based their prosperity on salt trade. From the 14th century, the Hanseatic League developed salt trade in Northern Europe. During the 15th century, Holland, Dubrovnik (Ragusa) and the Basque Country also greatly developed maritime salt trade.

Salt was produced in large parts of Europe, but some regions were entirely dependent on salt imports (the Scandinavian countries, western Alps, Bohemia and internal Balkans) and others still imported it massively (Italy, the Low Countries and all Northern Europe). Salt is a heavy commodity, therefore it was the price of the transport that burdened the final price (Hocquet 2019: 271). Salt travelled on ships, on which it also served as ballast, which can be documented starting from the 13th century (Hocquet 1979; 1981).[7] To reach the continental regions of Europe, salt needed to be transshipped to smaller boats and dragged by haulers and animals to warehouses and sorting areas, from where it was brought to further markets on the backs of men or animals on cart tracks and mule trails.

Early Middle Ages on the Eastern Adriatic

The Byzantine Emperor Justinian reconquered Dalmatia from the Ostrogoths in AD 537. In AD 639 the Avars destroyed *Salona*, the capital of the Roman province of Dalmatia. Soon later, the Croats (southern Slavs) settled in this part of the Balkans and in their turn destroyed the Roman cities and institutions. They caused a massive displacement of the local population that fled towards west, on the islands and towards Istria and Italy. In historiography, the arrival of the Croats marks the beginning of the Middle Ages (Matijašić 2012: 216-237).

The local Romance population survived in the territories of the **Byzantine Theme of Dalmatia** (a military-civilian Byzantine province, c. 870-1060s). According to the Byzantine Emperor Constantine VII Flavius Porphyrogenitus (AD 913-959), it encompassed the cities (also known as the **Dalmatian city-states**) of Krk (*Vecla*), Rab (*Arbe*), Osor (*Opsara*), Zadar (gr. *Diadora* or lat. *Jadera*), Trogir (*Tetrangurium*), Split (*Aspalathum*), Dubrovnik (*Rausium*), Kotor

[7] Genoa and Venice developed the *ordo salis* (salt order) – a set of guarantees and constraints that regarded the salt trade, among which there was the rule that salt had to be used as ship ballast (Hocquet 1979: 190; 1981: 4). The Venetian merchants loaded it in distant Mediterranean ports for their return trip to Venice. This massively augmented the amounts of salt in the Venetian warehouses, which was then sold to northern Italy at high price.

(*Decatera*) and all the islands up to *Beneventum* on the Italian peninsula (Jakić-Cestarić 1995: 118). The capital of Byzantine Dalmatia was Zadar (*Diadora/Jadera*) (Fig. 26).

Fig. 26 Dalmatian city-states.

At the beginning of the 9th century, the Croats formed the **Dutchy of Croatia** (Kneževina Hrvatska, AD 800-925), including most of the territories of present Croatia (without Istria, Zadar, Split and the islands) and Bosnia and Herzegovina. The Duchy did not have a permanent capital, but it shared different seats: Klis, Solin, Knin, Bijaći, Nin. It was a vassal state of the Franks that obtained formal papal recognition in AD 879, after the Christianization of Croats has been completed. In the 10th century Croatia became a **kingdom** (Kraljevina Hrvatska/*Regnum Croatiae*, c. 925-1102).[8] During the 11th century, at the time of King Petar Krešimir IV, after five centuries of Byzantine administration, the Dalmatian coastal towns and

[8] After the succession crisis that broke out after the death of the last heir of the Trpimirović dynasty, in 1102 the crowns of Croatia and Hungary united under the Árpád dynasty. Nevertheless, Croatia maintained a high degree of independence, with its own governor, the ban (viceroy) and the assembly of Croatian nobles, the Sabor.

islands were included in the Croatian Kingdom, but only for a brief period, before being subjugated by Venice.

After the fall of the Carolingian Empire (AD 888), **Venice** started to acquire more and more influence in the Adriatic Sea, gaining control over it at the end of the 10th and the beginning of the 11th century, under the doge Pietro II Orseolo. In AD 1000, after a naval expedition, Venice obtained suzerainty over western Istria and coastal Dalmatia and in this occasion defeated the **Narentines**, Slav pirates from the area around the Neretva River that caused much damage to the Dalmatian city-states and other coastal settlements during the 9th and 10th centuries. Doge Orseolo proclaimed himself "Duke of Dalmatia". In refund of protection, the Dalmatian city-states started to pay a tribute to Venice.

In the early centuries of the Middle Ages, salt production on the eastern Adriatic coast continued, managed by local religious and secular authorities (Adshead 1992: 66). The oldest mention of the existence of saltpans on Croatian territory is the document of the archbishop Eufrasius from Poreč in Istria, who donated one third of his saltpans on Brijuni Islands to his clergy (AD 542). According to a tradition that survived on the island of Pag, the bishop of Zadar Donat advised the inhabitants of Pag on how to ameliorate the exploitation of salt (Čolak 1963: 478; Peričić 2001: 46; 2007: 443; Granić 2011: 482). This would indicate that at the end of the 8th or the beginning of the 9th century the saltpans of Pag already existed. At the site of Pantan near Trogir in central Dalmatia, a pole from the possible submerged saltpans has been dated by radiocarbon to the 7th/8th century AD, attesting the continuity of salt production at this site, which has been exploited at least from the 4th century AD (Radić Rossi 2008: 496-497). A written note, published in the erudite work on the history of the Church in the Balkans *Illyricum sacrum* (1751-1817), which relied on huge quantities of archival documents from the previous centuries, might witness the existence of the saltpans in Pantan in the 8th century. According to this note, during Emperor Theodosius III (AD 715-717), three constructors coming from *salinas* repaired a church in Trogir (*Illyr. Sacr*., IV, 306-307). However, it exists another version of the note preserved in a codex from Zadar, where instead of *salinas* the city of *Salona* is mentioned (see Džino 2020).

High Middle Ages on the Eastern Adriatic

Similarly to other parts of Europe, from the 10th century on Benedictine monasteries slowly acquired fishing spots and saltpans along the coast. The most powerful abbey in Zadar at that time was Saint Chrysogonus (Sveti Krševan/San Crisogono). Supported by the donations and testaments of rulers, noble families, more or less wealthy citizens and the inhabitants of the district, during the 11th - 13th centuries this monastery became the leading economic power among the church institutions of the city (Čoralić 1991).[9] The same is true for the female Benedictine monastery of S. Mary. Both of them possesed big land properties, livestock, fishing spots and saltpans on the mainland and on the islands of the Zadar archipelago.

In the 10th century, the Benedictine monastery of S. Chrysogonus from Zadar got the rights on fishing spots around Dugi otok and Kornati islands; in 1095 it extended these rights also on the waters around the island of Vrgada, where it had the right to collect salt (Klaić, Petricioli 1976: 65; Faričić, Magaš 2009: 42). The saltpans of an unidentified place, *Uculus*, are mentioned in the will of Agape, daughter of the Zadar tribune Dabron, from 999 (Rački 1877: 26-28; CD I, 49). She left parts of the saltpans, which she had inherited from her parents and were located in between other saltpans that belonged to her relatives, to the monastery of S. Chrysogonus (Fabijanec 2015: 140). *Uculus* was most likely a place not far from Zadar, maybe the present Diklo (Čolak 1963: 480). The rule of S. Benedict banned meat to the monks, except for those who were sick (Adshead 1992: 70). They were allowed to eat fish and birds. It is maybe also for this reason, not only for the profits of salt trade, that they invested in building saltpans, which from the end of the 12th century are attested in Brbinj on Dugi otok (they were leased to tenants) and in Stara Novalja on the island of Pag.

During the 12th century, parts of Dalmatia passed under the rule of Byzantium, Venice and the Hungarian Kingdom. A document from 1170-1176 attests that the Croatian-Hungarian King had large revenues from salt (CD II, 134), parts of which were probably produced in coastal saltpans. In 1187 the Venetian doge Aureo Mastropietro promised to all who had participated in the attack on Zadar whole salt revenues that they would produce for the next twelve years (CD II, 214). Probably, he also meant the salt produced in Pag, which was already under

[9] The territorial growth of the monasteries was stopped by the statute of Zadar from 1305, which forbade the bequest of property to monastic and ecclesiastical institutions. Later, they were allowed to inherit estates, but they had six months to sell them to lay people. After the Venetian conquest of Dalmatia the monasteries became important cultural and art centers. Their feudal power gradually weakened (see Čoralić 1991: 212).

Venetian dominion (Čolak 1963: 481). At the same time, due to repeated Venetian raids, which likely impeded continuous salt production in the countryside and islands of Zadar, the city of Zadar had to import salt from the merchants from Pisa (CD II, 224 from 1188). Indeed, the battles between Venice and Zadar for the dominion over large parts of Dalmatia had much to do also with the control over the saltpans of Pag (cf. Čolak 1963: 482).

In 1202, during the Fourth Crusade, the crusaders looted and occupied Zadar on their way towards Byzantium and from that moment on the city started to be formally called *Zara*.

Venice, its salt monopoly and the faith of eastern Adriatic saltpans

According to the tradition, the city of Venice was founded in AD 421 on the previously uninhabited islands on the Venetian lagoon. In AD 452, when Attila invaded Italy, the inhabitants from the mainland sought shelter in the lagoon and adapted to the local environment, developing fishing and salt production. The Venetian Republic, known as *La Serenissima* (AD 697-1797) flourished, among other things, because of salt trade (Hocquet 1978; 1979; 1981; 2012; Adshead 1992).

In the period between 1000 and 1250, Venice tried to impose the monopoly on salt trade in the Po Valley, by trading salt that was produced in her own saltpans in Chioggia and in Istria: Muggia, Koper and particularly Piran. Venice's competitors were Comacchio, where the Benedictine monasteries of the Po Delta owned saltpans, Cervia, dependent from the archbishop of Ravenna, and Pag, under the Commune of Zadar. Venice gradually secured its salt monopoly by closing the saltpans of Comacchio, by destroying the saltpans of Cervia and by imposing quotas in the saltpans of Pag. At the beginning of the 13th century, the saltpans of Chioggia were damaged by storms, so Piran took the lead, becoming the main salt producer of the Venetian Republic (Adshead 1992: 89). Further rivals of Venice in salt production were Barletta, Brindisi, Durrës (Ital. Durazzo), Vlorë (Ital. Valona) and Ston, all of them on the Adriatic coast (Hocquet 1981).

Venice incorporated western Istria in his domains during the 12th and 13th centuries (Fig. 27), while in 1382 the Commune of Trieste (end of 12th century - 1382) voluntary submitted to the Habsburgs to prevent the expansion of Venetian power (Fanfani 1981).

In Dalmatia, Venice tried to impose its sovereignty. With the Treaty of Zadar (1358), Venice renounced to her Dalmatian holdings (the territories of Zadar and Dubrovnik), which remained under the influence of the Hungarian King. While Dubrovnik grew into a prosperous maritime republic, Ladislaus of Naples, who proclaimed himself Croatian King, in 1409 sold his rights on Dalmatia (including Zadar) to Venice (Fig. 27), under which they remained until the end of the Serenissima in 1797. The annexation of Zadar to Venice caused an enormous shrinkage of the city's economy (Raukar 1977; Di Vittorio 1981).

In the period from 1250 to 1400, Venice enlarged its network of customers in northern and central Italy and launched a long-distance maritime trade in salt, importing it from different areas of the Mediterranean: Alexandria, Cyprus, Crimea, Ra's al-Makhbaz in Libya, Cagliari, Ibiza and La Mata in Spain. Venice competed in maritime salt trade with the Republic of Genoa (11^{th} century - 1797), a big commercial power in the Mediterranean and the Black Sea. To both maritime republics, long-distance salt imports served to lower the price of other goods, like spices, which were loaded on the same ships and could therefore benefit of a minor final price (Adshead 1992: 89).

The Venetian *ordo salis* was a set of very restrictive rules that were launched starting from 1281. They were never applied for Adriatic salt (Hocquet 1981). Salt imports needed to be radically increased, therefore it was decided that salt would be used as ballast on ships. Each Venetian merchant who left Venice with a cargo had to return back with an amount of salt whose tonnage was equal to the value of the cargo transported on the way out. The state would then guarantee to the merchants a fixed price for the sale of salt. To make sure to sell that salt at a high price Venice annihilated the competition, heavily taxing the salt from other saltpans or destroying them by force. Salt had to be brought exclusively to Venice by Venetian merchants. Neither merchants nor ship owners could take initiative in salt trade, which was a state monopoly. If foreign merchants were authorized to transport salt in the Adriatic, they had to pay heavy taxes to the Venetians.

From 1400 to 1500, the Venetian monopoly entered a big crisis. All over the Mediterranean, years of bad crop and salt harvest succeeded. After 1409, Venice conquered the Dalmatian cities and the Dalmatian economy entered in the state system of Venice (Raukar 1970; 1977; 1981). The Venetians imposed a strong monopoly over salt production (by establishing strict laws concerning the quantities of salt produced and the surface of saltpans) and trade (by choosing the distribution channels and points of sale and by regulating the price). The production of salt concentrated at few chosen locations (Piran, Pag, Koper, Muggia, later also Šibenik), while the saltpans, which were difficult to monitor, were destroyed (Nin) or forcefully abandoned (Hocquet 1981: 8). Only minor quantities of salt could continue to be produced in certain saltpans for local needs (Rab, Trogir, Split). Nevertheless, during the whole period of Venetian salt monopoly, additional quantities of salt continued to be illegally produced and smuggled. The Venetians monitored the Adriatic Sea, which they called Gulf of Venice, punishing salt smugglers with fines and imprisonment.

Venice aimed to control the commercial traffic of Dalmatian cities, imposing a specific policy over salt production and trade. Before this, this economic branch was flourishing in Dalmatia and notably Zadar, whose patriciate raised to wealth and power precisely because of saltpans. According to a law from 1414, salt from the main Dalmatian saltpans of Pag on the homonymous island had to be stored in the warehouses of Pag and Zadar. Nine years later, the export of salt from Pag by land towards the hinterland of Pag and Zadar was prohibited. All the owners of the saltpans of Pag and of the Zadar archipelago, who were mainly nobles and rich merchantmen from Zadar, were forced to sell their salt to the Venetian public treasury (*camera veneziana*), which sold it directly to the hinterland itself. The exports of salt by sea (towards Senj and Rijeka, the Neretva River but also towards the opposite side of the Adriatic, in Marche and Abruzzo) were possible, but they were subjected to varying taxation (Raukar 1970; 1977; 1981). At the same time, Venice took possession of the saltpans of Nin and Ljubač on the mainland of Zadar, forbidding any salt exploitation. Contrarily to the owners of the saltpans of Pag, who kept one fourth of the salt harvest (renewing the contract already stipulated with Pag in 1352), the salt produced on the saltpans of the Zadar archipelago, which were quite profitable during the 14th century, was entirely withdrawn. 15th century Zadar notarial records show only a few sales contracts of saltpans, compared to the previous period. Their price was lowered to 50 % of their previous values. In the middle of the 15th century, the Venetian senator Zan Batista Giustinian was sent to Dalmatia to write a report for the *Provveditori al sal* (salt superintendents) in Venice. He wrote that in the Zadar archipelago churches and monasteries owned numerous small saltpans, which were producing low-quality salt (*sali bruttissimi*) for only two months per year (Ljubić 1880: 43; Hocquet 1978: 84). At the end of the 16th century, the Venetian rectors of Zadar communicated to the *Signoria* of Venice (the supreme body of government) that the Zadar saltpans were abandoned due to the Venetian salt policy and they suggested the promulgation of rules that would improve the conditions of the owners of saltworks (Raukar 1970; 1977; 1981). Therefore, as Raukar (1977; 1981) has shown, the Venetian measures had a devastating effect on the economy and social order of Zadar that entered a period of economic stagnation and regression.

From about 1460, Venice adopted a new economic policy, by reducing its salt imports from the rest of the Mediterranean and supporting the development of selected saltpans on its own territory (Hocquet 1981: 8-9). The main improvements were made in Cyprus, which was annexed to the Venetian *Stato da Mar* in 1489. Cyprus was then the second largest producer of Mediterranean salt after Ibiza, which was under the Aragon crown and was selling salt mostly to the Genoese. Cyprus was producing about 20 000 t of salt per year, while Pag and Piran were producing each 10 000 t. Piran shipped the whole quantity of salt to Venice, while Pag was free to trade one quarter of its production. Eventual surpluses had to be exported to Croatia, not to Italy (Hocquet 1978; 1981; Adshead 1992: 90). Salt production was incentivized in Muggia and Koper to increase the exports of salt towards the northern and eastern markets. Big investments were employed to construct the saltworks in Šibenik (see below). In whole Dalmatia, salt continued to be produced only in Pag and Šibenik. The saltpans of Rab (Arbe) and Trogir (Traù) were modernized, but they produced minor quantities of salt only for local needs (Kolanović 1995: 199).

1.3.4. Salt in the Modern period

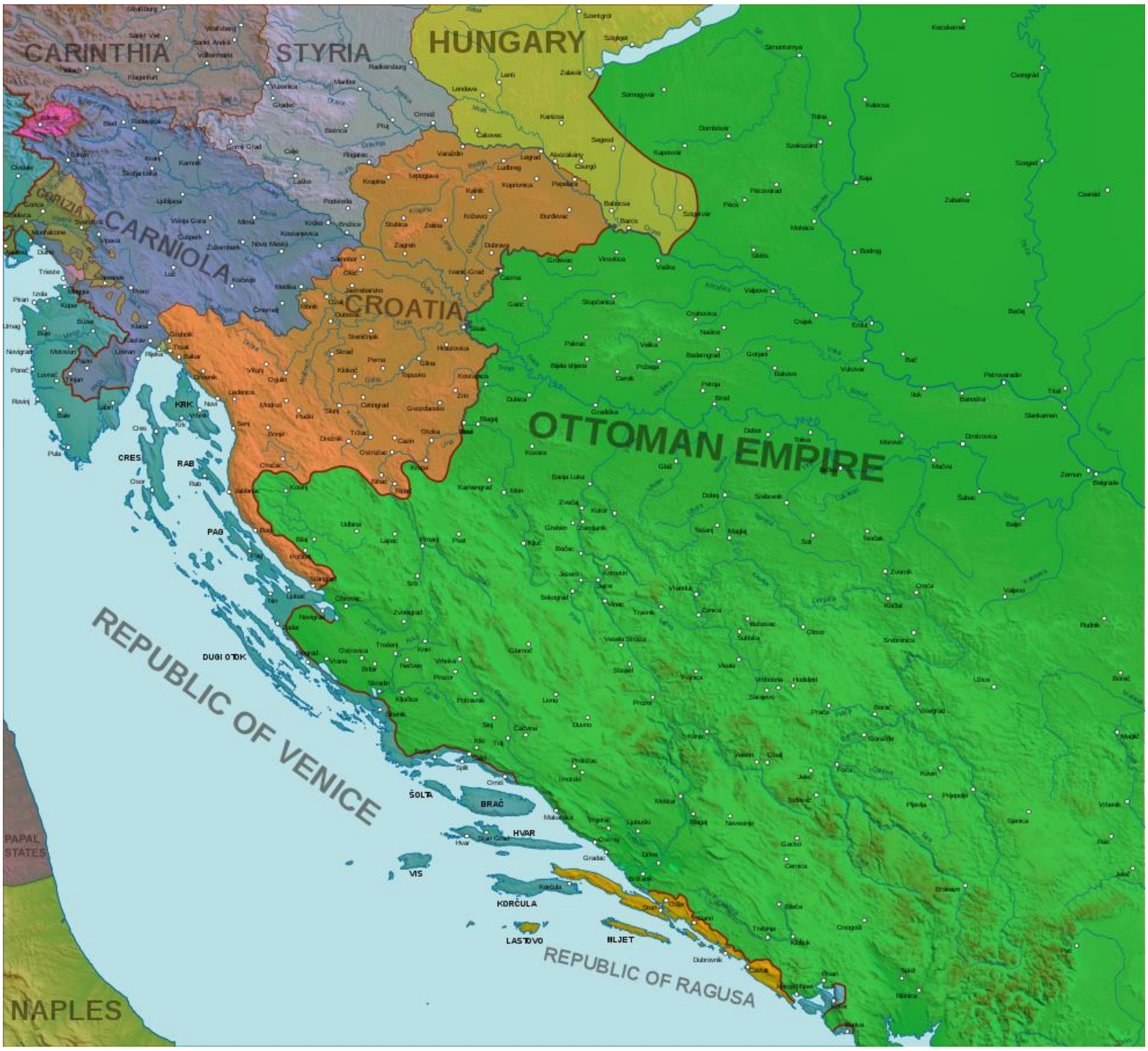

Fig. 27 Eastern Adriatic in 1558 (https://commons.wikimedia.org/w/index.php?curid=103260231, accessed 30.04.2022).

Salt was probably the most controlled commodity of the Ancien Régime. The French Kings heavily taxed the consumption of salt, introducing in the mid-14th century the so-called salt tax (*gabelle*), which was extremely profitable, allowing the funding of external conflicts. Peasant revolts broke out when this tax was extended to regions that had previously been spared, leading to waves of heavy repression. At the same time, smuggling of salt proliferated.

During the Renaissance, the population increased considerably and the demand for salt exploded in connection with new culinary practices that involved an intensification of cheese, butter and lard use (Adshead 1992: 100-101). In this period, the *ordines salis* of medieval city-states shrunk or declined, but smaller local networks developed, which finally traded with similar or even greater quantities of salt. The Venetian *ordo salis* lasted until 1509, when they lost the war against the French Kingdom in Agnadello, losing the access to the markets of northern Italy. Henceforth they turned towards the eastern markets, selling salt to the Slavic populations (Hocquet 1981).

In the period between 1550 and 1600, Trapani, with its advanced technology of salt production, became the leading producer of salt in the Mediterranean and sold its salt to both Genoa and Venice. Soon later, it declined due to internal revolts against the Spanish crown.

During the 15th and 16th centuries, the Dalmatian Communes were encouraged to keep smaller saltpans just for their own needs, while **Šibenik** (Ital. Sebenico) slipped out of this autarchic trend, founding its economic development on salt (Hocquet 1978: 86; Kolanović 1995: 202). During the 16th century, the Šibenik saltpans had 912 *cavedini*, playing a leading role in the Dalmatian economy (Hocquet 1978: 87; Kolanović 1995; Brakus 2019). The owners of the Šibenik saltpans, located mainly in Zablaće (Fig. 28) and Morinje south of the city, could freely produce the desired quantities of salt and sell it where they wanted: to the continental pastoral population of Venetian Dalmatia (Vlahi or Morlaci/Morlacchi), to the local fishermen for fish salting, but also to the western Adriatic coast. After the Ottomans conquered the internal parts of the Balkans (1499-1522, Fig. 27) Šibenik became an important salt market (*gabella de sal*), supervised by an Ottoman *emin*, who collected one part of the export customs (Kolanović 1995: 199-203).

During the 17th century, Venice encouraged salt production and increased salt imports in its *Stato da Mar* – Muggia, Koper, Piran, Pag, Šibenik, Corfu and Santa Maura on the island of Lefkada. Until the end of the Venetian Republic (1797), Piran, Koper and Pag still constituted the main saltpans of the Serenissima. Venice's monopoly on salt production and trade was strong in the Upper Adriatic, while in the southern Adriatic the Venetians could not interfere much in the maritime relations between Dubrovnik, Ancona and Apulia.

Fig.28 Šibenik saltpans in Zablaće, Veliko jezero: aerial picture (© Šibenik City Museum, photo of Tomislav Šmider, courtesy of Bruno Brakus) (a) and present state with illegal rubbish dumps (M. Grisonic) (b).

Dubrovnik (Ital. Ragusa) was a **maritime republic** (1358-1808) in southern Croatia, whose territory comprised the area in between Neum (in present-day Bosnia and Herzegovina) and the Prevlaka Peninsula (the southernmost point of Croatia), including the Pelješac (Ital. Sabioncello) Peninsula and the islands of Lastovo (Lagosta), Mljet (Meleda) and the Elaphiti Islands (Fig. 29). It was located in a strategic position between Europe and the Levant. Thanks to its neutrality, it exercised commercial freedom. Dubrovnik had its own ships and its area of influence was limited by the line that was ideally connecting Ancona (under the Papal States) and the Neretva River. Dubrovnik salt trade between the Adriatic and its hinterland is attested from the 14th century (Gecić 1955; Di Vittorio 1981). Salt trade and local production in Ston was one of the major sources of economic wealth of the Dubrovnik Republic. Both the production of salt in Ston and other minor saltpans of Dubrovnik, as well as the trade of salt imported from Italy and other parts of the Mediterranean, were state monopoly. Dubrovnik developed an important salt trade with its agricultural and pastoral hinterland (Bosnia and Herzegovina, Serbia, Kosovo, Macedonia) from the High Middle Ages. Salt was traded by land and river through the Neretva and Drin river valleys and by sea, through the harbor in Herceg Novi (Ital. Castelnuovo) in present Montenegro (Fig. 29; Di Vittorio 1981: 293). Dubrovnik's salt monopoly even consolidated when the Ottomans conquered Bosnia in 1483. The Republic formally had to pay one third of the profits of salt (*terziaria*) that were sold to the subjects of the Ottoman Empire to the Ottoman authorities (Di Vittorio 1981: 307) and the *bay* of Bosnia, in return for the monopoly of salt trade with the Ottoman hinterland. At the same time, on the stretch of the Adriatic coast from Split to Durrës, Dubrovnik was the only outlet to the sea of the products of the interior (Hajdarhodžić 1981: 311). During the 17th century, Dubrovnik finally emancipated from the Venetian and Genoese influences and became the principal exporter of salt from Manfredonia and Barletta (from 1879 known as saltpans of Margherita di Savoia, in honor of Italy's queen), greatly increasing the exports of salt in the Balkans through the Neretva and Drin waterways (Adshead 1992).

Fig. 29 The territory of the Dubrovnik Republic on a 1716 map of Nicolas de Fer (https://en.wikipedia.org/wiki/Republic_of_Ragusa, accessed 30.04.2022).

Adriatic salt under the Habsburg Empire

After the collapse of the Venetian Republic (1797) and a short period of French administration, when Trieste and large parts of present Slovenia and Croatia were included in the Napoleonic Illyrian Provinces (1809-1814), the Habsburg Empire appropriated of Istrian and Dalmatian saltpans. The Austrians improved the conditions of salt-making and increased the production in certain saltpans, like in Piran and Koper (Bonin 2009: 75). By 1912, only six saltpans were still operational: Koper, Piran and Strunjan in present Slovenian Istria and Rab, Pag, Dinjiška on the island of Pag and Ston in the present Croatian regions of Kvarner and Dalmatia. At the beginning of the 20th century salt production greatly diminished (about 8900 t in Piran, about 3500 t in Pag) compared to the 16th century, when the estimated amount of salt produced in these saltpans was about 20 000 t (Adshead 1992: 240-241). The reason behind this was the increase of salt production from inland sources that produced salt of superior quality and of much bigger quantities, which happened all over 19th century Europe. As an example, in Italy the marine saltpans of Margherita di Savoia, Trapani and others lost ground to the saltpans of Volterra and in France inland salt from Lorraine gradually replaced the salt from coastal Atlantic and Mediterranean saltpans. The same happened in the Balkans, where Tuzla in Bosnia and Herzegovina, which the Habsburgs obtained from the Turks in 1878, surpassed the Dalmatian marine saltpans (Adshead 1992: 243-244).

What is interesting for our study is that the Mediterranean saltpans, together with those on the French Atlantic coast, continued to produce salt in the traditional way known from centuries, with little technological improvements, which helps us understand how the saltpans from Classical Antiquity may have functioned.

1.3.5. Salt today

In the 19th century, with the discovery of salt chemistry and the development of new machines, the salt industrial sector was born. It is interesting to note that at the beginning of industrialization, 90 % of the salt produced was employed for human food preparation: anchovies and sardines, corned beef, cheese, butter, pickled vegetables, soy sauce. During the 1980s this trend that continues up to present completely inversed, with 90 % of salt produced worldwide being used for non-alimentary purposes, mainly in the chemical industry (Adshead 1992: 142-145). Salt serves to produce plastics, glass, polyester, leather and it is an essential component in the manufacturing of paper, tires and brass. It is employed in the clothing industry, because it helps to set the color into the fabric. It is used to clean gas and oil wells (Hocquet 2019). Another major employment of salt is for de-icing roads. In the alimentary market, salt is massively employed to preserve all kinds of precooked food (Adshead 1992: 141), which leads to an exaggerated consumption of salt in the modern population that has to contend with obesity and other diseases.

Today, huge multinational corporations share the profits of salt mining and trading. Most of today's salt is produced in China, followed by the USA, India and Germany. Together with big multinational salt corporations, small artisanal or semi-industrial farms remain. Mining techniques have been perfected, with the introduction of the practice of bringing water into deep drilling mines, where it forms a concentrated brine and it is then transported to the surface and evaporated as usual (Adshead 1992: 138). However, there is still a diversity of ways to acquire salt around the world, especially in the southern hemisphere. With the development of industrial tourism and the preservation of heritage, ancient salt production sites are restored and converted into salt museums.

On the eastern Adriatic coast, the following saltpans still survive to this day: Sečovlje and Strunjan in Slovenia, Pag, Nin and Ston (see Chapter 6). Montenegro is nowadays the only Mediterranean country, where salt production completely stopped (from 2013, https://rsis.ramsar.org/ris/2399) and it is entirely dependent on salt imports. In Albania, Skrofotina saltpans in the Narta lagoon north of the city of Vlorë (Valona) are still operational (Mladenov *et al*. 2018). On the western Adriatic (Italian) coast, salt production continues in Cervia and Margherita di Savoia.

2.

SALT PRODUCTION AND TRADE IN THE MEDITERRANEAN IN CLASSICAL ANTIQUITY

In antiquity, the Mediterranean coast had numerous flat muddy surfaces, like lagoons, shallow coastal marshes and lakes, often close to river and stream mouths that nowadays disappeared because of innumerous anthropic actions. At the edges of these natural shallow pools, but also on coastal rocks, the salty water stagnated and salt formed spontaneously by the action of the sun and winds. After the gathering of naturally formed salt (that, however, was full of impurities and had a bitter taste) and the artificial salt production with the briquetage and other techniques that implied the use of fire, a big technological improvement was made: the invention of saltpans. Driven by the increase of population and demand for salt, saltpans greatly reduced the costs and the workload that the previous techniques demanded. Saltpans spread all over the Mediterranean basin, which involved an enormous intensification of the quantities of salt produced and probably also the quality of salt itself. At the same time, small-quantity domestic salt production must have been widespread all over the Mediterranean shores, as well as the gathering of spontaneously formed salt. This continued where the natural environment did not allow the implantation of the more efficient saltpans, where the new salt exploitation techniques remained out of reach or where there was not the possibility to buy salt produced elsewhere.

At this point of research, we do not know when the technology of obtaining salt in saltpans spread all over the Mediterranean and beyond. Where there (as it seems logical) technological improvements in hundreds of years of Roman dominion? It is a question to be answered in the future, with the progress of archaeological investigations and with some luck with the state of preservation of the archaeological remains of ancient saltpans.

A thing that should be beared in mind is the connection between salt-making sites and the much better-known and preserved fish-processing workshops, which needed readily available supplies of salt for the preservation of the extremely perishable fish products (Carusi 2018). As Maniulis has hinted (*Astr*., V, 663-692; see below), saltpans and fish-salting facilities, as well as fishing spots, were frequently located very close.

This chapter is a review of the most important data on ancient salt production and trade in the Mediterranean. It aims to present the historical and economic framework, in which these activities took place in the ancient world, as well as the people, who were involved in these occupations. The discussion about coastal saltworks, which were the main source of salt, will be emphasized. At the same time, this chapter provides a revision of the fragmented literary sources handed down from ancient authors and raises some new questions about the technological processes required in ancient saltpans.

2.1. State of research

Several authors have enumerated the ancient saltpans spread over the Mediterranean, using ancient written, toponymic (Giovannini 1985; Traina 1992; Moinier 2012; Morère 1994; 2001) but also archaeological and other indirect sources (Carusi 2008: 49-148; Harding 2013: 68-69; Brigand, Weller 2015; Moinier, Weller 2015; García Vargas, Martínez Maganto 2017). Some of them have already produced maps of the locations of ancient saltpans and other salt sources in the Mediterranean (Carusi 2008: 316-317, Figs. 1-2; Harding 2013: 68-69, Fig. 6.1; Moinier, Weller 2015: 312-315). The exhaustive list of ancient salt production sites and natural salt sources known from ancient literary sources can be found in Moinier, Weller 2015 (p. 62), as well as a geography of the places of salt exploitation in the Mediterranean, the Black Sea and the Iberian Atlantic coast in Classical Antiquity (pp. 58-151).

Archaeological vestiges of saltpans from Classical Antiquity are slowly increasing. Remains of the Roman saltpans at the mouth of the Tiber gradually emerged during various archaeological operations (2001-2008) under the direction of the Soprintendenza Speciale per i Beni Archeologici di Roma - sede di Ostia in the former lagoon of Maccarese (Grossi *et al*. 2015). Fundamental was the finding of the incredibly preserved Roman saltpans in Vigo (Galicia, Spain), which were excavated during several archaeological rescue campaigns in between 1998 and 2016 (Castro Carrera 2006; 2008; Currás 2017; Castro Carrera *et al*. 2019). These are the biggest documented Roman saltpans, with an estimated surface of 8-10 ha. Part of them is exhibited in the museum *Salinae* - Centro Arqueolóxico do Areal in Vigo. In ancient Caunus/Kaunos in Turkey, an unusual, probably salt-making complex has been discovered in 2005. Its comprehension is hampered by the fact that it has not yet been entirely published. In 2019 the results of the rescue excavations, which unearthed parts of the Roman Republican and Early Imperial saltpans of Cervia on the western Adriatic coast have been published. The structures in Cervia constitute an interesting parallel with the archaeological evidence found in Makirina Cove in Croatia (see Ch. 4.1.1).

Other remains that might be connected to ancient salt exploitation have emerged in Spain (Alonso Villalobos *et al*. 2003; Alonso Villalobos, Ménanteau 2006; Currás 2017) and in France (Benoît 1959; Violino *et al*. 1993; Daveau, Sivan 2010). These evidences are still too fragmentary and demand to remain cautious about their attribution to salt-making activities. García Vargas and Martínez Maganto (2017: 203) have included these sites among the "pseudo-saltpans". In Portugal and the Spanish Galician coast, numerous installations located directly on the Atlantic shore, frequently next to fish-salting workshops, have been identified with ancient saltpans, although their dating to the Roman Imperial period is hardly demonstrable because of the lack of dating evidences (Currás 2017; Martins 2019; Brochado *et al*. 2022).

In Croatia, as we will see in the next chapter, new interesting data concerning ancient salt production is emerging.

2.2. Written sources

Ancient literary sources provide only scarce data about salt production and consumption in Classical Antiquity, which indicates that, like nowadays, salt was a quite common good. Moreover, it is difficult to understand when ancient authors are referring to artificial exploitations and when to spontaneous formations of salt, which implied different operational systems and management of resources (Carusi 2008: 45). Medieval and Renaissance authors provide more evidence about salt exploitation and trade, especially the German scholar Georgius Agricola, in the twelfth book of his work *De re metallica* from 1556 (see below) and Bernardino Gómez Miedes (c. 1515-1589), who produced the monograph on salt *Comentarios sobra la sal* (1572 and 1579[2], see the critical edition and translation of Ramos Maldonado 2003).

Salt-related terminology[10]

Latin *sal*, **Greek** ἅλς ***(hals)***, **Spanish** and **Portuguese *sal***, **Italian *sale***, **German *Salz***, **French *sel***, **Slavic *sol***, **Irish *salann*… or sodium chloride**. All these terms belong to the Indo-European lexicon (Curcă 2016: 222). The two radicals *sal* and ἅλς have been used for many salt-related toponyms, for instance Salzburg, Seille, Hall, Salapia (mod. Salpi), Alesiae… (for the salt-related toponymy in Europe see Nenquin 1961: 140-142).

Salarium: the Latin word for salary (It. and Sp. salario, Fr. salaire, Rom. salariu…), derives from *sal*. *Salarium* is as "a regular official payment to the holder of a civil or military post (Oxford Latin Dictionary)". It seems that the first salaries of Roman soldiers were paid in salt and that in the Greek and Roman world salt was exchanged for slaves (Zaninović 1991: 257). It is thought that the word *salarium* indicated originally salt rations for the soldiers, later the money for food rations and lastly salary (Plin., *Nat. Hist*., XXXI, 88; Marzano 2013: 123).

Salinae: ancient literary sources[11] allude that this word indicates only artificially built saltpans. The denomination ***campus salinarum*** is less frequent; it is attested in Columella (*R. R*., II, 2, 15), on an inscription from Severan age found on the right bank of the Tiber (*CIL* XIV 4285) and on the inscription of the *conductores* of the saltpans of Rome (Cébeillac-Gervasoni, Morelli 2014; see below). The word for saltpans in Ancient Greek is *halopegia*: sing. τὸ ἁλοπήγιον, -ου / pl. τὰ ἁλοπήγια, while ἁλή, -ῆς (almost exclusively in plural form) probably refers to natural salt ponds, rather than to artificially implanted saltpans (Carusi 2008: 33, 55; cf. Curcă 2016).

Salinator (less commonly ***salarius***) is the person who works on the saltpans, but it can also mean salt merchant (Kajanto 1982). According to Ørsted (1998: 21), during the Roman Republic *salinator* meant collector of a *vectigal* on salt or the buyer of salt, while during the Empire it indicated the purchaser and trader of salt. Napoli (2007) showed that at the end of the 1st century AD in *Gallia Belgica* and *Germania* this term indicated salt workers, while salt merchants were called *negotiatores salarii*. *Salinator* became a *cognomen* (in the case of M.

[10] For a comprehensive salt-related terminology in Ancient Greek see Curcă 2016.
[11] Caes., *BCiv.*, II, 37, 6, 1; *BAfr.*, 80, 1, 1; Cic., *Nat. D.*, II, 132, 4; *Leg. Man.*, XVI, 6; *Fam.*, VII, 32, 1, 6; Varro, *Ling.*, VIII, 48, 4; Colum., *Rust.*, II, 2, 16, 5; X, 1, 1, 135; Livy, I, 33, 9, 3; VII, 19, 8, 4; Manil., *Astr.*, V, 682; Plin., *Nat. Hist.*, II, 233, 8; XXXI, 81, 1; XXXI, 81, 7; XXXI, 82, 1; XXXI, 82, 4; XXXI, 89, 5; XXXI, 90, 1; XXXI, 92, 6; XXXI, 109, 3; XXXI, 114, 6; Vitr., *De arch.*, VIII, 3, 11, 1; X, 4, 2, 9; Festus, 238, 20; Rut. Namat., *De reditu*, I, 475; *Dig.*, III, 4, 1, pr.5; XXVII, 9, 5, 1, 1; XXVIII, 5, 60, 1, 2; XXXIII, 2, 32, 2, 2; XXXIII, 2, 32, 3, 1; XXXIX, 4, 13, pr.1; XXXXVIII, 19, 8, 8, 2; XXXXIX, 15, 6, pr.1; L, 15, 4, 7, 1; L, 16, 17, 1, 3.

Livius Salinator, cos. 219, 207 BC).[12] The only mention of a salt worker in Ancient Greek is ἀνὴρ ἁλοπηγός (Nicander of Colophon, *Alexipharmaca*, 518-520, 2nd century BC).

Salsarius is "the one dealing in salted provisions" (Oxford Latin Dictionary). A *negotians* (merchant) *salsarius* (*CIL* VI 9677) and another *salsarius* (*CIL* VI 1744a) are known from Rome.

Salsugo or ***salsilago***, as explained by Pliny, is the concentrated seawater in the saltpans, it is liquid and much saltier than seawater (*Nat. Hist*., XXXI, 92). We can translate it as brine (Oxford Latin Dictionary; Serbat 1972: 162).

Flos salis is the flower of salt (Plin., *Nat. Hist*. XXXI, 85, 90), but also "an unknown oily deposit found near salt-mines (Oxford Latin Dictionary, referring to Plin., *Nat. Hist*. XXXI, 90-92)". Longhurst (2007) convincingly explained that *flos salis* is also the alga *Dunaliella salina* that floats in the salt pools, a source of glycerol.

Salsamentum (ὁ or τὸ τάριχος) means salted food, but it mainly means salted fish.

Muria designates not only a fish sauce (Grainger 2014), but also the brine and simple salty water (see Morère Molinero 2008: 371-372).

Ancient sources on the saltpans of Rome and the via Salaria

Dionysius of Halicarnassus (II, 55, 5) and Livy (I, 33; II, 9; XXIX, 37) reported two different traditions over the founding of the most known saltpans in Classical Antiquity, those located at the mouth of the Tiber. Both of them described the conflicts between the fourth king of Rome Ancus Marcius (reigned 642-617 BC) and the inhabitants of the Etruscan *Veius* for the possession of saltpans at the estuary of the Tiber. According to Dionysius of Halicarnassus (a tradition reported also by Plutarch, *Rom.*, 25, 5), these saltpans already existed at the time of Romulus, when the Romans took possession over them, signing a treaty. The *Veientes* continued to claim back the saltpans, until Ancus Marcius definitely defeated them (Dion. Hal., III, 41, 3). A different story is narrated by Livy (I, XXXIII, 9; Plin., *Nat. Hist*., XXXI, 89): King Ancus Marcius founded Ostia and established the first saltworks (at the southern bank of the

[12] Other consuls with the same *cognomen*: C. Livius Salinator, cos. 188 BC; Cn. Pedanius Salinator, cos. suff.? AD 61; Cn. Pedanius Fuscus Salinator, cos. AD 118 (Cooley 2012).

Tiber). It seems that Ostia was founded explicitly for salt production (Meiggs 1973: 268). After the conquest of *Veius* in 396 BC, the Romans still had to fight against the Etruscans to prevent the recapture of the saltpans. Although not all scholars agree, most of them are convinced that the saltpans at the mouth of the Tiber were divided between the northern and southern banks (see the discussion in Carusi 2008: 136-137).

From the saltpans of Ostia, salt was loaded on ships and transported on the Tiber until the Foro Boario and the location called *Salinae* under the Aventine Hill, where probably already in the Bronze Age a point of storage and trade of salt developed (Coarelli 1999). It has been supposed that here started the famous Roman road ***via Salaria***, through which salt was being traded with the Sabines and other populations in the interior of the Italian Peninsula (Varro, *R. r.*, I, 14, 3; III, 1, 6.2, 14; Plin., *Nat. Hist.*, XXXI, 45, 85, 89; Festus, 327, 3; 436, 8; 437, 4). In the Republican period the road passed under the Servian Wall, close to Porta Collina (by the Quirinal Hill) in Rome. After the Aurelian walls have been built (AD 270-275), the road passed under the new *Porta Salaria* (nowadays destroyed, located by present Piazza Fiume), leading through the Tiber Valley to the Sabina Region, where it linked *Reate* (Rieti) and *Interocrium* (Antrodoco). It then crossed the Apennines through the Velino gorges towards the Picenum region: it followed the Tronto Valley, led to *Asculum* (Ascoli Piceno) and continued until *Castrum Truentinum/Truentum* (Martinsicuro) at the mouth of the *Truentus* (Tronto) on the western Adriatic coast (Cappelli 2003). According to Pliny (*Nat. Hist.*, III, 4, 13, 110) this was the only ancient settlement of the Liburni that survived in Italy until his days. *Via Salaria* was the most ancient Roman road, the name of which is linked to its commercial function. Originally, *via Salaria* was a prehistoric or protohistoric transhumance trail that preexisted the city of Rome itself and most likely already linked both sides of the Apennines (Cappelli 2003: 12). From the beginning of the 4th century BC, a consular road was gradually built and consolidated with the progress of the conquest of the central Italian region. Under August it became one of the major imperial roads: it was restored and extended on the coast towards south, until *Castrum Novum* (Giulianova) and *Hatria* (Atri). The Tabula Peutingeriana attests the toponym *Salinis* next to *Hatria* and further south, at the mouth of the Saline River, where there was the *statio Ad Salinas* (Marina di Città S. Angelo), which hints to the presence of saltpans along the Abruzzo coast. Very probably salt was imported to the internal Apennine region also from the Adriatic and not only from the Tyrrhenian coast (Cappelli 2003: 54).

The saltpans at the mouth of the Tiber were a very important source of income for the Romans. Already at the time of the kings, these saltpans were owned by the treasury and Ancus Marcius introduced the tax on saltpans - *salinarum vectigal* (Aur. Vict., *De vir. ill*., V, 3). According to Livy (XXIX, 37, 3) it was in 204 BC that the consul M. Livius made the tax on salt permanent, to obtain enough means for the war against Carthage. Because of this, he achieved the *cognomen Salinator* (Zaninović 1991: 260). This *cognomen* is attested on various inscriptions[13] and might had alluded to a turning point in the economic activities of the persons that designated.

Pliny the Elder's discussion on salt

The most extensive still-surviving passage on different types of salts, their production and uses in Classical Antiquity is contained in **Pliny** the Elder's encyclopedic work *Naturalis Historia* (XXXI, 73-105).[14] This passage shows the knowledge on salt that it has been acquired until his times, for which Pliny referred to older authors whose works have been for the most part lost. Pliny based most of his discussion upon Hellenistic philosopher Theophrastus' lost treatise on salts entitled περὶ ἁλῶν, νίτρου, στυπτηρίας (On salts, niter and alum) from the 4th century BC. He also cited the 1st century BC Roman author M. Terentius Varro (Carusi 2008: 15-18) and maybe the other authors that he cited among his references of the book XXXI (Carusi 2008: 255). At the same time, Pliny himself observed the facts that he described, thus being an **important witness of his time** (Morère Molinero 2008: 366).

Pliny distinguished the **naturally formed** (*nativus*) and **artificial salt** exploited by men (*facticius*). For the first one he used the verb *gignitur* (= it is generated), while for the artificial salt he employed the verb *fit* (= it is made, fabricated). According to him, both the natural and artificial salt could be obtained in many ways, but there were only two causes that lead to the formation of salt: condensation or evaporation (*coacto umore vel siccato*). He stated that naturally formed salt developed out of salty waters (sea, lagoons, marshes, lakes, streams and

[13] Examples from the Italian Peninsula: from Aquileia: AE 1992, 716. From Ostia: AE 1971, 64; AE 1988, 175; AE 2001, 697; AE 2001, 725; EDR101806; EDR181850; EDR181851; CIL XIV 271, 889, 1212a, 1566, 1567, 1568, 1569, 1570, 1571, 1572, 1919, 4569. From Rome: AE 1985, 127. From Rome or Veii: AE 1987, 64; AE 2001, 964; CIL XI 3823, 3824, 3825, 3826, 7749. From Pompeii: CIL X 895.

[14] See the text with the English translation in Jones 1963: 422-433; the French commentary in Serbat 1972: 153-172; the Italian translation of I. Garofalo in Conte 1982.

springs) and from rock salt deposits, while artificial salt was obtained from saltpans, where seawater entered a system of shallow pools (where it evaporated, leaving salt crystals). He clearly differentiated the natural salt collected in the salt marshes and lagoons (*stagna*) from the salt obtained in man-made saltpans, *salinae*.

Out of the **naturally formed salts**, he explained that salt spontaneously appeared in the shallow Tarentine lake, where it dried out by the summer sun and its whole surface turned into a layer of salt (*Nat. Hist.*, XXXI, 73). The same occurred in Sicily, where salt naturally formed at the edges of the lake *Cocanicus* and in another one near Gela (*Nat. Hist.*, XXXI, 73). Salt was gathered out of the lakes of Citium/Kition on Cyprus and Memphis in Egypt and then dried in the sun (*Nat. Hist.*, XXXI, 74).

Pliny explained that salt spontaneously formed out of the foam (*spuma*) on the shore and coastal rocks, where it had a sharper taste. It also appeared on the surface of the rivers, "the rest of the stream flowing as it were under ice, as near the Caspian Gates are what are called 'rivers of salt'…" (Jones 1963: 425). The rivers Ochus and Oxus in Bactria (northern Afghanistan) carried flakes of salt from the salty mountains (*Nat. Hist.*, XXXI, 75). Hot springs too could be salty, as those at Pagasae in Thessaly (*Nat. Hist.*, XXXI, 76). Pliny also talked about salt mountains and mines, from where salt was extracted in blocks, adding that the Kings of India had greater revenues from salt than from gold and pearls (*Nat. Hist.*, XXXI, 77). He cited the interesting fact that at Gerrha in Arabia houses and walls were built with blocks of salt cemented with water (*Nat. Hist.*, XXXI, 78).

Salt could also be found underneath the sand, like in Cyrenaica, which was famous for ammonia salt,[15] in the form of long opaque slabs. This contained chlorides of sodium, calcium and magnesium and did not have a very good taste, but it was used in medicine (*Nat. Hist.*, XXXI, 79).

After describing the naturally formed salt, Pliny then passed on to discuss the **artificial salts**. Most artificial salt was obtained in coastal saltpans, where seawater was let in the salt pools and fresh water could be added, but this was not done in Crete (*Nat. Hist.*, XXXI, 81). The practice of adding fresh water in the saltpans will be discussed shortly below. Pliny continued that in

[15] Pliny says that ammonia salt is the one found under the sand, deriving from Greek ἄμμος = sand. Serbat (1972: 156) warned that the term derives rather from Ἄμμων, the Libyan Zeus-Ammon.

Utica, Africa, salt was collected in heaps big as hills, where it was let to dry and where it hardened under the sun and the moon, until it was difficult to cut even with iron.

He then described inland saltpans, where the salt pools were filled with water from salty springs, citing Babylon and Cappadocia as examples (*Nat. Hist.*, XXXI, 82). These practices of salt making remained unchanged in the inland saltpans on the Iberian Peninsula during the Middle Ages and the Modern period (see Morère Molinero 2006) and continue up to this day in the Salinas de Añana in the Basque Country (see Plata Montero 2022).

Pliny continued his examination by describing the different techniques of obtaining salt by fire, common to the people living far from the sea and wrote "In the provinces of Gaul and Germany they pour salt water on burning logs." Tacitus explained more in detail this procedure, practiced in Germania by the Hermunduri and Chatti (see below). According to Pliny, the best wood to use for this purpose was oak, but also hazel. Salt obtained from wood was dark. Pliny then cited Theophrastus, explaining that the Umbrians boiled the ashes of reeds and rushes in water, until a small amount of liquid remained and salt was obtained (*Nat. Hist.*, XXXI, 83). Aristotle likewise mentioned this practice of obtaining salt in Umbria (*Meteor.*, II. III, 35-40). In fact, a mix of salt crystals and potash was obtained with these procedures (Serbat 1972: 158; Weller 2004: 99-101). This shows that when salt was not available locally, the populations living in the interior of the continent produced a substitute to salt. According to Pliny, there was also the possibility to recover salt by reboiling the brine used for salted foods, the best being the one obtained from sardine brine.

The next passages describe various salts obtained in different areas of the Mediterranean. The most appreciated sea salt was produced in Salamis on Cyprus, while among the lakes the best and whitest salts were the ones from Tarentum and Tatta[16] (present Tuz Gölü at 940 m a.s.l.) in Phrygia. Both were used for eye diseases (the best being that of Tarentum), while salt from Cappadocia (imported in small bricks) and Citium/Kition (present Larnaca) on Cyprus was best for softening the skin (*Nat. Hist.*, XXXI, 84).

Salt was also produced in Tragasai, near present Tuzla (Turk. *tuz* = salt) in NW Anatolia, Acanthus on the Athos Peninsula in Greece, Centuripae, Agrigentum and Gela in Sicily,[17]

[16] The salt lake of Tatta is also mentioned in Strabo (XII, 5, 4; XII, 6).

[17] In Centuripae in inland Sicily rock salt was collected, in Agrigentum there were mines of rock salt, as well as salt produced in the coastal salt marshes, in Gela salt was obtained from salt lakes (Solinus, *De mirabilius mundi*, V; see Harding 2013: 68, Fig. 6.1). Strabo (VI, 2, 9) states that in the salt lake of Agrigentum a man could float.

Memphis in Egypt, the Oxus River (present Amu Darya). Each one of them had a different color that could spread from red to transparent (*Nat. Hist.*, XXXI, 86). Other salt exploitation sites were in Baetica, Attica and Euboea. The best for meat preservation was the one from Megara. In the various kinds of seasonings, the taste of salt was dominant. Salt encouraged sheep, cattle and draft animals to pasture, it made them produce more milk and consequently a cheese of better quality (*Nat. Hist.*, XXXI, 88).

Pliny then stated that a civilized life would be impossible without salt, that from *sal* derived the term *salarium*, mentioned the *via Salaria*, through which salt was imported to the Sabines. He explained that the King Ancus Marcius was the first one to have constructed the saltpans. The importance of salt was evident, because sacrifices could not be performed without the *mola salsa* (*Nat. Hist.*, XXXI, 89; Ovi., *Fast*., I, 335), the salted flour used in sacrificial ceremonies.

The purest and whitest salt (XXXI, 90) was *flos salis*, the flower of salt, which formed only thanks to northern winds (XXXI, 85). There was another thing called *flos salis*, a sort of salt rust of yellow-red color, which had fat (*Nat. Hist.*, XXXI, 90-92). According to Longhurst (2007), he meant the alga *Dunaliella salina* that floats on the surface of the salt pools and the fat would be glycerol, which was used in the fabrication of perfumes and detergents, but also in medicine.

Pliny then explained that *garum* was so precious that gave notoriety to the nations that produced it. Antipolis, Thurii and now also *Dalmatia* were known for *muria* (*Nat. Hist.*, XXXI, 94). The fish sauces could be used as medications (*Nat. Hist.*, XXXI, 95-97). He finished his account on salt describing the uses of salt in medicine (*Nat. Hist.*, XXXI, 98-105). He specified that salt was above all used to cure eye problems, for which the salts of Tatta and Caunus in Asia Minor were the best. Theban salt was used for boils, psoriasis and other skin problems.

The important elements to be retained from Pliny's discussion on salt for the present study are:

1. Natural salt was collected in the salt marshes and lagoons that he called *stagna*, while most salt was obtained from man-made saltpans, *salinae*. The difference between *stagna* (*salsa palus* in Rut. Nam., I, 475) and *salinae*, as Rutilius Namatianus explained in the 5th century, was the presence of artificial channels that brought seawater in the salt marsh, where there was an area

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Close to Gela there was a salty stream flowing from the salt mines into the Himera River (Strabo, VI, 2, 9; Diodorus Siculus, *Bibliotheca historica*, XIX, 109; Vitr., *De arch*., VIII, 3, 7), the present Salso.

with numerous compartments (for the concentration of brine and the evaporation of water). Pliny's passage thus testimonies the coexistence both of natural and artificial production of salt along the Mediterranean shores (Morère Molinero 2008: 369) in the 1st century AD, which probably continued in the following centuries. This must be kept well in mind when searching for ancient salt sources.

2. Far from the sea, there were inland saltpans that must had functioned in a similar way of the coastal ones, the difference being the source of salty water – inland salty springs instead of the sea.

3. Fresh water could had been added in the saltpans – but this practice was not employed everywhere, for example not on Crete.

4. Salt was collected in heaps that in Utica were big as hills and they were let to dry day and night (under the sun and the moon).

Pliny's passages about fresh water being added in the saltpans

In the above-treated discussion on salt, Pliny explained that most salt was obtained in saltpans (*in salinis*) "by running into them seawater not without streams of fresh water (*non sine aquae dulcis riguis; rigua* = irrigations), but rain (*imber*) helps very much, and above all much sunshine (*sole multo*), without which it does not dry out (*inarescens*). […] It is also however made (*fit*) in Crete without fresh water (*sine riguis*) by letting the sea flow into the pools (*mare in salinas infundentibus*)..." (*Nat. Hist.,* XXXI, 81; translation of Jones 1963: 427).

Pliny also wrote that "all salt is made sweet by rain water, more agreeable, however, by dew, but plentiful by gusts of north wind. It does not form under a south wind." (*Nat. Hist.,* XXXI, 85; translation of Jones 1963: 431).

The use of adding fresh or rainwater into the saltpans is also mentioned in other two passages of the *Naturalis Historia:*

Nat. Hist., II, 233: "…; pluvias salinis aquas utiliores esse quam reliquas, nec fieri salem nisi admixtis dulcibus;" "…that rain water is more useful than other water for salt-works, and that fresh water has to be mixed with seawater for the salt to be deposited; …." (translated by Rackham 1938).

Nat. Hist. XXXIV, 125: "….fit et in saxorum catinis pluvia aqua conrivato limo gelante; fit et salis modo flagrantissimo sole admissas dulces aquas cogente. …." "(The shoemakers' black color) is also made in pans hollowed in the rocks, into which the slime is carried by rain-water and freezes, and it also forms in the same way as salt when very hot sunshine evaporates the fresh waters (*aquae dulces*) that were brought (*admissae*)." (translated by Rackham 1952, with modifications).

Summarizing, according to Pliny, salt was not made (v. *fio*) if fresh water was not added in the saltpans. Streams of fresh waters (*rigua aquae dulcis*) were brought (v. *admitto*) in the saltpans. He also stated that rainwater was the one that was most useful in the saltworks, giving to salt a sweeter taste. What did Pliny mean with this? Simply that after it had rained the salt collected was sweeter (because it washed away the so-called "bad salts")? That rainwater was the best fresh water to be added in the salt pools to help the crystallization? Or he meant that rain was useful because it washed the impurities once salt has been gathered? However, Pliny pointed out that in Crete fresh water was not let in the saltpans. Was Crete an exception of what it was a standardized practice in most saltpans of the Roman Empire?

In his work, Pliny mentioned both the use of fresh water and the usefulness of rainwater three times, which means that he was well aware of this procedure: it is something that he had personally seen, heard of or that he had read in his references. Also Vitruvius mentioned the practice of adding fresh water in the saltpans to dilute the brine in the salt pools (Vitr., *De arch.* X, 4, 1-2; see below). Serbat's comment (1972: 157) that fresh water did not contribute to the formation of salt, but that it was only useful for removing the bitterness of the magnesium from the sea salt, is not convincing.

In modern saltpans, the "bad salts" are progressively removed in successive evaporation basins, until the common salt is obtained, freed from most impurities. This might had been practiced also in Classical Antiquity (Trakadas 2015: 18). Another way of eliminating the impurities is by adding fresh water to raw salt (Harding 2013). Although the problem remains unexplained, Pliny and Vitruvius hint to the fact that in the 1st century AD fresh water was added in the saltpans, because it was thought that it helped salt crystallize, while in later historical periods all fresh water was sistematically kept away from the saltworks.

Strabo

In the work *Geographiká* (Geography), written in AD 14-23, Strabo (XI, 14, 8) mentioned the ἁλοπήγια (sing. ἁλοπήγιον = saltpan, where salt is artificially obtained) only once, while in various occasions he used the word λίμνη, meaning coastal salt marsh (Morère Molinero 2001: 520).

The salt sources that Strabo numbered in his geographical work are enumerated in Morère Molinero (2001). In all of them salt spontaneously formed in nature by evaporation. Except for the allusion of the ἁλοπήγια in the continental lake of Mantiane in Armenia, Strabo did not describe anthropic salt production (Morère Molinero 2001: 520-521).

Tacitus

The books of *Annales* describe the history of the Roman Empire from the period of Emperor Tiberius until Nero (AD 14-68). In one passage (*Ann.*, XIII, 57), Tacitus illustrated the fight of the two Germanic populations of the Hermunduri and Chatti over a salty river. They used to obtain salt by burning great piles of wood, on which they poured the water from this river, which was rich in salt and located at the frontier between the territories of the two tribes:

"[...] salt in that river and in these forests was not produced, as by other peoples, by allowing water to evaporate in a **pool left by the sea** (*eluvie maris arescente unda*), but by pouring it on a blazing pile of trees, crystallization taking place throughout the union of two opposed elements, water and fire." (translation of Jackson 1937: 98-101, with modifications).

In fact, as water got in contact with fire, it evaporated and salt precipitated in the ashes.

Although Tacitus does not directly mention the saltpans, he briefly indicates that in many countries salt was commonly obtained by letting the seawater (*unda*) dry out (v. *aresco*) in a pool (*eluvies*) by the sea.

Marcus Manilius

In the 1st century AD, in the fifth book of his didactic poem about astronomic phenomena *Astronomica*, written in hexameters, Manilius described the astronomic influences of men who were born under various constellations. Those born under Cetus, the Whale, were inclined to fish and to produce fish sauces and salt. He offered some verses that describe saltpans (V, 682-692):

“*quin etiam magnas poterunt celebrare salinas*
et pontum coquere et ponti secernere virus,
cum solidum certo distendunt margine campum
adpelluntque suo deductum ex aequore fluctum
claudendoque negant; tum demum suscipit unda
aëra et epoto per solem umore nitescit.
Congeritur siccum pelagus messisque profundi
canities semota maris; spumaeque rigentis
ingentes faciunt tumulos, pelagique venenum,
quo perit usus aquae corruptus amaro,
vitali sale permutant redduntque salubre.”[18]

“Moreover, [men] will be able to fill great salt-pans (*salinas*), / to condense the sea (*pontum coquere*), and to extract the sea’s venom[19] [i.e. salt]: / they level a field with solid bottom (*solidum campum*) and surround it with a safe embankment (*margine*), / next they conduct therein the wave deviated from the sea / and by closing (v. *claudo*) it, they stop it; finally the water gets / heat and begins to glisten as the water is drained off by the sun. / The sea’s dry element is accumulated, harvest (*messis*) from the seabed, / the whiteness (*canities*) [i.e. salt] separated from it; they make from solid foam (*spumae rigentis*) / huge mounds (*ingentes tumulos*) and the poison of the open sea (*pelagi*), / which prevents the use of sea-water, vitiating it with a bitter taste, / they commute (v. *permuto*) to life-giving salt and render it healthy.” (translation of Goold 1977: 354-357, with modifications).

It is important to note that Manilius was a poet describing astrological phenomena, not a specialist of saltworks. His point was not to precisely describe the saltpans, nor did he fully understand the functioning of such coastal facilities. He depicted the saltpans in general and not

[18] Text accepted by D. Liuzzi (1997, see discussion on pp. 159-160) and W. Hübner (2010), which slightly differs (in the v. 686, 687, 689) from the text edited by G. P. Goold (1977).
[19] Salt is poison because it prevents the seawater to be drunk (Liuzzi 1997: 159).

a precise location, although he might have had observed the functioning of some contemporary saltpans. Nevertheless, we can still extrapolate some important information from his verses.

The **saltpans** (*salinae*) described by Manilius have a **field with solid (hardened) bottom** (*campus solidus*) inside a **safe embankment** (*margo, -inis*). By "the wave deviated from the sea" he meant a **channel** and by "closing (the wave deviated from the sea)" he most likely alluded to a **sluice gate** that trapped the seawater inside one or more salt basins, where the seawater **condensed** (*coquere pontum* in v. 683). He added that "they make from solid foam huge mounds", which indicates the **harvest of salt making mounds** (*tumuli*), where salt was let to dry. The last part of the sentence alludes to the eliminations of impurities that are originally present in seawater, which (the men who work on the saltpans) eliminate to avoid the bitter taste of the final product.

Manilius' account raises several questions. How did the men working on the saltpans obtain the elimination of impurities? With the whole technological process that went on in the saltpans, by letting the "bad salts" progressively precipitate in successive salt basins, until the comestible kitchen salt was obtained? Did they wash the salt with fresh water, as attested in later historical periods? Did the system of adding fresh water in the salt pools, a contemporary practice attested in Pliny and earlier by Vitruvius, had something to do with it? Manilius used the verb *permutant*, referring to men: it is they who eliminate the impurities, not simply the rain.

In the preceding verses (*Astr*., V, 663-675) Manilius described the men engaged in fishing and cutting tunnies and most likely mackerel (v. 676 ss.; Liuzzi 1997: 158; Felici 2018: 89). They put them in large tanks (*ingentis lacus*) and barrels or wine containers (*Bacchi dolia*), where *garum* and other fish sauces, flavored with salt, were made. This shows that fishing spots, fish-salting facilities and saltpans were closely related, probably located in proximate vicinity.

Rutilius Claudius Namatianus

In the early 5th century AD, in the poem *De reditu suo*, Rutilius Namatianus described his return trip from Rome to Gaul by sea. In one passage, he illustrated the saltpans annexed to the *villa* of his dear friend Albinus in Vada, in the territory of Volterra, Tuscany (I, 475-484):

“*subiectas villae vacat aspectare salinas;*

namque hoc censetur nomine salsa palus,

qua mare terrenis declive canalibus intrat

multifidosque lacus parvula fossa rigat.

Ast ubi flagrantes admonuit Sirius ignes,

cum pallent herbae, cum sitit omnis ager,

tum cataractarum claustris excluditur aequor,

ut fixos latices torrida duret humus.

Concipiunt acrem nativa coagula Phoebum

et gravis aestivo crusta calore coit,

[...].”

Translation of the verses 475-490:

“I find time to admire the salt-pans (*salinas*) lying beneath the *villa*: / with this name a salt marsh is designated, / where the sea enters the sloping terrain (*terrenibus declive*) through channels dug in the land (*terrenis canalibus*), / and a little trench (*parvula fossa*) floods the manyparted ponds (*multifidos lacus*). / But after Sirius has advanced his blazing fires, / when grass turns pale, when all the land is thirsty [i.e. summer], / then the sea is shut out with the barriers (*claustris*) of the sluice-gates (*cataractarum*), / so that the torrid ground may harden the stagnant waters (*fixos latices*). / The natural incrustations (*nativa coagula*) so produced absorb the penetrating sun (Phoebus), / and because of the summer heat, a heavy crust [of salt] forms, / just as when the wild Hister stiffens with ice / and carries huge wains upon its frost-bound stream. / Let him who is given to weigh natural causes examine / and investigate the different effect worked in the same material: / frost-bound streams melt on catching the sun, / and on the other hand liquid waters can be hardened in the sun.”(translation of Wight Duff, Arnold M. Duff 1934, with modifications).

Contrarily to Manilius, Rutilius Namatianus described the saltpans of his friend Albinus that he had personally seen along the Tuscan shore. They were located on the coast below the *villa* (*subiectas villae*). Although the language is mediated by the poetic form and his aim was not to analytically describe these man-made installations, with which he was not particularly familiar, he explained what saltpans (*salinae*) are, giving the main elements that characterized them:

seawater entered **in low gradient** through **earthen channels** (*canales*, sing. *canalis*), from where it was presumably brought to another **small trench** (*fossa*) and next to the **manyparted pools/basins** (*multifidi lacus*) of the saltpans. *Multifidus* means divided into many parts. Channels were provided with **sluice-gates** (*cataractae*) that were closed in the summer time, so that the salt production process could start.

The *villa* of Albinus with the saltpans was located at an unidentified position, on the coast close to S. Gaetano di Vada (Livorno), where there were numerous coastal marshes suitable for salt making. Medieval documents, which attest salt exploitation in the area from the 8th to the 13th centuries (Ceccarelli Lemut 2000), and the toponym *padule delle saline* (= marsh of the saltpans, *padule* is the Tuscan variant of the It. *palude* = marsh), still present in 18th century maps of Vada, confirm the presence of saltpans in two different areas, south of the River Fine and south of the River Cecina (Sangriso 2011: 209-211). We can imagine that these were not the only saltpans in the area when Rutilius Namatianus visited it. Fragments of briquetages have been discovered in two different sites: Galafone at the mouth of the Fine River (Early Iron Age) and at Isola di Coltano (Pisa), south of the mouth of the Arno. At the latter site there was a village implanted next to a coastal lagoon, specialized in the production of salt cakes during the period from 1600 BC to 1200 BC (Pasquinucci, Menchelli 2002). At the end of the 1st century BC the same area was occupied by a Roman *villa*, which was operational up to Late Antiquity, possibly continuing an economic activity that prospered in the area from the Middle Bronze Age.

Vitruvius and the tympanum

In the tenth book of his *De architectura*, a work dedicated to Emperor Augustus, Vitruvius (c. 80/70 BC - c. 15 BC) described the construction and use of machines. He started the section of water-lifting devices (*De arch.*, X, 4, 1-2) by describing the simplest one, called *tympanum*:

"*Ita hortis ad inrigandum vel ad salinas ad temperandum praebetur aquae multitudo.*"

"[…] in this manner, a large quantity of water is provided for irrigation in gardens, or for diluting (*ad temperandum*) (salt) in the saltpans." (translation of Granger 1934: 303 and Forbes 1955[2]: 37, with modifications).

Although several scholars translated this passage with "a large quantity of water was provided for supplying the needs of salt-works" (Carusi 2008: 35; Marzano 2013: 124), the verb *tempero* means to mix, temper. Vitruvius is probably referring here to the practice of deliberately adding fresh water in the saltpans, which is later attested in Pliny (*Nat. Hist*., II, 233; XXXI, 81; XXXIV, 125).

About the tympanum, Vitruvius says that it "does not raise water to a great height, but draws a large amount in a short time." (translated by Granger 1934: 303).

Tympanum (*mech.*), Gr. τύμπανον is a term that Vitruvius employed in his work with various meanings (see Callebat, Fleury 1986: 135). It was a machine used for drawing water, either for drying (V, 12, 4) or for irrigation. In the passage about water-lifting devices *tympanum* is the drum or wheel for raising water. Vitruvius wrote that this machine was driven "*hominibus calcantibus*", which several scholars have translated with "driven by men that treaded the rim with the pressure of their feet" (Granger 1934: 303; Forbes 1955[2]: 37; Marzano 2013: 124), while others argued that the presence of men inside the wheel can be excluded (see Callebat, Fleury 1986: 139). On the premise that Vitruvius' original drawings got lost and that his descriptions are lacking mathematical details and moreover they do not often exactly correspond to the reality, various interpretations and drawings of the *tympanum* have been produced, starting from the Renaissance.

In 1511, Fra Giovanni Giocondo published the first illustrated edition of Vitruvius' work, based on the descriptions of the ancient architect. He produced the resulting drawing of the *tympanum* (Fig. 30). This machine had an axle (*axis*, Fig. 30, a), around which there was the *tympanum* or drum of planks fitted together, reinforced by eight transversal iron bars placed at equal intervals (Fig. 30, b). The whole machine was probably anchored to the ground by two uprights, the *stipites* (Fig. 30, c). At the rim of the drum, there were about 15 cm large openings (*semipedales aperturae*) that were receiving water (Fig. 30, d), which flew through the holes next to the axle into a trough (*canal*) and then to a wooden basin (*labrum ligneum*).

Fra Giocondo interpreted the *tympanum* as a smaller device that could had been operated manually. A different drawing of the *tympanum* can be found in Callebat, Fleury (1986: 136, also published by Moinier, Weller 2015: 56, fig. 5), which has been reconstructed as a water-lifting device of much larger dimensions. As no archaeological remains of this nor of other possible kinds of pumps have yet been found on ancient saltpan sites, the question remains open. Remains of waterwheels have nevertheless been recovered in the mines of Rio Tinto and in the bath quarters of the Roman *villa* of Calpe, in Spain (see Marzano 2013: 124).

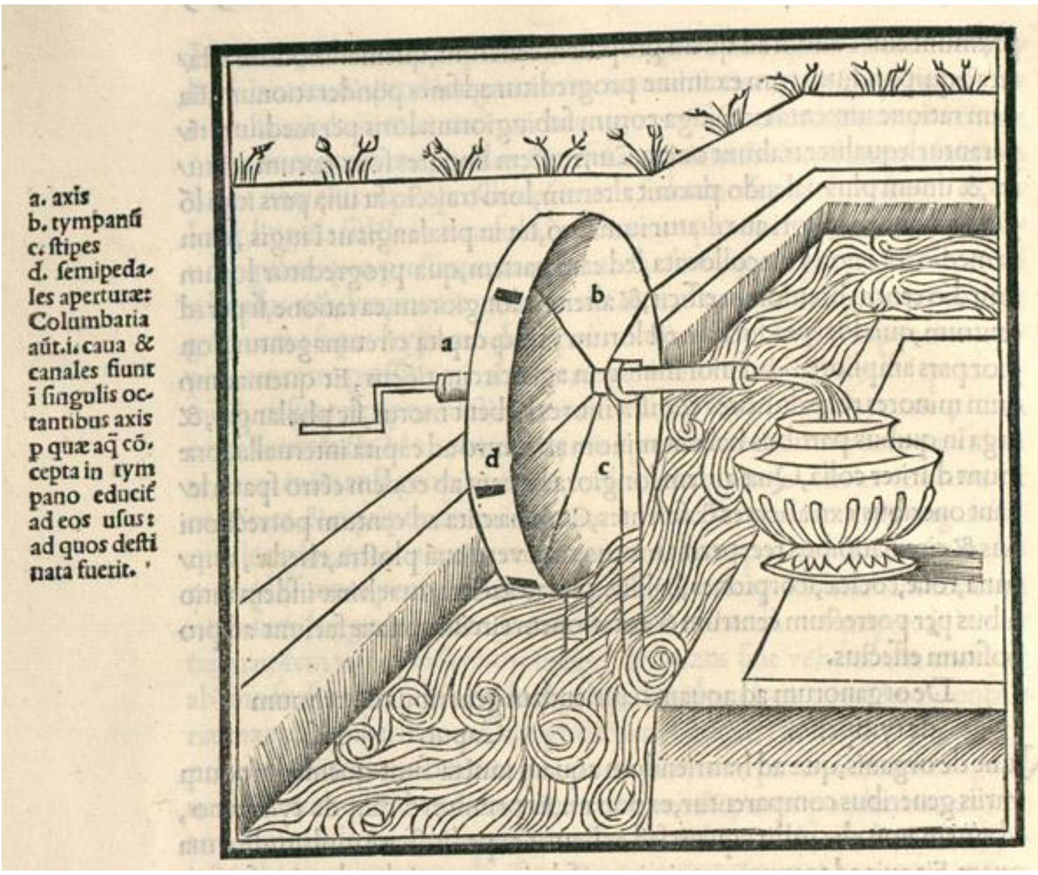


Fig. 30 Fra Giocondo's woodcut illustration of the tympanum *in his edition of the* De architectura *of M. Vitruvius, 1511, p. 100 (http://architectura.cesr.univ-tours.fr/Traite/Images/CESR_2994Index.asp, consulted 30/07/2022).*

In the majority of still-working saltpans, pumps are used to raise water from lower to higher parts of the saltworks, when the natural slope of the terrain does not allow the flow of seawater from the sea to the different compartments of the saltpans. The use of pumps has been hypothesized in the Roman saltworks of Vigo in Galicia (Currás 2017; see below). At the same time, in Punta de l'Arenal (Alicante) there is an about 100 m long channel cut in the coastal rock, which in the Arab period has been employed for raising seawater in the saltpans with a waterwheel (Rosselló 2004: 259-261). The presence of a tuna-fishing site and a fish-processing workshop, with the epigraphic monument of a *salinator* (*CIL* II 3599; Napoli 2007) all hint to the fact that there were Roman saltpans in the area, which might have already used the same channel and similar water-lifting machines.

Cassiodorus

In a letter dating to AD 537 (*Variae*, XII, 24, 6), Cassiodorus (c. 485 - c. 585) described the resources of the inhabitants of the Venetian lagoon – hunting, fishing and salt production:

"*In salinis autem exercendis tota contentio est: pro aratris, pro falcibus cylindros volvitis: inde vobis fructus omnis enascitur, quando in ipsis et quae non facitis possidetis. moneta illic quodammodo percutitur victualis. arti vestrae omnis fluctus addictus est. potest aurum aliquis minus quaerere, nemo est qui salem non desideret invenire, merito, quando isti debet omnis cibus quod potest esse gratissimus.*"

"All your attention is concentrated on salt-works (*salinis*). Instead of using ploughs and sickles, you roll cylinders (*cylindros*). Thence your whole crop is produced, since in them you have a resource you do not manufacture. There is, so to speak, your subsistence-money coined. Every wave is a servant of your art. A man may have small interest in seeking gold, but there is no one who does not wish to acquire salt; and deservedly so, since all kinds of food owe its savor (to salt)." (translation of Barnish 1992: 178, with modifications).

The cylinders mentioned by Cassiodorus have been interpreted in three ways: as the cylinders of water-raising machines, like the *tympanum* (Carusi 2008: 35, 145), the Archimedean screw or water screw (Marzano 2013: 124-125) or the rollers that levelled and compacted the ground in the saltpans (Currás 2017). The latter explanation is in my opinion the most probable and the most similar comparison to the previously mentioned ploughs and sickles. In the saltworks of Sečovlje (Piran), Slovenia, stone rollers "rodoli" with two wooden handles "canigiare" were used to smooth the base of the crystallization basins, after they have been compacted with rammers called "pestoni" (Žagar 1995: 56-57; Lusa 2005: 59). In the saltpans of Trapani stone rollers were used to compact the bottoms of the salt pools (Manuguerra 2013: 46). In Cervia, these rollers – the big cotice ("cotg") or the small cotice ("cutgèna") – were wooden.

Cotice ("cotg", Fig. 31) was a heavy oak or mulberry cylinder, about 1.30 m long and about 32 cm high. It had longitudinal grooves and it was equipped with iron pins ("polsi") planted in the center of the roller that served to attach the wooden rods ("tincell") used for handling the cotice. It was mainly used at the beginning of the season, to compact and level the bottom of the crystallization pools ("cavden"), the embankments ("vargulen") between the crystallization and evaporation basins and the wide flat paths in the center of the saltpan ("verghi"), which allowed the passage of the cart ("cariol") to collect the salt. The cotice was used in the evaporation tanks only exceptionally (Giunchi 2013).

Fig. 31 Cotice ("cotg") employed in the saltpans of Cervia at the beginning of the 20th century (courtesy of Nino Giunchi).

The **small cotice** (piccolo cotice, "cutgèna") was a roller smaller in size compared to the "cotg". It did not have grooves on its surface. It was also used to make the bottom of the salt basins more compact and smooth (Giunchi 2013).

In Cervia, the wooden cart ("cariol", Fig. 32) used to collect salt had handles that were about 4.5 m long (to relieve the burden on the arms of the salt workers) and it was also provided with a single cylindrical roll (Giunchi 2013).

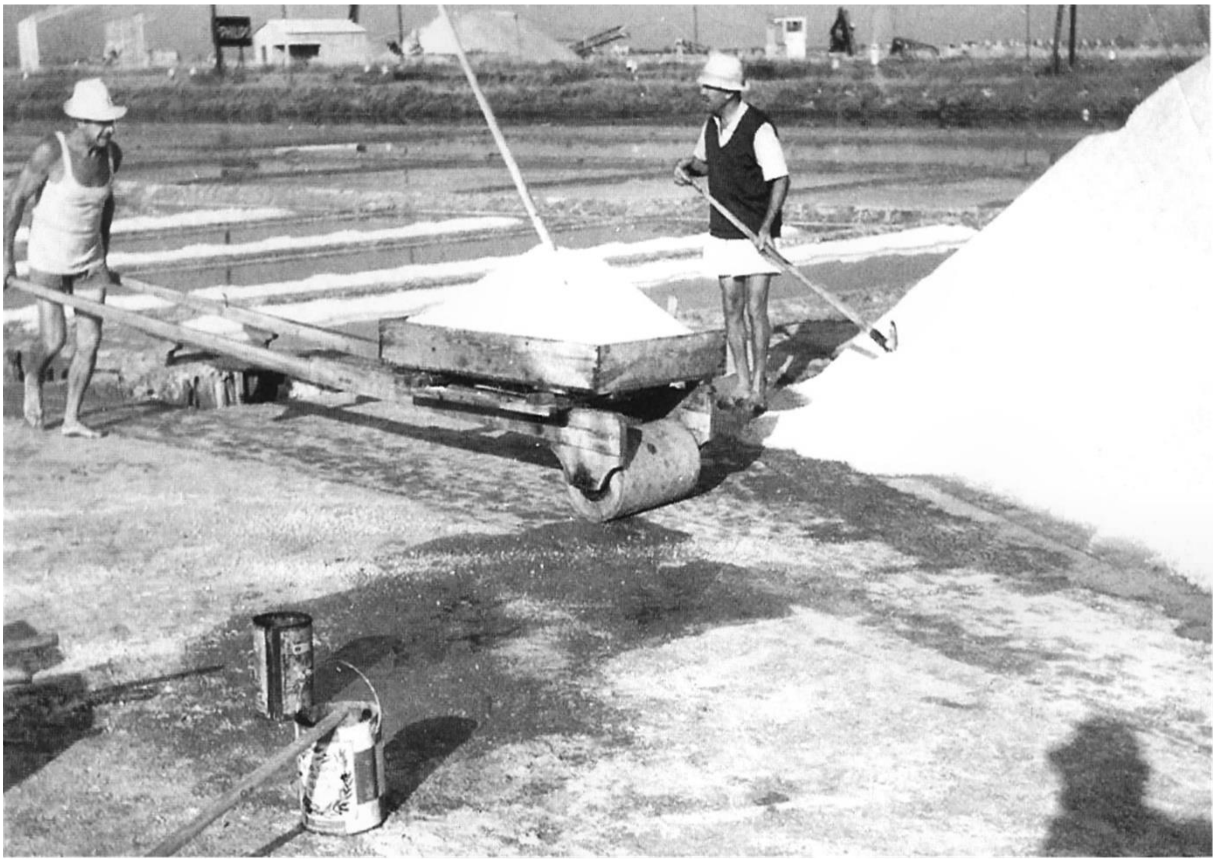


Fig. 32 Salt harvest in Cervia with the aid of the "cariol" (courtesy of Nino Giunchi).

Georgius Agricola

Georgius Agricola (1494-1555) talked about the production of salt in the twelfth book of his *De re metallica* that was published in 1556 (English translation by Hoover, Hoover 1950: 545-558). He used Pliny as a reference, but added plenty of valuable data about the construction of the saltpans of his time. He coined numerous Latin terms that he used in his text.

Agricola explained that salty water condensed in salt pits, where thanks to the heat of the sun or by the heat of a fire, it evaporated leaving salt crystals.

He then described how saltpans work (Fig. 33). They are built next to the seashore, in calm coastal lakes/pools and other plain surfaces, at a safe distance from the sea tides. Three to six trenches (about 1.83 m wide, 3.66 m deep, at least 183 m long) are dug in the ground: the trenches are 61 m distant from one another. Three transverse trenches are built between them and the salt basins on the plain ground among them. The water from the lake/pool then flows into the trenches and into the salt basins, which need to be shallow and with even bottoms. The basins are encircled by 30 cm high earthen embankments, constructed with the earth removed to build or clean the salt basins. The embankments have the function of retaining the water let into the basins. The trenches have openings (sluice gates) to introduce the water into the salt basins, which in their turn need sluice gates to move the concentrated brine from one basin to the following ones. The slight slope of the terrain assures the movement of water among the successive compartments.

The main sluice gate is located at the mouth of the coastal lake/pool, which contains seawater, together with rainwater and fresh water from possible nearby rivers and streams. When the main sluice gate opens, the water fills all the trenches. Next, the sluice gates of the first basins are opened and this same water from the first basins is first let into all successive basins to condense and incrust their bottoms, to create an impermeable layer that retains the brine, but it also prevents the mixing of brine with mud.[20]

Subsequently, the first evaporation basins are filled again with the same water from the nearest trench. In the first basins much of the liquid evaporates, leaving a condensed brine, which is then moved to the second basins, where the procedure is repeated. When the concentrated brine reaches the third basins, salt is ready to be gathered. This is done with wooden rakes and shovels that are used to throw the salt out of the basins. After the harvest of salt, the basins are again filled with seawater and the process starts over again.

After the saltpans, Agricola described the different methods and places where salt was obtained by boiling salty water or from rock salt (see Hoover, Hoover 1950: 546-558).

[20] In the saltpans of Piran, the microbial mat called "petola" is manually cultivated at the bottoms of the crystallization basins for the same purpose.

A—SEA. B—POOL. C—GATE. D—TRENCHES. E—SALT BASINS. F—RAKE.
G—SHOVEL.

Fig. 33 Saltpans in G. Agricola, De re metallica, *XII, 1556 (Hoover, Hoover 1950).*

2.3. Iconographic sources

Iconographic sources of fish and marine scenes are widespread in the *villae* and public buildings all over the Mediterranean, both on wall paintings and mosaics. Fish and other marine motifs appear on sculptures, sarcophagi reliefs, on ceramic, bronze and lead vessels, lamps, coins and other objects (EAA, LIMC). Among these sources salt is again almost invisible.

A scene depicted on the floor mosaic in the early Byzantine church of Saint George in Madaba, Jordan, shows two boats sailing on the Dead Sea. The boat on the left is loaded with what has been interpreted as a probable mound of salt (Avi-Yonah 1954: 38; Bergier 1982: 50). Ships transporting salt have only been mentioned generally by Plutarch (*Mor.* 685d; Bresson 2007: 184).

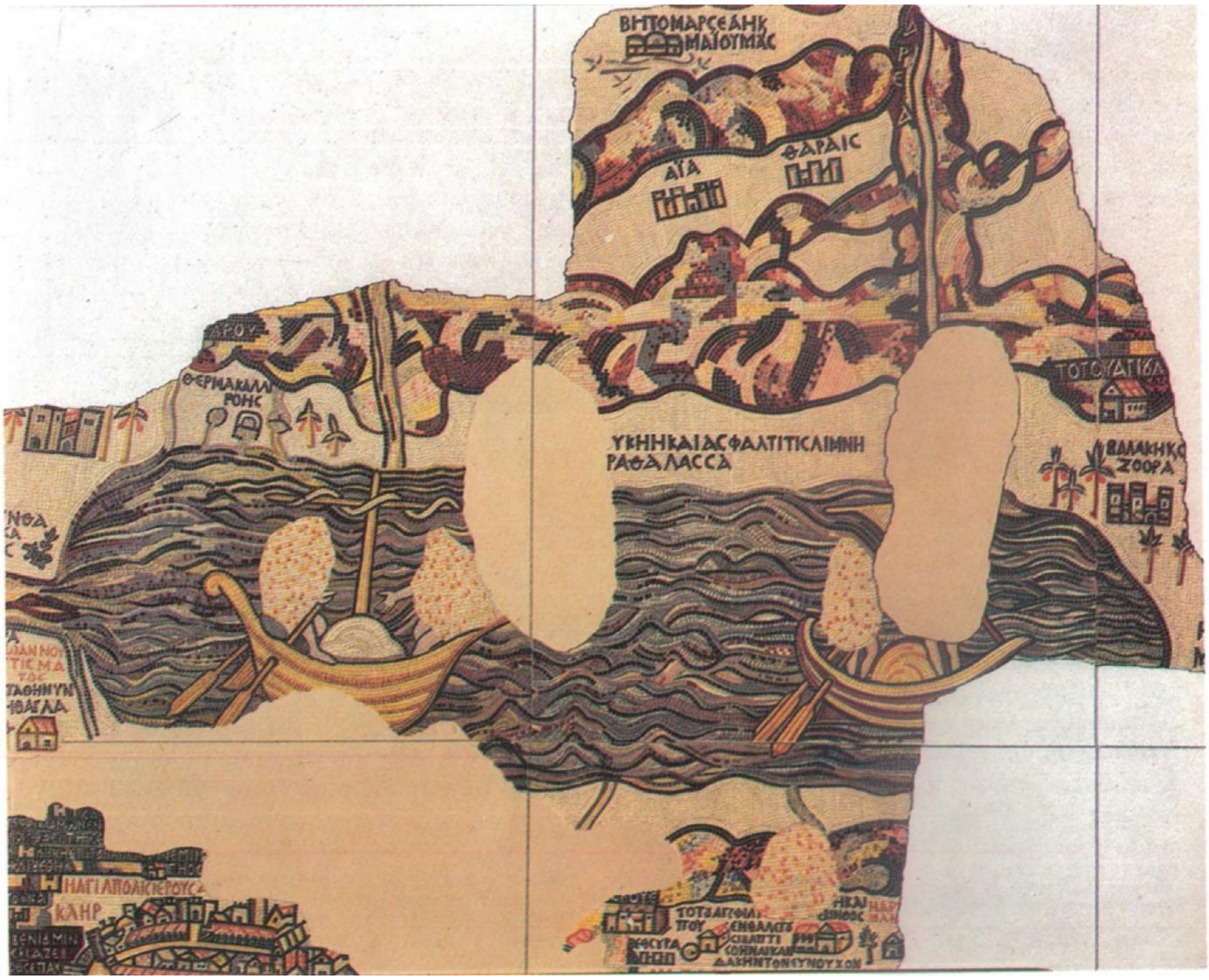


Fig. 34 Mosaic in Madaba probably representing a mound of salt on the boat on the left (Bergier 1982).

Saltpans are schematically drawn on the famous Tabula Peutingeriana, a 12/13th century copy of the Late Antique (around AD 350) *itinerarium pictum* or "illustrated road atlas" of the ancient world, the only one that has been preserved to present. It is depicted on a c. 740 x 34 cm large parchment strip, named after the humanist Konrad Peutinger from Augsburg (1465-1547), who died before seeing it published (see Magini 2003). The most widely accepted explanation is that the Tabula Peutingeriana represents the *cursus publicus* or the state administrated and supervised postal system of the Roman Empire (Levi, Levi 1967; Bosio 1985). The Tabula indicates two sites called *Salinas* (Seg. VI, 1: north of Pescara on the western Adriatic Sea – in between the present rivers of Saline and Pescara and Seg. II, 1: *Salinas Nubonenses/Tubonenses* in present Algeria), as well as two sites called *Salinis* (Seg. VI, 3: Salpi/Cerignola close to the saltpans of Margherita di Savoia and Seg. VIII, 2: the interior saltpans of Ocna Mureş in Romania). Additionally, two lakes where there were saltpans are schematically depicted on the map, accompanied by a short description. The first lake with saltpans is depicted in *Tripolitania*, east of *Leptis Magna*, with the note "*Saline immense quae cum luna crescunt et decrescunt*" (huge saltpans that increase and decrease with the moon, Seg. VII, 4), meaning that they have tides (Magini 2003: 10; see Schörle 2020: 345-346). The second lake "*lacus salinarum hic sal per se conficitur*" (saltpans' lake, here salt produces itself, Seg. IX, 4) is one of the lakes on the Taman Peninsula, in between the Azov and Black seas in Russia, close to the site of *Phamacorium/Phanagoria*.

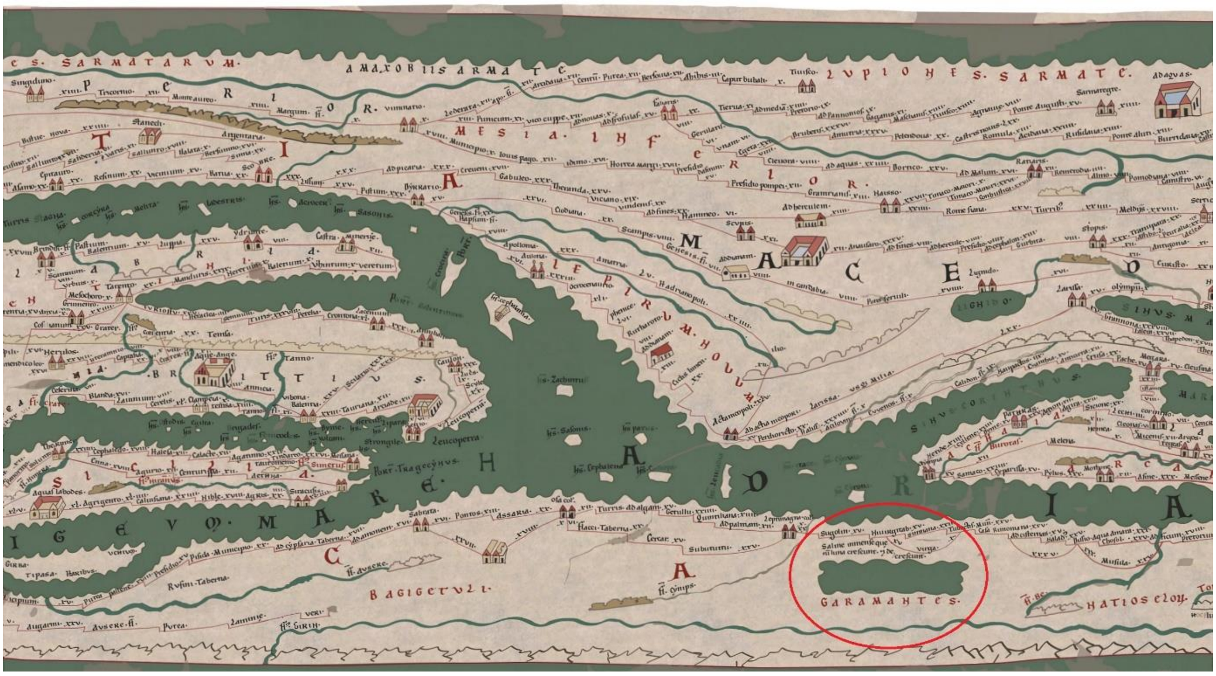


Fig. 35 TP, Weber, Seg. VII, 4 (https://www.tabula-peutingeriana.de).

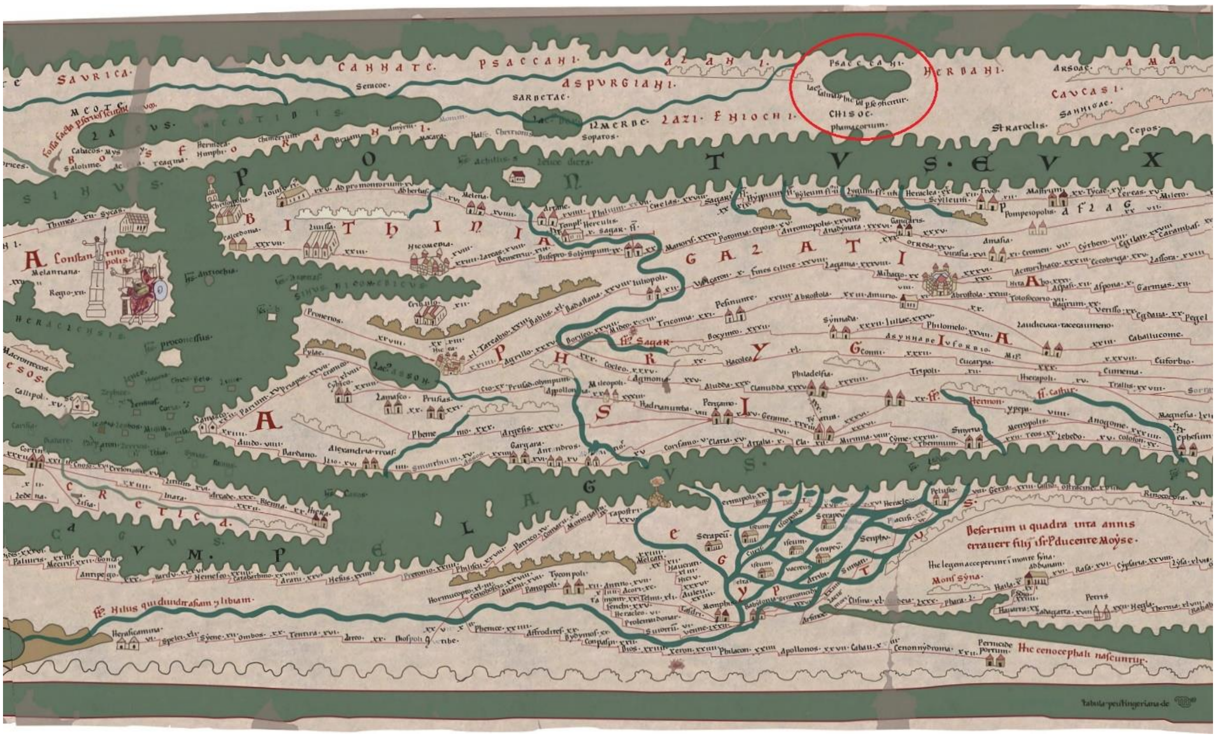


Fig. 36 TP, Weber, Seg. IX, 4 (https://www.tabula-peutingeriana.de).

Fig. 37 TP, Weber. Zoom on the saltpans on the two segments Seg. VII, 4 (a) and Seg. IX, 4 (b) (https://www.tabula-peutingeriana.de).

2.4. Epigraphic sources

There are several epigraphic sources about salt workers, merchants and other figures connected to salt exploitation in the Mediterranean and Europe in general, but they provide very fragmentary details, not allowing a more comprehensive understanding of the organization and management of salt sources.

In southern Sardinia, in Santu Iacci close to San Nicolò Gerrei, about 50 km from Cagliari, the known **trilingual inscription** in Latin, Greek and Punic (*CIL* I^2 2226; *IG* XIV 608; *CIS* I 143), found in 1861 and donated to the Regio Museo di Antichità di Torino (present Museo di antichità) mentions saltpans (Culasso Gastaldi 2000; Ghiotto 2008). The inscription was incised on a votive bronze column base for Aesculapius / Asclepius / Eshmun Merre and dedicated by Kleon, who thanked the god for the healing. In the Latin text, Kleon, of Greek origin, defines himself servant of salt contractors (Cleon salari(orum) soc(iorum) s(ervus)). In the Greek text, he describes himself as ὁ ἐπὶ τῶν ἁλῶν "the one in charge of the saltpans" (Carusi 2008: 127-128). In the Punic text, he is "the one of the contractors that (operate) on saltpans" (Culasso Gastaldi 2014). The inscription probably dates to the first half of the 1st century BC (see Carusi 2008: 128).

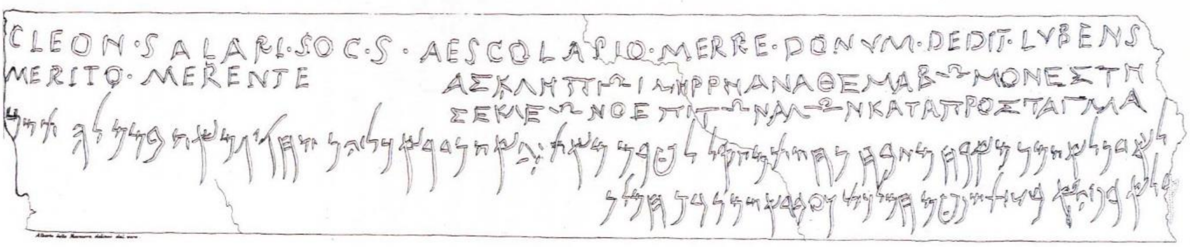


Fig. 38 Trilingual inscription from Sardinia (Culasso Gastaldi 2000: 13).

Four inscriptions from the area of *Minturnae* on the Tyrrhenian coast from the first half of the 1st century BC (*CIL* I^2 2691; *CIL* I^2 2693, 1.7; *CIL* I^2 2698; *CIL* I^2 2703) have been dedicated by slaves of a *societas salinatorum* (Johnson 1933). Their owners probably contracted the exploitation rights on public saltpans (Carusi 2008: 139).

South of the canalizations that can be attributed to the saltpans of Rome at the right bank of the Tiber, the *Campus Salinarum Romanarum* attested by ancient authors, a building with numerous rooms has been discovered. It probably englobed spaces for the storage of salt and/or for the salt workers. In one of the rooms, the epigraphical monument of L. Virtius Epaphroditus and L. Cornelius Hesper, *conductores campi salinarum romanarum* has been found, dedicated to Neptun and dated to AD 135 (Cébeillac-Gervasoni, Morelli 2014). The two men were probably both freedmen, who worked together on the saltpans. It has been supposed that the addition of *romanarum* was their will to emphasize that their function concerned the saltworks on the right bank of the Tiber, on the *ager publicus* of the city of Rome, and not the saltworks of the colony of Ostia, which were located on the left bank. *Conductor*, just like *manceps*, means farmer, the one who has a public contract with the state (see the discussion in Cébeillac-Gervasoni, Morelli 2014).

The inscription of a *salinator?* from *Dianum* (Punta de l'Arenal, *CIL* II 3599) has been found in the province of Alicante, Spain, near a tuna-fishing site and a fish-processing workshop (Fernández Nieto 2002). Another *salinator*, the *libertus* Lucius Salonius Hilarus, is mentioned on an inscription found in Peyrac-de-Mer close to Narbonne in southern France (*CIL* XII 5360), in a marshy area very suitable for salt production.

Ownership and management of saltpans

From the available sources it is not easy to understand the juridical context of the management of saltpans – it is complicated to distinguish between the public and private property and whether authorizations were needed to exploit the saltworks. In the Greek world, at least in two cases sanctuaries owned saltpans, which were located inside their possessions: it is the case of the Artemision of Ephesus and the sanctuary of Athena Polias in Priene (Carusi 2008: 81-85, 192-195, 232-233). The same situation can be postulated for other sanctuaries as well, but at the same time Carusi estimates that the lack of official documents of the *poleis* concerning salt exploitation indicates that the private initiative was prevailing in this economic branch.

In the Roman period, the largest and most important saltpans were probably entrusted to the *publicani*, managed by the *conductores salinarum*, who assembled in *corpora* and *societates*, who paid a fixed tax to the state. In some passages of Justinian's Digest (XXXIX, 4, 13; L, 16, 17, 1) saltpans are considered of public property, managed by the *societates publicanorum* (Guarnieri 2019: 18-19). Such *societates* appear on the described four inscriptions from

Minturnae and the trilingual inscription from Sardinia. Nevertheless, the words *societates* or *socii* do not always indicate state possessions, but also city-state and private ownerships, creating confusion (Marzano 2013: 138).

While epigraphic data over the ownership of coastal saltpans are incomplete and can lead to different interpretations, the inscriptions of *conductores pascui et salinarum* from the salt mines from *Dacia* indicate that inland salt sources were public, the same as mines (Mihailescu-Bîrliba 2016). It seems that in most cases marine saltpans were owned by the coastal settlements or private individuals (Carusi 2008: 252; Marzano 2013: 138-141).

Concerning the management of saltpans, during the Roman Republic and Empire, the ***salinatores aerari*** were the supervisors of the saltpans, which could have been **rented to the *conductores salinarum*** or ***salarii***. Two inscriptions from Flavian age found in Rimini mention *salinatores civitatis Menapiorum* (*CIL* XI 390) and *salinatores civitatis Morinorum* (*CIL* XI 391) from the province of *Gallia Belgica*. This means that the two *civitates* had probably leased their saltpans to the *salinatores* (Napoli 2007: 158-159).

An inscription from Ostia (*CIL* XIV 4285 = EDR106126) from the time of Septimius Severus was dedicated to the *Genio* ***saccariorum salarior(um)*** *totius urbis* and *camp(i) sal(inarum) Rom(anarum)*. These *saccarii* were most likely a *collegium* of sixteen members, supervised by imperial procurers, who protected the *aerarium* and guarded the *arca sal(inarum) Rom[anarum]*. They were in charge of the transport of salt on the Tiber until Rome and were maybe the successors of the earlier *conductores salinarum, salinatores* or *salarii*. In Late Antiquity the *saccarii* were called *mancipes salinarum* (*Cod. Iust*., IV, 61, 11; Zaninović 1991: 260-261).

Salt merchants

In 1970, the sanctuary of the Celtic goddess Nehalennia (whose name shares the common root with Greek ἅλς) was discovered off the coast of Colijnsplaat in Netherlands, on the territory of the Menapii in the province of *Gallia Belgica*. 130 altars were recovered, which various artisans and merchants trading between Brittany, northern Gaul and the Rhineland in the period between the end of the 1st to the middle of the 3rd centuries AD dedicated to the goddess who was born from the salt and the sea. She protected navigation and the cargos (Stuart, Bogaers 2001; Napoli

2007). Among them, there were four *negotiatores salarii* (AE 1973, 362; 364; 378; AE 2001, 1464 = AE 2003, +1228), as well as three *allecarii* (AE 1973, 365; 375; AE 2001, 1460 = AE 2003, +1228), the traders of *allec* or more generally fish sauces. All the inscriptions of the *negotiatores salarii* can be dated between the second half of the 2nd and the middle of the 3rd century AD.

Fig. 39 Altar dedicated to Nehalennia by M. Exingus Agricola (M. Grisonic).

One of them (AE 1973, 362, Fig. 39) was dedicated to Nehalennia by M. Exingus Agricola, a citizen of *Trever* (Trier), a salt merchant who willingly and rightly executed the wish of the goddess in *Colonia Claudia Ara Agrippinensium* (Cologne).

The altars of Nehalennia represent her sitting on the throne inside a temple, holding in her hands symbols of prosperity: in one hand a fruit basket and in the other hand wheat, vegetables or flowers. At her feet there are another fruit basket and a dog who protects her (Hoët-Van Cauwenberghe 2017).

The inscriptions of salt merchants are not very frequent. Only two of them were found in Rome: a 2nd century AD freedman who was *negotians salsarius* (*CIL* VI 9677) and another *salsarius* (*CIL* VI 1744a) from the 4th century AD (Tsigarida 2014).

T. 2 Inscriptions mentioned in the text				
Content	**Origin**	**Dating**	**Inscription number**	**References**
conductores campi salinarum romanarum	Ostia antica, Maccarese lagoon, *Regio I. Latium*	AD 135	AE 2014, 264 = EDCS-71200588	Cébeillac-Gervasoni, Morelli 2014
conductor pascui et salinarum	Mărişelu, *Dacia*	AD 107-250	AE 1930, 10; AE 1957, 273; AE 1967, 388 = HD014884	Mihailescu-Bîrliba 2016
conductor pascui et salinarum	*Micia* (present Veţel), *Dacia*	AD 151-200	CIL III 1363 = HD052485	Mihailescu-Bîrliba 2016
conductor pascui et salinarum	*Apulum* (present Alba Iulia), *Dacia*	AD 222-275	CIL III 1209 = HD038745	Mihailescu-Bîrliba 2016
conductor salinarum	close to *Micia* (present Veţel), *Dacia*	AD 101-200	AE 2005, 1296 = HD052485	Mihailescu-Bîrliba 2016
conductor salinarum	Mărtiniş, *Dacia*	AD 151-270	AE 1937, 141 = HD014884	Mihailescu-Bîrliba 2016
l(ocu)m(?) salinarum	Caralis (Cagliari), church of SS. Cosmas and Damian, *Sardinia*	AD 401-600 (EDR) / 6th century AD (Ghiotto 2008)	AE 1924, 122; AE 1982, 427 = EDR078720	all references in Ghiotto 2008: 85, n. 20
saccariorum salarior(um) campi salinarum romanarum	Ostia antica, Campo Saline, *Regio I. Latium*	AD 197-211	CIL XIV 4285; CIL XI 7725	see EDR106126
salariorum sociorum servus	Santu Iacci, *Sardinia*	1st century BC	CIL I^2 2226	Culasso Gastaldi 2000
Salin[ator? - - -]	S. Donà di Piave, *Regio X. Venetia et Histria*	100-51 BC (HD) / AD 1-50 (EDR)	AE 1985, 457 = HD003258 = EDR079853	Petraccia Lucernoni 1985

salinator?	*Dianum* (Punta de l'Arenal), *Hispania*	1st century AD	CIL II 3599	Fernández Nieto 2002
salinator	Peyrac-de-Mer, *Gallia Narbonensis*	27 BC-AD 14	CIL XII 5360 = EDCS-09302557	Carusi 2008: 124-125
salinatores civitatis Menapiorum (Gallia Belgica)	*Ariminum, Regio VIII. Aemilia*	AD 75-100	CIL XI 390 = EDR144693	Thoen 1975; Napoli 2007
salinatores civitatis Morinorum (Gallia Belgica)	*Ariminum, Regio VIII. Aemilia*	AD 75-100	CIL XI 391 = EDR144697	Thoen 1975; Napoli 2007
societas salinatorum	*Minturnae, Regio I. Latium*	first half of the 1st century BC	CIL I^2 2691	Johnson 1933
			CIL I^2 2693, 1.7	
			CIL I^2 2698	
			CIL I^2 2703	
(negotiator) salarius	Colijnsplaat (NL), *Gallia Belgica*	AD 151-250	AE 1973, 362	Stuart, Bogaers 2001
			AE 1973, 364	
			AE 1973, 378	
			AE 2001, 1464 = AE 2003, +1228	
(negotians) salsarius	Roma, *Regio I. Latium*	AD 151-200	CIL VI 9677	see EDCS-19301219
salsarius	Roma, *Regio I. Latium*	AD 358	CIL VI 1744 a = CIL VI 31916c	see EDCS-18100555

2.5. Archaeological documentation

In this catalogue I have included the Mediterranean sites that are certainly preserving the remains of ancient saltpans. I have excluded the sites, which García Vargas and Martínez Maganto (2017) have defined as presumable saltpans or "pseudo-salinas": Bas-Lauvert in Antibes (Daveau, Sivan 2010; Violino *et al*. 2013) and San Fernando in Cádiz (Alonso Villalobos *et al*. 2003). I have included in this catalogue the coastal production complex in Caunus in Anatolia, a possible salt production site, where the techniques to obtain salt surely differed from other known "classical" saltpan sites. Lastly, I have added the remains of saltworks of Elaia in Anatolia, several Roman and early medieval structures of possible saltpans from the Venetian lagoon and the recently published Roman saltpans of Cervia.

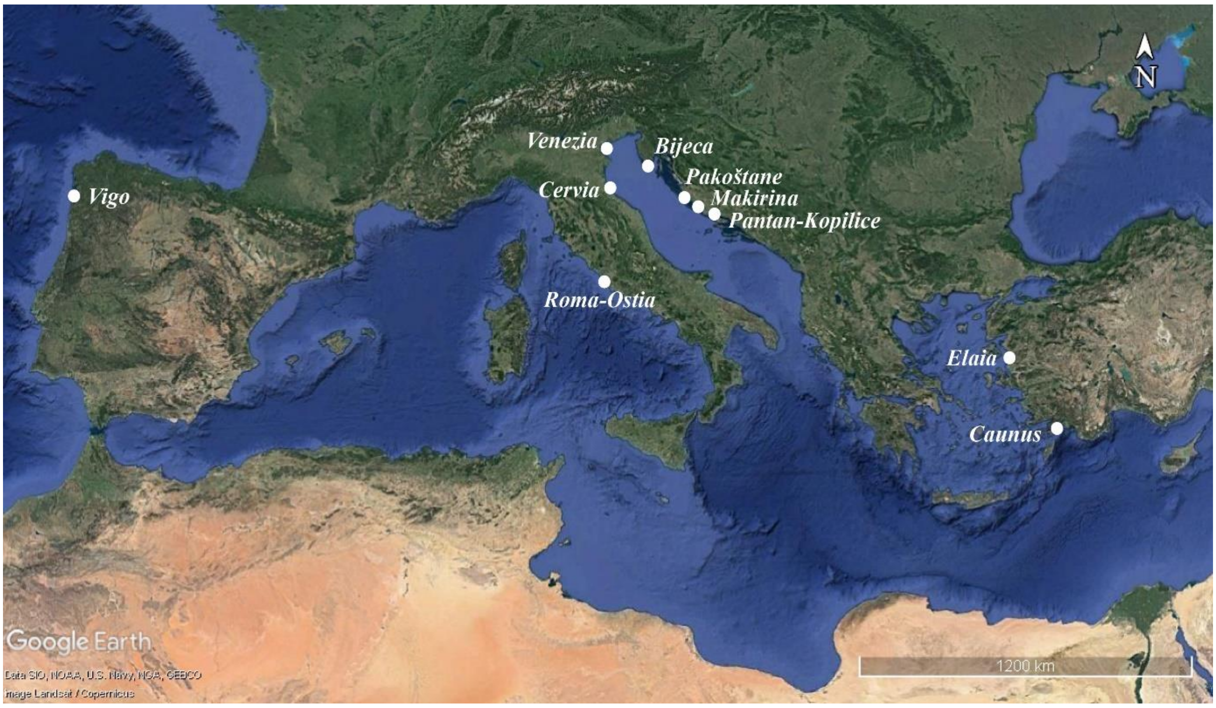


Fig. 40 Sites with material evidences of saltpans from Classical Antiquity. For additional evidences on the Iberian Atlantic coast see Currás 2017; Brochado et al*. 2022.*

Most sites of ancient saltpans across the Mediterranean have been discovered during rescue excavations. Only two sites, Caunus and Elaia in Turkey, have been investigated in the framework of a systematic research of the ancient cities and their surroundings. All sites but one (Caunus) have been recovered under alluvial sediments or reclaimed areas in nowadays heavily anthropized areas, which are located even several km from the present coastline. Among them, just the site of Caunus was discovered on the coast, while Elaia seems to be so far the only submerged Mediterranean saltpan site outside the Adriatic Sea known from published data. In most sites, traditional archaeological excavation has been complemented with aerial photography, LiDAR scanning, paleoecological and palynological research, as well as the xylological and dendrochronological analyses of wooden remains. Due to the loss of the functional height of the submerged parallel walls in Elaia Bay, ancient sea-level changes could not be studied in Elaia.

Attested sites of ancient coastal saltpans

- *Campus Salinarum Romanarum*

During preventive archaeological excavations at the right bank of the Tiber, close to its estuary in the former Maccarese lagoon, which was dried out at the beginning of the 20th century, an extensive complex of canalizations with the remains of a more than 1 km long dam made of 1439 amphorae (Dressel 6A, 6B, 20) and earth have been discovered. The function of the dam, nowadays located in the area of the Interporto Roma-Fiumicino, was to close the access to the lagoon. Two channels in masonry, provided each with two sluice gates, crossed the dam perpendicularly (Fig. 41): from them two long canalizations departed, dug in the earth. Inside the area protected by the dam, a system of canals was identified, which created large square plots of about 102-150 x 202-300 m that probably contained salt evaporation pools. On the southern side of these installations, a building dating

Fig. 41 Walled channel with two sluice gates in the Maccarese lagoon (Grossi et al. *2015: 95).*

from the 1st century BC to the end of the 2nd century AD, probably used as warehouse and strictly connected with the saltpans, has been unearthed. Inside the building the epigraphical monument of two *conductores campi salinarum romanarum* has been found, dedicated to Neptun and dated to AD 135 (Cébeillac-Gervasoni, Morelli 2014). All these remains can be identified with the saltpans of Rome at the right bank of the Tiber or the *Campus Salinarum Romanarum* known from the ancient sources, of which Rome appropriated after the victory over the Etruscan Veii in 396 BC (Morelli *et al*. 2004; Morelli, Forte 2014; Grossi *et al*. 2015). The archaeological data indicate that the channels were in use from the 2nd century BC until the end of the Roman imperial period, with frequent renovations and modifications. During the Middle Ages, some channels continued to be used, while others were modified, following less regular patterns.

Smaller salt evaporation and crystallization pools, which have been discovered in Vigo (see below) were not identified in the excavated part of the *Campus Salinarum Romanarum*. The excavators have postulated that the seawater, distributed through the artificial channels, flooded the vast orthogonal areas between them, where evaporation and crystallization took place (Morelli, Forte 2014).

- The saltpans of O Areal in Vigo (Galicia, Spain)

The finding of the Roman saltpans of O Areal (a toponym that means “sandy area/beach”, Currás 2017: 327), buried underneath the modern city of Vigo in Galicia, on the Spanish Atlantic coast, has shown that the technological process of obtaining salt through coastal saltpans was very similar to modern times (Carusi 2008: 34-38). The saltpans of Vigo are the best preserved of the Roman world. Nowadays they are located in an urbanized area of the city of Vigo, but originally they were built on the coastal plain behind the O Areal beach (Currás 2017: 327). The area was later filled with alluvial sediments.

The Roman saltpans of Vigo have been excavated during numerous rescue excavation campaigns in the years 1998-2000, 2007-2010 and 2016 (Castro Carrera 2006; 2007; 2008; Currás 2017; Iglesias Darriba *et al*. 2017; Tallón-Armada *et al*. 2018; Castro Carrera *et al*. 2019; 2022; Martín-Seijo 2019; Teira-Brión 2022). The most recent publications present a better-defined picture of the whole site. Parts of the saltpans are preserved in situ in the museum

Salinae, Centro Arqueolóxico do Areal, which was built in 2009 and is part of the Museo do Mar de Galicia.

Two different areas, probably of the same complex of saltpans, which was spreading along the coast of O Areal, have been excavated: an eastern sector and a western sector. The estimated total surface of the saltpans must have been roughly 8.5 ha. The researches presume that the saltpans had a connection with the close by fish-salting factories in the street of Marqués de Valladares and the Plaza de Compostela in Vigo, located west of the saltpans and implanted between the 1st and 2nd century AD (see Currás 2017: 328, fig. 2).

The saltpans consist of successions of parallel rectangular evaporation ponds of various dimensions, showing what Rutilius Namatianus meant with manyparted ponds (*multifidi lacus*) (*De reditu suo*, 475-490). They are oriented E-W and follow the ancient coastline. The ponds are paved with compacted clay, some of them have a pavement in gravel. The ponds are delimited with vertically driven schist and granite slabs, reinforced by a coat of clay, which is 10 cm thick. The stones are about 10 cm higher than the revetment of clay (Castro Carrera 2006; Currás 2017).

Fig. 42 W sector of the saltpans of O Areal: the crystallization basins (Castro Carrera 2006).

Only in the western sector fifteen basins of smaller dimensions interpreted as crystallization pools have been discovered: they measure 5 x 2.5 m and are paved with carefully laid flat slabs covered with a thin layer of clay (Fig. 42). The basins are surrounded with slabs that are about 10 cm high. The evaporation ponds were larger basins of 10 x 5 m that also had bigger edging stones, having a height of 15 to 25 cm. Six such ponds have been discovered. In the eastern sector twelve square basins were identified, with sides measuring 8 m and the delimiting stones being 20 to 30 cm high. Immediately south, a larger pond with a different orientation has been partially excavated. In the same sector there were at least three other ponds measuring 15 x 8 m and an even bigger one (20 x 10? m) that was located west of the canal. These larger ponds, the closest ones to the sea, were delimited by vertically driven slabs about 80 cm high, leaning on an earthen wall, which differentiates them from the rest of the pools, where the enclosure was made with simple slabs stuck in the ground.

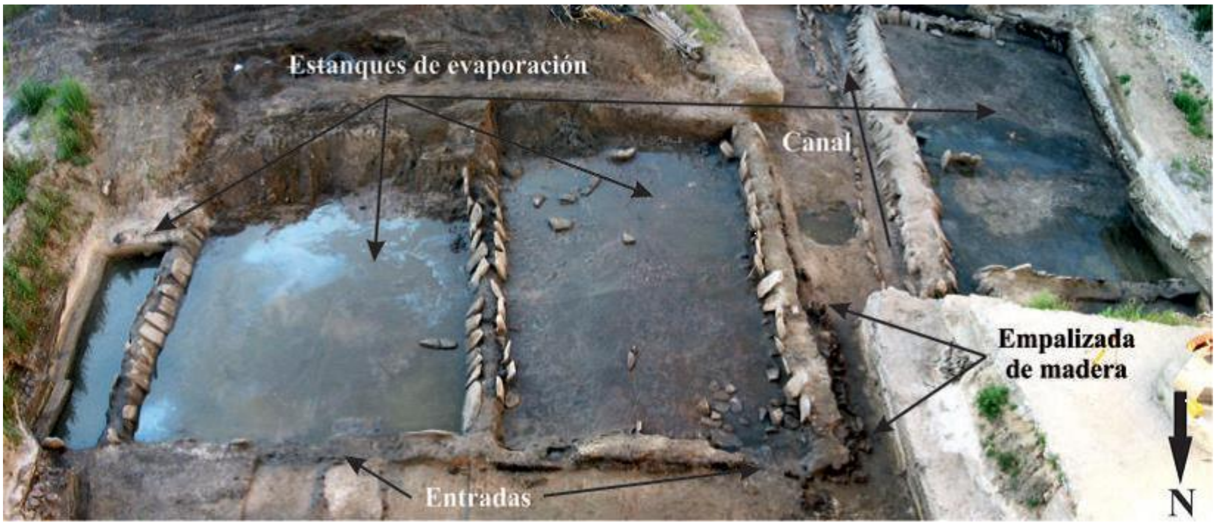


Fig. 43 Remains of evaporation basins, the wooden palisade and the canal in the eastern sector of the saltpans in Vigo (Castro Carrera et al*. 2019).*

In the western sector, immediately west of the crystallization basins, about 10 m of a channel dug in the sediment edged with two rows of big aligned stones (more than 1 m high) have been unearthed. In the eastern sector another channel has been dug: it was built with big stone slabs and wooden poles (Fig. 43). In both canals, which are orientated N-S, openings have not been found and it seems that they were rather used for draining rainwater far from the saltpans than bringing seawater into them (see Currás 2017: 341). Clear sluice gates have not been found in O Areal (Currás 2017), but some evaporation basins on the eastern sector have openings (Fig. 43). According to Currás, the same system found in the saltpans at the estuary of the Tiber can be postulated in O Areal: in the Maccarese lagoon the water was let into two canals built in masonry. Their edges were funnel-shaped, which permitted a better flow of water inside the saltpans during high tides. The access of water was regulated with sluice gates. He supposes that similar structures and a big embankment, which separated the sea from the saltpans, existed in the area north of the saltpans of O Areal, which has not yet been excavated.

Surprisingly, although at least two concentration and one crystallization stages can be postulated, in the saltpans of O Areal no connections among the different salt pools have been found, therefore it is not clear how the brine was moved from one compartment to another. In addition, the peculiarity of the salt pools of Vigo is that their depths do not progressively diminish: the smallest basins (the crystallization basins) are located at the highest ground, while normally they should be implanted at the lowest level, to allow the brine to flow into them by gravity, after it had passed all previous evaporation stages. The difference in height between successive basins can vary from 20 to 50 cm! When the slope of the terrain did not allow the flow of seawater to successive salt pools by gravity, as in the saltpans of O Areal, different water-lifting devices, an example of which is the *tympanum* mentioned by Vitruvius (*De arch*., X, 4, 1-2), could have been used to move water among the different compartments of the saltpans. The exact functioning of the saltpans of Vigo remains unclear, it seems that water was moved to different basins with different concentration phases but in a lengthy and discontinued way (Currás 2017: 342), maybe even manually with shovels, as attested in the 19th century saltpans of Pag (see Ch. 3.4).

The fact that the saltpans needed constant maintenance has been documented in Vigo: a series of overlapping pavements have been found (Currás 2017: 340). Also, the dimensions and numbers of basins were not static, but slightly changed over time.

The saltpans of Vigo can be dated from the middle of the 1st century AD to the 3rd and 4th centuries AD and were dedicated to large-scale salt production (Castro Carrera 2006; Currás 2017: 333). They were constructed in the same period when the fish-salting industry was spreading in *Lusitania*. They were probably abandoned because of the progressive sedimentation of the area that was turned into a necropolis in the 3rd and 4th centuries AD.

- Caunus

Caunus/Kaunos was a city in *Caria*, Anatolia, which was known for the production of salt used to cure eye diseases (Plin., *Nat. Hist*., XXXI, 99). An important inscription (*I.Kaunos* 35) from the customs office of Caunus, which says that the taxes obtained from salt should remain at the same rate, furthermore testimonies that in the period of Emperor Hadrian the city contracted saltpans of municipal property through its own "department for salt", defined as ἁλικὴ ὠνή. Given that his term is known only in Egypt, it might provide a clue that during the 3rd century BC Kaunos was included in the dominion of the Ptolemaic dynasty (see Carusi 2008: 85, 237-239).

In 2005 on the beach of Iztuzu Bay (Dalyan, Muğla Province, Turkey), few km south of ancient Caunus, 48 circular vats and four rectangular canals in masonry have been found, inserted in a rectangular plan of about 35 x 50 m (Fig. 36). They have been interpreted as remains of ancient saltpans, possibly constructed in the 1st century BC next to a coastal lake. Preliminary data of the excavation (Atik 2008) has been followed by a more detailed publication (Işik, Atik Korkmaz 2012). The complex has been furtherly discussed by Marzano (2013: 126-128), Moinier & Weller (2015: 121-122) and García Vargas & Martínez Maganto (2017).

Fig. 44 Saltpans in Caunus (photo of Cengiz Işik, from Işik, Atik Korkmaz 2012).

The productive complex is composed of 48 circular vats, having a diameter of about 4.3 m and a depth of 14-18 cm, with a 10-13 cm thick edges in *opus caementicium*, paved with a 5 cm thick plaster coated with a layer of cocciopesto (Işik, Atik Korkmaz 2012: 98). The vats are inserted into a rectangular plan: at both short sides there are six vats in a row, while the internal space is divided in three lots of twelve vats (two rows of six vats) each. The three central lots (of about 9.9 x 28.5-31.5 m) are delimited at both long sides with a rectangular channel (28.5-32 x 1.5-2.4 m, 0.4 m deep), so that there are four channels in total. The channels and the circular vats are built in masonry with rows of irregularly-cut calcareous stones bound by mortar. They all have concave profiles. The northern sides of the canals are rounded, while the southern (towards the sea) sides of all canals but of the third one were closed with transversal walls in *opus caementicium*. The channels are paved with smaller irregular rocks and mortar. At least one channel was internally divided with a transversal wall, creating an about 10 x 2 m rectangular basin towards the seaside. The distance among the vats and between them and the channels is 0.5 m. Apparently there is no connection between the channels and the vats and among the vats themselves. It has been supposed that the vats were filled manually. The different plasters covering the vats suggest that they have been in use during different chronological phases (Atik 2008: 43-44).

Marzano (2013) assumes that the initial evaporation took place in the long deeper channels and from there it was transferred to the circular pools, where the impurities were progressively eliminated and salt crystallized. Another hypothesis is that during the winter season the coastal lake flooded the vats and canals, where seawater remained trapped and evaporated in the summer, leaving crytallized salt (García Vargas, Martínez Maganto 2017). In this way, however, way too small amounts of salt would be produced to justify the construction of a similar structure in masonry.

The saltpans of Caunus are unique in the ancient world. They greatly differ from all known solar evaporation saltworks. As García Vargas & Martínez Maganto have pointed out, the evaporation pools are rounded instead of being rectangular, the channels are not connected with the pools, neither are the pools connected among them, there are no visible sluice gates. Another not common element to solar evaporation saltpans is that the whole complex is built in masonry, all the basins have hard waterproof linings and all the basins and channels have a concave profile, which means that the water/brine stagnated in the central parts, when at the edges of the pools it evaporated faster. This does not seem an efficient system for the crystallization of salt, nor for the concentration of brine, which need uniform flat-bottomed surfaces for the water to evaporate evenly under the action of the sun and winds. The concave bottom makes sense if the liquid contained inside the basins needed to stagnate on purpose to be more easily collected manually and transferred to other vats.

Because of all this, the question arises spontaneously: did this productive complex really serve for salt production? If so, was it then so different from other saltpans because of the special nature of the salt of Caunus, which was so renowned in Roman times? Did they inherit a different tradition of salt-making, a tradition that maybe goes back to the Ptolemaic dynasty, which, as observed by Carusi, possibly dominated Caunus in the 3rd century BC?

A remarkable ethnographic parallel of the saltpans of Caunus are the round and shallow solar evaporation ponds in the Lagunas de Chacahua, on the Pacific coast of the Mexican state of Oaxaca (Fig. 37), where salt is obtained by leaching salty coastal earth (Williams 2015: 36, 74-75, 184). The salty soil, usually an aquifer located at low points in the landscape, is first filtered with water in a flat filtering basin (1 x 1.6 m, 0.7 m deep), where brine is obtained, separated

Fig. 45 Salt making in Chacahua, western Mexico: the well (foreground), the filtering device, round solar evaporation salt pools and mounds of leached earth (at the sides) (photo of David Grove, from Williams 2015).

from the soil. The brine is then transferred to the round pans, divided in several sectors of two successive rows, where it concentrates and evaporates with the heat of the sun.

If the comparison with Caunus and the Lagunas de Chacahua is right, we can presume that the productive complex in Caunus produced salt by leaching salty sand, a technique attested also in the Mediterranean (for instance, in the protohistoric site of Puntone in Tuscany, see Sevink *et al*. 2021) and possibly on the Atlantic coast of Morocco during the Roman imperial period (see Hesnard 1998), but instead of the artificial heating of brine washed from earth, in Caunus the brine, purified from the soil, was probably transferred into the rounded evaporation pools, where it evaporated thanks to the action of the sun and the winds.

- *Elaia*

In front of a salt marsh in Elaia Bay in western Anatolia, approximately 1 km south of the ancient harbor basin of Elaia, the harbor of Pergamum, there are six parallel submerged walls, located at 1 m depth, covering an area of c. 1150 x 265 m^2. They are 80 to 265 m long and 1 m wide, rising few decimeters above the sandy seabed (see Ch. 4.1.1). The building technique of the walls constitutes of two parallel rows of ashlars and quarry stones, with the inner core filled with smaller stones and debris. The ashlars have dowel holes, indicating that they are reused *spolia*. These walls have no solid foundations and most of them date between the 4^{th} and 6^{th} centuries AD, with possible later reuses. They were interpreted as walls of ancient saltpans, built, as observed by the authors, in a fast and economic way, without foundations, reusing available blocks from demolished city buildings (Seeliger *et al*. 2014: 151-152). Most of the submerged walls in Elaia were demolished because of anthropic or natural causes and therefore their functional height (useful for the reconstruction of ancient sea levels) remains unknown (Seeliger *et al*. 2014).

- *Venetian lagoon*

Five sites with remains of embankments, probably of saltpans or salt fields (fondamenti salinari – independent units of salt production) from the Roman and early medieval periods have been found in the northern part of the Venetian lagoon (Canal 2013). The first three sites are located in the city center of Venice and the other two have been discovered in the part of the lagoon north of the city, between Altino and Venice. These sites, excavated mainly during rescue excavations and not exhaustively published, are unknown to the majority of scholars who are studying ancient salt production.

The most interesting remains were found in the area of the S. Giovanni Crisostomo (Malibran) theater in 1998 (excavations directed by R. Cester). Embankments constructed with horizontally placed trunks and others with a succession of vertically driven poles, placed at a short distance one from each other, have been interpreted as dykes of saltpans. In addition, an inclined structure built with interwoven fagots and twigs was detected. It is probably the *scamnum* known from medieval documents, a slide for the boats that also created an elevated area above the tide level for the storage (salario) and the house of the salt worker and/or owner (domenicale). Radiocarbon dating, calibrated with dendrochronological curves, has dated this structure in the period of AD 360-400. The artifacts recovered from the site date from the 2nd century AD to the Middle Ages (Canal 2013: 204, site 81.22; 207-208).

Fig. 46 Embankment of presumed saltpans under Teatro Maliban in Venice (Canal 2013: 208).

Another site with similar wooden structures was discovered in 1999 in Fondamenta Toffetti, Dorsoduro, in the garden in front of the Renier school, under the direction of R. Cester. The recovered archaeological materials date from the 3rd to the 8th centuries, while the radiocarbon analysis of wooden elements has dated the shallowest of them to the 7th/8th centuries and the deeper ones to the 3rd/4th centuries (Canal 2013: 204, site 81.18; 207).

In 2002 the site in Borgoloco Pompeo Molmenti - S. Maria Formosa, not far from the site n. 81.22, restituted two parallel wooden embankments, at a 1 m distance one from another. The southern one, about 1 m wide, constituted of vertically driven poles at both sides and the inner part filled with mud. The northern embankment was made with a

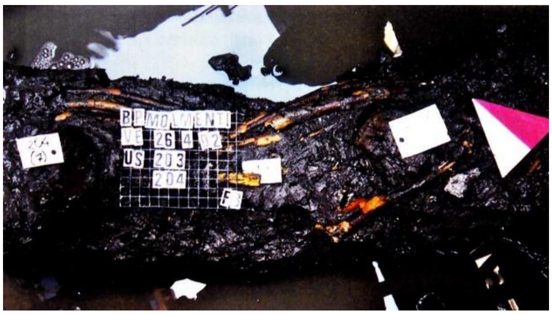


Fig. 47 Another embankment of presumed saltpans found in Venice (Canal 2013: 211).

single row of vertically driven poles that sustained intertwined branches. These structures should probably date before the rise of the mean sea level that occurred in the 9th/10th century (Canal 2013: 204, site 81.27; 211).

In 1975 remains of saltpans were found in Burano da Terra, in the marshes in between the islets of S. Francesco del Deserto and S. Erasmo. A wooden element from the foundations of the structures was dated with radiocarbon and calibrated with dendrochronological curves to AD 650-800. A document from 1043 (Codice Diplomatico Veneziano, Rialto n. 74) testifies that in this area there was a salt field called *Arcones* or *Vetere*, built at the end of the 8th or at the beginning of the 9th century. Firstly owned by the Duchy, it then passed to the church of S. Maria di Murano and it was rebuilt at the end of the 10th century (Canal 2013: 268, site 116.74-75; 286-287).

In 1991 excavations have been conducted in the central-southern part of La Cura Island (under the direction of G. L. Ravagnan). A U-shaped wooden structure was unearthed. Its eastern dyke was built with vertically driven poles and intertwined branches. On its upper part a bone comb with studs was found, probably from the Longobard period. The northern part of the U-structure constituted of three massive poles vertically driven in the ground and one placed horizontally: above them there was a mat made of intertwined marsh reeds. At the southern side of the structure two big poles were found. The mud from the internal part of the structure contained carbonized branches and foraminifera, among which there were *Trochammina Inflata* and *Ammonia Tepida*, which show that the structure was located in brackish waters at the intertidal level. Two poles of the structure, which has been interpreted as a saltpan or a fishpond, have been dated with radiocarbon and calibrated with dendrochronological curves to AD 680-870 and AD 695-935 (Canal 2013: 347, site 134.12; 349).

All the described sites from the Venetian lagoon show few common characteristics: the presence of embankments made with one or two rows of vertically driven poles, possibly reinforced with horizontal wooden elements, holding together or surmounted with intertwined twigs, branches and marsh reeds. Radiocarbon analyses of wooden poles and planks from these sites show the continuation of use of several same locations in the timespan from the 3rd to the 10th centuries, probably for salt production and/or fishing activities.

- Cervia

Cervia, in the province of Ravenna in the region of Emilia-Romagna, and Margherita di Savoia, in the province of Barletta-Andria-Trani in Apulia are the only remaining and among the most important historical saltpans on the western Adriatic coast. Archival documents attest the presence of saltpans in Cervia from the 10th century (Candida 1951). The existence of more ancient saltworks in Cervia was only a supposition until 2014, when the wooden remains of Roman saltpans were discovered, during road construction works of the roundabout on the Romea state road. Rescue excavations, completed by very detailed paleoenvironmental, geopedological, archaeobotanical, archaeozoological and anthropological studies, have determined that the beginning of salt production in Cervia started at least a thousand years before it was previously known (Guarnieri 2019; Guarnieri *et al*. 2021).

The Roman saltpans were implanted on a small coastal lagoon. Due to the alluvial sediments of nearby rivers, coastal progradation has occurred and the coastline has been pushed 1.2 km towards east from the Roman period. The excavated area of the saltpans consists of shallow rectangular basins paved with clay and channels dug in the earth: three of them brought water from the coast that was located on the east. Other channels were most likely moving the brine in different compartments of the saltpans. Three movable sluice gates and the connected containment structures were found (Guarnieri 2019: 118, figs. 19-20): they were built in wood, in some cases reusing wooden elements of boats, both sewn and mortise-and-tenon built (Beltrame 2019). One sluice gate (structure 1, Fig. 48) was built with two bigger poles vertically inserted in the ground, provided with mortise-tenon joints, holding in place a beam with a groove, designed for the movable gate. The sides of the sluice gate were partially built with reused elements of a sewn boat, which has been dated with radiocarbon to the 4th/3rd centuries BC! The area in front of the gate was paved with two *tegulae* put one next to the other, to create a solid ground for the operations of opening and closing of the gate (Guarnieri 2019: 117; Caporali 2019: 135-142).

The wood for the elements recovered on the saltpans was taken from the surrounding coastal woods, including mainly oak and elm. The poles were of ash, while poplar was used for smaller poles and planks. Pollen and archaeozoological analyses of the samples taken in the excavated area of the saltpans have determined the presence of brackish species (see Guarnieri 2019).

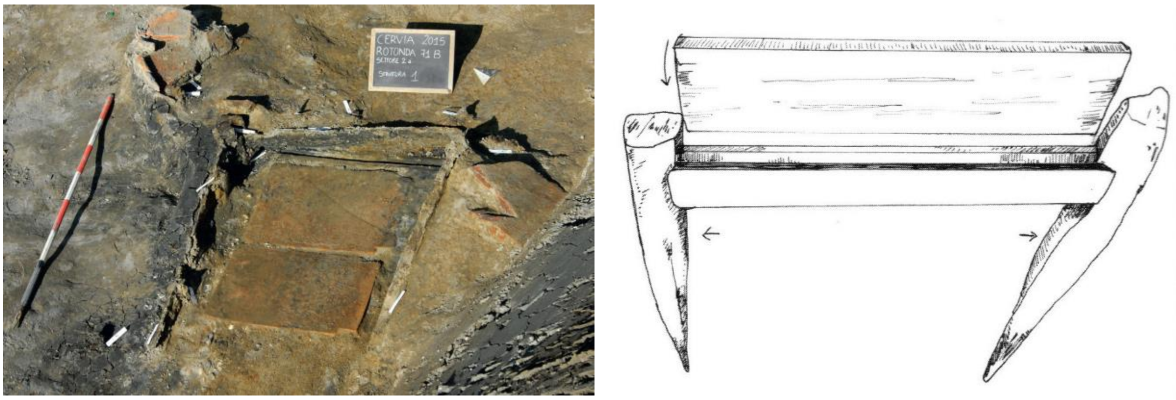


Fig. 48 Roman saltpans of Cervia, structure 1. Photo (Guarnieri et al*. 2021: 50, fig. 8) and reconstruction drawing (Caporali 2019: 137, fig. 10).*

The excavations have brought to light only one part of what were probably much larger saltpans. Three or four different chronological phases have been detected on the excavated part, together with several maintenance or rearrangement works. The period when the saltpans were in use ranges from the end of the 3rd (?) century BC to the middle of the 1st century AD, when some tombs appear in one area of the saltpans (Guarnieri 2019: 125-127). According to the archaeologists, the origin of the saltpans of Cervia should be linked with the foundation of the colony of *Ariminum* (present Rimini) in 268 BC and the beginning of the Roman expansion in the Po Valley, with the construction of the *via Aemilia* (187 BC) and *Popilia* (132 BC). Interesting for the comparison with the saltpans of Ston in Dalmatia (see Ch. 3.7.1) is that some alignments inside the excavated part of the Roman saltpans of Cervia (an internal path and some drainage channels) follow the same NW-SE direction of the centuriation grid of the surrounding countryside. In addition, some canals of the modern saltpans in Cervia maintained the directions of the axes of centuriation (Guarnieri 2019: 20-22; Guarnieri *et al*. 2021: 48).

2.6. Salt trade in Classical Antiquity in the Mediterranean and in the Eastern Adriatic: a summary

Salt constituted one of the main trade and exchange goods in history. Nevertheless, in Classical Antiquity salt was not one of the main trading goods like in the medieval and modern periods, when it was a state's monopoly, favored by the political fragmentation. We can suppose that most ancient towns/villages/villas produced their own salt for their needs. For this reason salt production and trade is not very present in ancient literary sources, if we compare it for example with the state-run grain trade (Carusi 2008; 2018).

Literary sources indicate that in Classical Antiquity saltpans were widespread throughout the antique Mediterranean. Saltpans produce big surpluses of salt, making this resource naturally eligible for trade. Salt was a bulky and heavy product that could be produced almost everywhere in the Mediterranean (Carusi 2008: 248-250; 2018; Marzano 2013: 125; García Vargas, Martínez Maganto 2017). It was usually traded over short distances by sea or river, which seems to have continued in the Early Bizantine Empire (Adshead 1992: 65). It was therefore a rather cheap product. Only specific kinds of salts that were famous for their use in medicine (salt of Caunus, Tatta, Tarentum and others) were considered luxury products and were possibly traded over longer distances.

The cost of salt increased when it was traded with the tribes from the interior of the continent. It is not a case that the few ancient literary mentions of salt trade regard exactly these situations (see Ch. 3.3). "Željan kruha kao vlah soli. (Eager of bread like Vlach is eager of salt.)" is an expression from the Croatian coast, referring to the populations from the hinterland (Zaninović 1991: 257).

On the eastern Adriatic coast, salt was imported from the sea to the interior of Bosnia following the Neretva water route (the Drijeva-later Gabela market close to Metković), on the Bojana/Buna River (Sveti Srđ/San Sergio) at the present Montenegrin-Albanian frontier, in Albania through the Drin River, as well as on other mule trails that crossed the mountain passages over Dubrovnik and Kotor (Adshead 1992: 91; Peričić 2005: 155). This trade is documented from the Middle Ages, but probably has continued along the same paths since Prehistory.

Neretva River (Gr. *Naron*, Lat. *Naro*) constituted a very important route, which connected the central eastern Adriatic coast and its islands with Bosnia and other areas in the interior of the Balkan Peninsula (Wilkes 1969: 245-252; Rapanić 1980), as it is shown by the underwater archaeological investigations in the river (Manenica 2012; Taras 2021). *Narona* was located by the delta of the river (Cambi 1980; Marin 1999; Gros *et al*. 2015). It was a Greek *emporion*, attested in the 4th century BC by Pseudo-Scylax (24) and Theopompus (Strab., VII, 317). Archaeological excavations have confirmed the presence of the *emporion* at the site of the Roman colony of *Narona*, founded in the final decades of the 1st century BC (Marin 2003). Before the establishment of the colony, it constituted a base for Roman troops for the wars against the Delmatae, which brought numerous Italic immigrants to the city. In the mid-1st century BC, it was a *conventus civium Romanorum*, the administrative and jurisdictional center of the region (Wilkes 1969: 156). *Narona* kept its importance also in the 6th century, becoming an episcopal see.

Trade and exchange routes between the sea and the internal part of the Balkans were crossing also in Obrovac, the port on the Zrmanja River in the NE part of the present Zadar County, where in the Middle Ages and the Modern period salt from Pag was exchanged for wheat and other goods from Bosnia (Peričić 2001: 75). Close to the river harbor, there was a Liburnian settlement and later the Roman *Corinium.*

Salt production and trade were directly connected with the needs of fishing and the preservation of its surplus. Fish is extremely perishable and needs to be salted soon after it has been caught. At the same time, big quantities of salt were needed for the production of fish sauces, which can leave important archaeological remains. The salting operations took place in the *cetariae* or fish processing workshops, which were provided with typical fish tanks and annexed structures coated with waterproof mortar (Ponsich, Tarradell 1965; Lagóstena *et al*. 2007; Botte 2009; Marzano 2013; Botte, Leitch 2014; Trakadas 2015). The quantities of salt needed for fish salting are debated, depending on the final products and regional differences (Schörle 2020: 343), but generally the estimated quantity of salt needed for fish salting was equal or at least half the weight of the product (see Felici 2018: 138). Salted fish and fish sauces were among the most consumed and traded products of the Classical world. They were much more profitable and easily transportable than the bulky salt, although this in some cases (for specific renowned types of salt, which were more lucrative) probably followed the same trading routes (Carusi 2008: 250). Fish sauces were transported in distinct types of amphorae specifically designed for the purpose, sometimes provided with stamps and *tituli picti* indicating their content and origin (Botte 2009; Carre *et al*. 2009; Pesavento Mattioli, Carre 2009).

During the Middle Ages, salt acquired considerable value and started to be traded over longer distances. Bulky commodities like salt and grain were used as ballast on the ships' return journey (Hocquet 1978), and "competed for the same cargo space" (Adshead 1992: 101). We can suppose that this was taking place also in earlier periods. When saltpans were located next to bigger harbors salt might had been used as ballast on ships, with the advantage of having embarked a foodstuff that had an economic value (Schörle 2020: 339-340).

Summarizing, we cannot speak about a state's monopoly for the exploitation and trade of salt in the Classical world, with the exemption of few cases and in defined historical periods (it is the case of Rome and Byzantium, where salt carried a very important role in local economy). Ancient sources, which barely mention taxes on salt, speak in favor of this statement. A big role in salt production and trade in Classical Antiquity must have had the private initiative (Carusi 2008; 2018).

We can suppose that like in later historical periods, in Classical Antiquity salt was probably directly embarked on ships and then packed in bags, which can leave some traces in the archaeological record only in exceptional cases. Amphorae and wooden barrels, which have been suggested among the possible salt containers (Suić 1974: 60), certainly did not provide suitable packaging options for this type of product.

3.

SALT PRODUCTION IN CLASSICAL ANTIQUITY IN THE EASTERN ADRIATIC

The entire eastern Adriatic coast from the Istrian Peninsula to the northwest and the Karaburun Peninsula to the southeast is very suitable for salt production. Salt trade represented one of the main economic branches of this region in all historical periods, until the beginning of the Modern period. This chapter presents the synthesis of the available information on salt production on the eastern Adriatic coast in Classical Antiquity, comprising the Istrian Peninsula, most of which was part of the *Regio X. Venetia et Histria*, and the northern coastline of the Roman province of *Dalmatia*. At the present state of research, there are no data that can be linked with possible salt production in the Greek *poleis* and *emporia* in the southern part of the region in the Hellenistic period. The correlation of existing data sets is integrated by examples of active fieldwork, carried out to identify archaeological remains of saltpans along the coast, both under and above water. The Croatian coast still preserves many remains of historical saltpans. Multiple factors have contributed to this survival, including the still low rate of anthropization of large parts of the coast, especially in the Dalmatian region, the lack of big industries, the relatively small sea level fluctuations, and the absence of big rivers, which in other parts of Europe substantially changed the environment. This makes the Croatian shore an exceptional location for studying the history of salt production in the Mediterranean.

The presence of numerous protected shallow bays, as well as the high insolation and relatively low precipitation rates, the high percent of salinity in the sea and frequent winds, all contributed to the development of saltpans (Grisonic 2022). Most saltpans on the Croatian shore were arranged in these small, shallow, flat coves and lagoons, close to Mediterranean marshes and streams of mostly seasonal character. At the bottom of these calm and shallow pools, the sediments brought in by fresh water and the sea mixed, forming compact waterproof loamy and clay sediments (Koludrović, Franić 1954: 28-31) and Peloid mud[21] (Vujčić-Karlo 2012). These deposits became the raw materials needed to construct the salt basins and the embankments of the saltworks. As even today Peloid mud is considered to have healing properties, a number of

[21] 'Peloid is a maturated mud or muddy dispersion with healing and/or cosmetic properties, composed of a complex mixture of fine-grained natural materials of geologic and/or biologic origins, mineral water or sea water, and commonly organic compounds from biological metabolic activity' (Gomes *et al.* 2013).

these locations are still attended by people, searching for a natural remedy to cure skin, rheumatic and other diseases (Grisonic 2022). Since the relative sea level in this part of the Adriatic has risen over the past 2,000 years, most remains of Roman coastal structures, including saltpans, are nowadays partially submerged. The saltpans from Classical Antiquity on the northeastern Adriatic coast are located at approximately 1 to 1.5 m depth below relative sea level (Faivre *et al.* 2010).

The three main Croatian saltpans that are still active today – the saltpans at Pag on the homonymous island, the nearby mainland saltpans of Nin close to the city of Zadar and the saltworks of Ston close to Dubrovnik in southern Croatia – are all situated on broad exploitable terrain. Although the oldest mentions of their existence date back only to the Middle Ages, scholars believe that most likely all three of them had developed in Classical Antiquity (Zaninović 1991: 261; Peričić 2001: 46; 2005: 140). In these locations, because of the continuity of use of the exploitable terrain and their innumerous adaptations over centuries, there is very little chance to find traces of salt exploitation from Classical Antiquity. Smaller saltpans, which were scattered in hidden coves on the islands and the mainland, possess more archaeological potential, preserving the remains of past salt-making activities. In fact, today these marshy places rarely attract tourists, with the exception of individuals searching for Peloid mud.

In the Eastern Adriatic, salt production and trade in the Middle Ages and in the Modern period have been studied by multiple scholars (Gecić 1955; Herkov 1971; Hocquet 1978-1979; 2005; 2012; 2013; Raukar 1970; 1977; 1981; Usmiani 1984; Erceg 1977; 1981; Kolanović 1995; Peričić 2001; 2005; Piplović 2003; Dokoza 2015; Brakus 2019 and others). However, only one researcher has attempted to study the history of salt in this area in Classical Antiquity (Zaninović 1991). Bearing in mind that salt production was one of the most important sources of income of this region in later historical periods, we can assume that it held a primary importance already in Classical Antiquity and maybe even beforehand. It is reasonable to postulate that in many cases there was a continuity of exploitation of salt production spots from Classical Antiquity to the Middle Ages, as several saltpan sites, where at least two different chronological phases can be detected, seem to suggest (see below and Ch. 4). Due to the historical importance of salt in this region, this gap of knowledge in Classical Antiquity also represents a large gap in our understanding of the economy of ancient *Histria* and *Dalmatia* as a whole.

3.1. Methodology of research

Because of the scarce material traces that salt production leaves in the archaeological record, the question of salt exploitation in the Eastern Adriatic has not yet been examined exhaustively. Archaeological stratification plus a small number of diagnostic artifacts makes it challenging to identify antique salt production sites. Thus, a combination of archaeological and toponymic data, historical sources and a multidisciplinary approach, which includes geoarchaeological research, is needed. Due to the above-mentioned potential for the Croatian coast to demonstrate new evidence of antique saltpan sites, this research aims to bring new data on salt exploitation and trade on the eastern Adriatic coast.

The methodology of research followed for the identification of new saltwork sites from Classical Antiquity includes:

- the systematic mapping of coastal remains of potential saltpans located close to archaeological finds dating to Classical Antiquity, including the correlation of historical sources mentioning medieval saltpans and the mapping of indicative toponyms with Croatian lexemes *sol* (salt) and *slan* (salty), like *Soline, Solana, Solina, Solinice, Slano, Slana, Slanac, Slanci, Slanica, Slanik* and others (Skračić 2016: 217-218), which derive from the Latin *sal* (salt) (Skok 1971), with satellite and aerial images;
- archaeological survey on selected sites, both along the coast and under water;
- geoarchaeological studies, focused on site formation and sedimentation processes, including relative sea-level movements;
- archaeological test excavations; and
- comparative study of all the collected data.

Often, salt exploitation sites are attested indirectly by recurrent toponyms, like *Soline*, originating from the Latin *salinae*. Location names are often chosen based on some notable characteristic for a particular spot, which differentiates it from other locations around it (Šimunović 2005: 23). Archaeological remains from Classical Antiquity sites, which preserve toponyms connected to salt, in particular the ruins of Roman *villae*, fishponds and fish processing facilities, are strengthening the hypothesis of the existence of antique saltworks on these spots (Grisonic 2022).

It is becoming clear that many sites demonstrate the continuity of salt extraction from Classical Antiquity to the Middle Ages. In this light, the work of medieval historians plays a key role in identifying the locations of many antique and medieval saltpans based on their appearance in archival documents (Rački 1877; CD I-XIV; Raukar 1970; 1977; 1981; Hocquet 1978; 2012; Dokoza 2015). Most medieval saltpans were destroyed or abandoned after 1409, when Venice took posession of these territories and monopolized salt exploitation and trade (Hocquet 1978: 177-190; 1981; Raukar 1970; 1977; 1981). Additional archival research followed by confirmatory fieldwork is required to conclusively identify these saltpans (Grisonic 2022).

3.2. The geographical context of the eastern Adriatic coastal region

The eastern Adriatic coastline is very uneven, with more than a thousand islands and islets, copious promontories and hidden coves. These features made the navigation along the eastern Adriatic shore safer, naturally protecting the ships from quite strong to very strong winds, like the northeastern bura/bora, the southeastern jugo/scirocco and the northwestern maestral. On the other hand, these shores offered many hiding spots for unforeseen pirate attacks (Wilkes 1995).

The eastern Adriatic area begins immediately south of the city of Trieste. Muggia/Milje, the last Italian coastal town, is located in northern **Istria**, the largest peninsula on the eastern Adriatic coast. It covers 3,558 km², of which 38 km² are in Italy, 385 km² in Slovenia and 3,135 km² (88% of the area) in Croatia. Istria consists of three areas: the hilly northern Karstic edge (White Istria), lower flysch hills abundant in rivers (Grey Istria) and low limestone plains covered with fertile red soil (Red Istria). The main city, Pula/Pola, is located in southern Istria (Croatian Encyclopedia).

The following **Kvarner** region encompasses the northern part of the Adriatic Sea between the Velebit and Istrian coasts. Velebit is the mountain range that runs for 160 km in parallel to the coastline of the Velebit Channel, in between the sea and the Lika plateau in the hinterland. It is part of the Dinaric Alps. The Croatian Kvarner region comprises numerous islands, of which the bigger ones are Cres/Cherso, Lošinj/Lussino, Krk/Veglia and Rab/Arbe. The main cities are Rijeka/Fiume and Senj/Segna.

Dalmatia is a geographic and historical region in present-day southern Croatia, stretching south from Pag Island to the coast of Montenegro. It comprises an area of about 400 km along the Adriatic coast, including most of Croatia's islands, and extends about 70 km into the interior. The subregional division of Dalmatia into northern, central and southern Dalmatia is conditioned by the gravitational influences of its larger cities. North Dalmatia is the gravitational area of Zadar and Šibenik (Zadar and Šibenik-Knin Counties), central Dalmatia gravitates around Split (Split-Dalmatia County) and south Dalmatia around Dubrovnik (Dubrovnik-Neretva County). The biggest Dalmatian islands are Brač, Hvar, Pag, Korčula, Dugi otok and Mljet. Dalmatia is characterized by karst relief; it is mainly built of limestone and dolomite. The two exceptions are the large flysch area of Ravni Kotari north of Zadar and the Lower Neretva Valley, which constitute the most fertile parts of the region.

The **Roman province of *Dalmatia*** comprised a much larger territory, spreading from the eastern Adriatic coast (and the Italian *Regio X. Venetia et Histria*) to the provinces of *Pannonia* to the north, *Moesia* to the east and *Macedonia* to the southeast. The coastal part of the province of *Dalmatia* extended from the mouth of the *Arsia* (present Raša) River in southeastern Istrian Peninsula, to the Mati River and nearby coast in present-day north-central Albania, including all the islands along the coast (Croatian Encyclopedia).

The **Montenegrin littoral** includes a narrow coastal strip from the Oštra Peninsula (Croatia) to the mouth of the Bojana/Buna River (the border with Albania) and the Bay of Kotor. The coast is 293.5 km long and moderately indented.

In the **Albanian** part of Epirus, the mountains extend to the coast. Further south the coast is low, marshy and poorly indented.

Salt production in Istria was mainly taking place on the western coast, at the submerged mouths of the Rosandra/Glinščica, Dragonja/Dragogna, Rižana/Risano Rivers, and most likely also at the mouths of Mirna/Quieto and Raša/Arsa Rivers (Matijašić 1998: 354). The rivers brought to coastal zones layers of flysch that shaped flat clayey and muddy surfaces, suitable for salt exploitation (Guštin 2008). On the Dalmatian coast, shallow, mostly northwest-, but also southeast-oriented flat and muddy coves, which are the result of Holocene marine ingression into marly sandstone valleys (corresponding to tectonic synclines), bounded by karstic ridges (tectonic anticlines), were being systematically chosen for the implantation of saltpans, which are documented from the Middle Ages. These coves, suitable for salt making, are located on the northern Adriatic islands of Krk, Rab, and Pag, in the northern part of Dalmatia including present-day Zadar and Šibenik-Knin Counties and on the Pelješac Peninsula in Dubrovnik-Neretva County. Different salt production sites were also located in the Gulf of Kaštela in Split-Dalmatia County. In Montenegro, salt was produced mainly in the Bay of Kotor (Boka kotorska) and in Albania in the marshy coastal lagoons. Strong winds, like the bora, are very positive for salt production, as the quite important sea level fluctuations in the northern Adriatic area (Fanfani 1981: 164), where the tide amplitude can reach 1.8 m (± 0.9 m in the Gulf of Trieste), the highest values of the Mediterranean basin (Antonioli *et al*. 2007).

3.3. The historical context

In pre-Roman times the Eastern Adriatic was inhabited by different Illyrian populations: the Histrians lived on the Istrian Peninsula, the Liburnians on the coastal territory in between the rivers *Arsia* (Raša) to the northwest and the river *Titius* (Krka) to the southeast. The eastern neighbors of the Histrians and Liburnians were the Japodes, settled in the hinterland, on the plateaus of Gorski kotar and Lika. The territories on the coast comprised between the rivers Krka and Cetina and the hinterland of Split were inhabited by the belligerent *Delmatae*, after whom the Roman province of *Dalmatia* with the capital *Salona* (present Solin close to Split) was named. In the southern part of the region the Greeks started to found colonies and *emporia* in 4th century BC, first on the central Dalmatian islands and later also on the continent, boosting new trading routes with the native populations (Matijašić 2009: 31-37, 56-57).

The Romans conquered the Eastern Adriatic in the 2nd and 1st centuries BC and later established the province of *Illirycum*, which appears organized after the beginning of the *pax Romana* in 27 BC. At first, the province of *Illirycum* with the capital *Salona* was united to *Pannonia*, comprising the territory along the eastern Adriatic coast from the river *Formio* (present-day

Rižana next to Koper in Istria) until the *Drilon* (Drin) River in northern Albania. The northeastern boundaries of the province coincided with the Danube River in southern Austria and Hungary (Matijašić 2009: 167, 184). With the Augustan reform the Istrian Peninsula was englobed in the X. Roman region *Venetia et Histria* and the boundary with the province of *Illyricum* was set on the river *Arsia* (Raša) in eastern Istria. At the time of Julius Caesar, the colonies of *Parentium* (Poreč/Parenzo), *Pola* (Pula/Pola), *Iader* (Zadar/Zara), *Salona* (Solin), *Narona* (Vid by Metković) and *Epidaurum* (Cavtat) were founded. With the exception of *Narona*, which was built on the upper delta of the Neretva River, the other colonies were built along the Adriatic coast, at an almost equal distance one from another (Matijašić 2009: 20-21, 138).

The Augustan age was a flourishing period for the Eastern Adriatic: new Roman colonies and municipalities were founded, adorned with *fora*, public buildings, theaters, aqueducts, whose monumental traces can be still admired nowadays. After the uprisings of the Dalmatians and Pannonians in 16 BC, in 14-9 BC and AD 6-9, it became evident for the Romans that the province of *Illirycum* was too extended. Therefore, probably around AD 9 they decided to split the province in two, founding the new provinces of *Dalmatia* and *Pannonia* (Matijašić 2009: 159-160, 184).

During the 1st and 2nd centuries AD, the economy of *Dalmatia* and *Histria* reached its peak: like on the Italian Peninsula and in the other provinces, the land properties were organized in *fundi*, containing *villae*, self-sufficient farmhouses that produced various kinds of foodstuffs, with the surpluses intended for trade. Smaller *villae* contained a residential part for its owner or administrator (*pars urbana*) and productive and storage spaces (*pars rustica* and *fructuaria*). The magnificent residential estates built on or next to the coast (*villae maritimae*) generally comprised grandiose and richly decorated residential areas and several detached productive buildings (*villae rusticae*), sometimes directly annexed to the residential parts (Lafon 2001; Brun 2004). In the territories of the colonies of *Pola* and *Parentium* in Istria, extensive maritime villas were owned by powerful senatorial families from Rome, like the *Laecanii* and the *Statilii Tauri*, while the *Calpurnii* had their maritime estate on the island of Pag. The *gens Octavia* had its properties close to the city of *Nedinum* (present Nadin in the Ravni Kotari fertile plain, north of the colony of *Iader*). The *fundi* mainly produced oil and wine, but also greatly exploited the maritime resources. The *oleum Liburnicum*, probably produced in Ravni Kotari and on the

Zadar archipelago, was known for its distinctive flavor and was exported to Italy (Škegro 1999: 179).

The ships that sailed the Adriatic followed coastal routes, moving along the eastern Adriatic coast from southeast to northwest. The main trans-Adriatic route connected Monte Gargano, the islands of Palagruža (Pelagosa), Vis, Hvar and reached the colonies of *Salona*, *Narona*, *Iader* and the municipalities of *Aenona* and *Senia*. The main destination of most merchant ships was the port of *Aquileia*, one of the main commercial hubs of the Empire. From here various land and sea routes departed, leading to the provinces of *Dalmatia* and *Pannonia*. The *Aquileia* - *Emona* road served as the main link towards *Pannonia*, the *Aquileia* - *Tarsatica* road connected the *X. Regio* to *Dalmatia*, while the *via Flavia* from *Tergeste* reached the colonies of *Parentium* and *Pola*. These roads served as an alternative to the maritime transport and were mostly used during the winter season (Matijašić 2009: 199-200).

In the Diocletian age the province was divided in *Dalmatia* with the capital *Salona* (under the jurisdiction of the Western Emperor) and *Praevalitana* with the capital *Scodra* (pertaining to the Eastern Empire). After the abdication in AD 305, Diocletian chose to retire to *Aspalathos* (present Split) near *Salona*, where he built his magnificent palace, which after his death in AD 313 continued to be temporarily used by some members of the imperial family. Between AD 475 and 480 probably also Julius Nepos, the last legitimate emperor of the West, resided in the palace in Split.

The 4th century is characterized by the strong expansion of Catholicism. The deep political and military crisis of the Empire led to the impoverishment of its inhabitants and of the city élites. Excessive taxation on land properties led to the depopulation of the countryside. The decrease in spending capacity led to a diminishment of the quantities and qualities of produced and imported goods.

In the first half of the 5th century, the Dalmatian cities received the refugees from *Pannonia* escaping Barbarian invasions. Every citizen, of any social scale, was required to contribute to the construction of the city walls (*Cod. Theod*., XV, 1, 49), for which *spolia* were generally used.

Dalmatia was in the hands of the Ostrogoths for about forty years (AD 490-530). One part of the Gothic war took place on the territory of *Dalmatia*, which was reconquered by the

Byzantines in AD 537. *Salona* served as a base for the reconquest of Italy. The Byzantines built a whole series of *castra* and watchtowers along the eastern Adriatic coast, at strategic points along the routes that led to Istria and Ravenna, to ensure safe navigation. The coastal Adriatic cities prospered under Justinian (Matijašić 2012). At the end of the 6th century, the Slavs and Croats appeared on the scene and began to settle in these lands.

3.4. Eastern Adriatic saltpans: ethno-historical data

Traditional saltpans are man-made intertidal facilities built with mud, wood and stone, where, at the end of process, in which brine progressively concentrates, common salt is obtained, more or less purified from the various minerals, organic and inorganic impurities that are originally contained in seawater. During high tide, seawater is channeled into a system of shallow pools (basins), usually lined in mud. With the aid of sluice gates and gravity, water-lifting devices or simply by hand, seawater is gradually moved to successive evaporation basins, where thanks to solar evaporation it concentrates and the undesired minerals precipitate. At the final stage, saturated brine reaches the crystallization basins and salt can be gathered.

The area of the saltpans is usually divided in four evaporation stages and the final crystallization stage, the only area where the sodium chloride or common salt precipitates. If salt would precipitate on the entire surface of the saltpans, we would obtain a c. 6 mm thick layer, which would be impossible to collect and protect from rain. Simultaneously, this kind of salt would be of very bad quality, because together with sodium chloride it would contain all the undesired minerals and other impurities, which would give it a bitter taste (Rumora 1997). To obtain 1 kg of salt approximately 17 kg of seawater are required (Moinier 1985: 77).

The complex techniques used in the saltpans have been handed down from father to son from centuries. Thanks to the archaeological findings of the Roman saltpans in Vigo and Cervia, we can confirm that these techniques have been in use in Europe well before the arrival of the Arabs (cf. Adshead 1992; Petanidou 2005: 12-13).

The work on the saltpans was an extremely hard seasonal job, which took place during the summer months, from May until the end of Septemeber or October, depending on the climate. Nevertheless, to obtain high-quality salt during the summer season the salt basins and channels needed to be well prepared in advance and this is why in Piran there was the saying that "Salt is made in winter." During the summer months, salters worked all day long under the scorching sun, supporting high rates of humidity, with temperatures normally exceeding the 50°C and with no shade. Salt workers from Pag used to carry the sacks of salt in pairs, the weight of which was adjusted to 70 kg in the 1940s! Salters were men, women and kids not necessarily from the same family. The work on the saltpans was also an occasion for boys and girls to meet ant this resulted in numerous contracting marriages.

Most Mediterranean saltpans have been modernized (industrialized), although this usually implies a combination of traditional and modern techniques: brine is moved by pumps in successive evaporation basins, where it is let evaporate and then salt thermically crystallizes inside the factories. This is the case of the saltpan of Pag, a combined solar evaporation-thermal saltpan, which is the major producer of salt in Croatia.

Traditional (opposed to modern) saltpans are large- or small-scale saltpans, where salt is produced in man-made pans with the action of sun and wind and collected by hand using mainly (but not exclusively) traditional tools. The salt pools are not always paved with clay, but also with stone (granite) slabs and concrete. These saltpans, among which we can enumerate Ston and Nin, were declining for decades, operating below capacity, while nowadays they have turned mainly towards tourism, offering high-quality local salt, cosmetics but also other delicacies, like salted chocolate, cookies, oil and cheese. At the same time, they have developed minor salt museums and touristic tours (with salt harvesting experiences) on the saltpans. A special place in the category of the traditional saltpans have the Piran saltworks (Sečovlje and Strunjan), where only traditional tools are used, the salt basins are paved with clay and the crystallizers are covered with "petola", a cultivated microbial mat, which prevents the mixing of mud with salt. In addition to traditional saltpans, there are smaller saltpans or independent units of production, where usually one salter operates manually at all stages of salt production. These saltpans, which can be defined as **artisanal**, can still be found in France (Guérande), Portugal, Italy (Cervia, Marsala), Bulgaria (Pomorie), Greece (Koukouri) and Malta (Petanidou 2005: 13). This was typical for the Piran saltworks from the Middle Ages until the 1960s, when the privately owned salt fields were abandoned. Thanks to the commendable work of the Sergej

Mašera Maritime Museum from Piran, this type of salt production has seen a revival in one area of the Sečovlje saltpans, where there is the Museum of salt.

Microclimate is very important for saltpans. Saltpans in the territory between Muggia and Koper to the north and the island of Pag to the south have similar weather conditions with much wind. Pag and Piran were less rainy and were more advantageous for salt exploitation than Koper and Muggia, this is why the latter two salt-making areas were closed under the Austrian rule at the beginning of the 20th century, while salt production continues in the first two sites (Bonin 2009: 80). The productivity of the saltpans in Koper at the very beginning of the 20th century was 3 kg/m^2, compared to 4.5 kg/m^2 of Piran, 5.5 kg/m^2 of Ston, 3.75 kg/m^2 of the old saltpans of Pag (Koludrović, Franić 1954: 138).

T. 3 Still-active saltpans on the eastern Adriatic coast			
Location	**Type**	**Used surface**	**Productivity**
Strunjan	traditional	17 ha	few kg
Sečovlje - Lera	traditional	263 ha	2,500 t
Sečovlje Salt Museum - Fontanigge	artisanal	175 ha	few kg
Pag	industrial	225 ha	20,000 t
Nin	traditional	55 ha	3,200 t
Ston	traditional	40 ha	500 – 2,000 t

Like all Mediterranean saltpans, the eastern Adriatic ones had to deal with imports of cheaper salt from the northern African coast, Asia and other markets, as well as the less expensive rock salt. With the exception of the saltpans of Pag, which produce important quantities of salt almost exclusively for the Croatian market, other saltpans found a niche market for their high quality organic sea salt.

Saltpans of Piran: Sečovlje and Strunjan

The town of Piran, located on the present Slovenian coast, built its fortune on salt. The saltpans of Piran were the most important Istrian saltpans since the Middle Ages. Nowadays they are the only still-active saltworks in the Upper Adriatic area: the main saltworks of about 650 ha are located in Sečovlje and smaller ones of 17 ha in Strunjan. In both saltpans salt is being produced and harvested daily in the traditional way, with the use of traditional wooden tools, which are not treated nor coated with chemicals. Present Piran saltpans also produce the renowned flower of salt, very popular in present *haute cuisine*. While kitchen salt crystallizes at the bottom of the crystallization pools, the flower of salt crystallizes on their surface in the

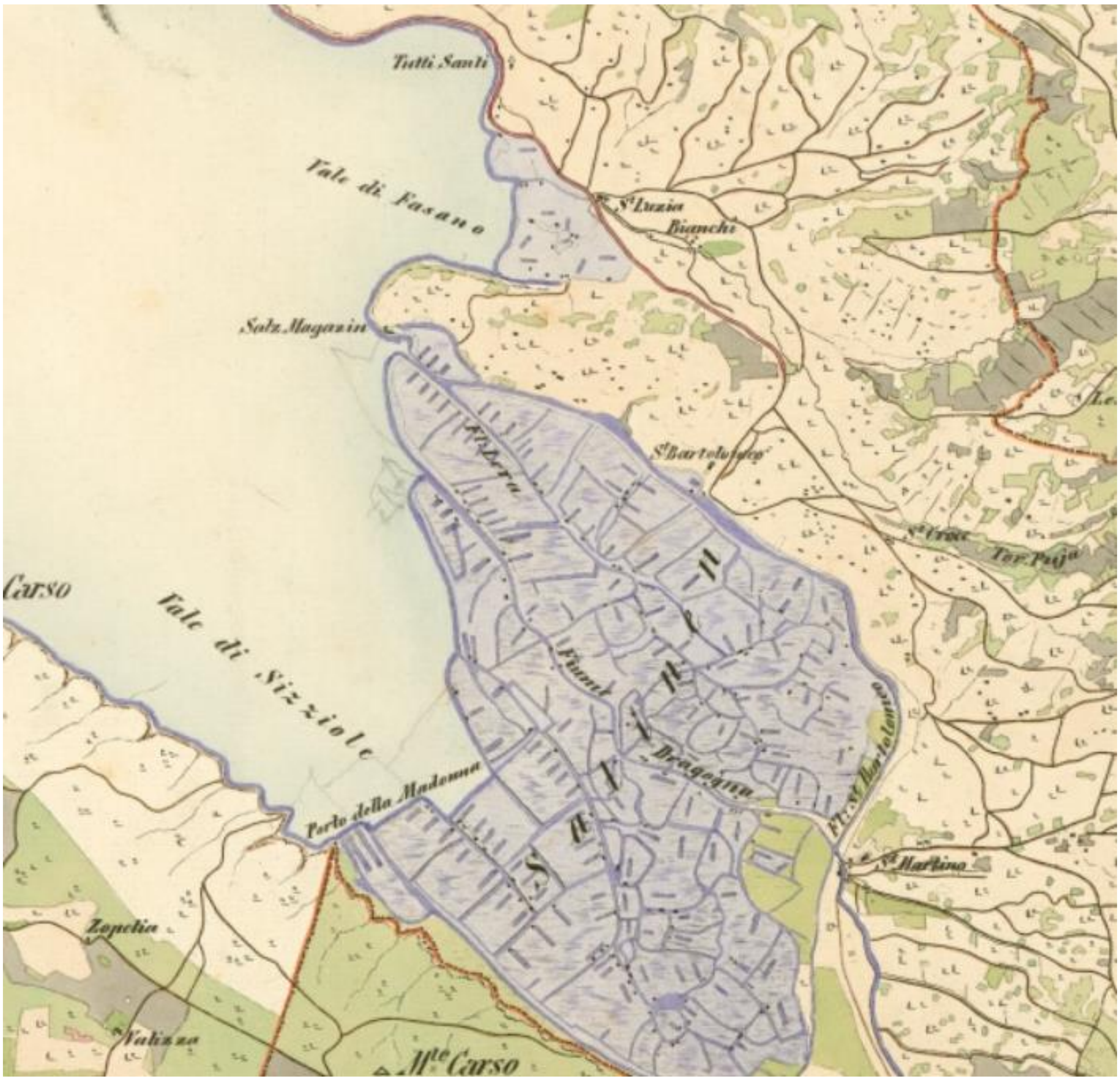


Fig. 49 Saltpans (Salinen) of Sečovlje (Sizziole) and Fazan (Fasano). Extract of Catasto Franceschino, Carta corografica del litorale n. 27, first half of the 19th century (http://www.catasti.archiviodistatotrieste.it/Divenire/ua.htm?idUa=10653124).

form of a thin delicate crust, only during sunny and not windy weather. Even the slightest breeze cracks the crust on the surface of the crystallization basins and makes it sink to the bottom. The flower of salt is collected with a net fixed on a wooden frame, which requires a lot of manual work for relatively small quantities that must be further dried in the sun. It can cost up to 10 times more than the price of common kitchen salt.

The saltpans of Piran are mentioned for the first time in the 1274 statute of the town, while the first reference of those in Strunjan dates even earlier, to 1258 (Hocquet 1978: 82; Guštin, Preložnik 2015). The peculiarity of Piran was that its saltpans were located few km from the town, in the valleys of Strunjan, Lucija (Fazan) and Sečovlje, where the inhabitants of Piran had to arrive by boat. In the second half of the 16th century, along with private and public warehouses, they started to build saltpan houses, where they would move with the entire family from the end of April until the end of August to work on the saltpans (Zalin 1981: 246-247; Bonin 2006: 44).

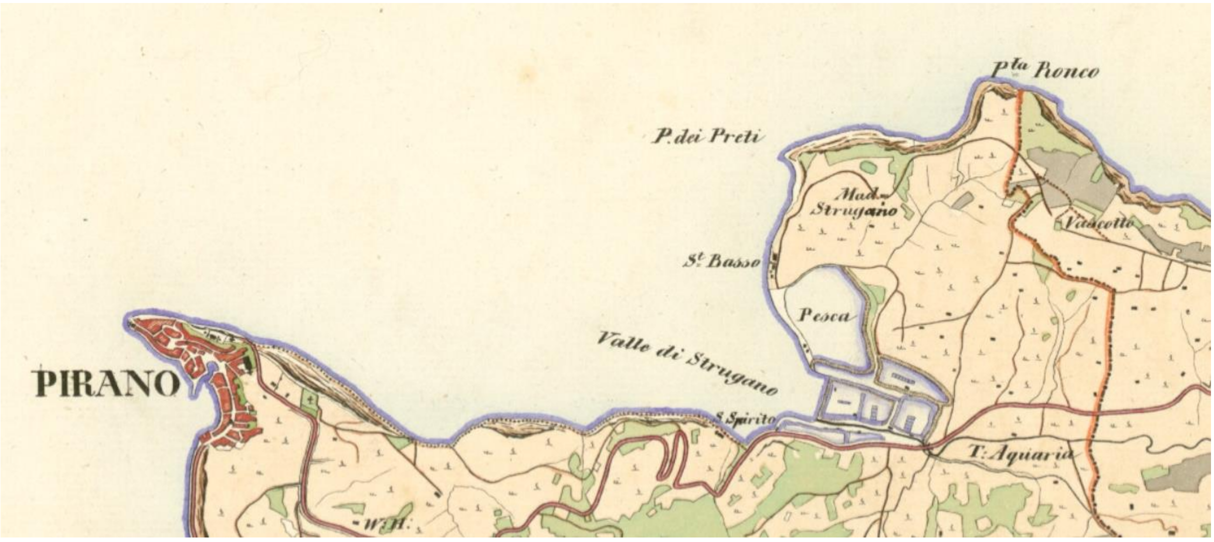


Fig. 50 Saltpans in Strunjan (Strugnano). Extract of Catasto Franceschino, Carta corografica del litorale n. 26, first half of the 19th century (http://www.catasti.archiviodistatotrieste.it/Divenire/ua.htm?idUa=10653123).

In 1283, when the Commune of Piran accepted the Venetian supremacy, the crystallization basins of the saltpans in Sečovlje were 1200. Their number gradually increased in the years. In 1370-1380 salt exploitation was modernized by introducing the salt-making technique used in Pag, which implied a new pattern with 21 "servidori" (evaporation basins) and 21 "cavedini" (crystallization basins) and the use of "petola" in the crystallization basins (Bonin 2006: 44). "Petola" is 1 to 2 cm thick, artificially cultivated microbial mat (Glavaš *et al*. 2018) that prevented the mixing of salt and mud, resulting in the production of pure white salt. In the early 14th century, the Serenissima allowed 3200 *modia* per year (1 *modium* = about 800 kg) to be produced in the Piran saltpans. Piran hosted the office of the *Collegio dei XX dei Sali*, which stipulated five- or ten-year contracts on the use of saltpans, determining also the quantity of salt which was allowed to be produced, its trade, its price for a ten-year period and also the need of maintenance works on saltpans. Smuggling of salt developed: illegally produced salt in Piran was sold in Friuli and in the continental Slovenian regions of Carniola (Kranjska), Styria (Štajerska) and Carinthia (Koroška) (Bonin 2006: 44-45).

The main saltpans of Piran have always been located in Sečovlje, the supervision of which in 1428 required two officers, while the saltpans of Strunjan and Fazan only had one. Around 1574 the three valleys of Piran had together 2680 "cavedini": Sečovlje had 2186, Fazan 327 and Strunjan only 167 (Hocquet 1978: 82).

After the collapse of the Venetian Republic in 1797, Istrian saltpans passed under the Austrian rule and the conditions in the Piran saltpans progressed: the crystallization basins were doubled and the allowed quantity of salt produced abolished (Bonin 2006: 45). At the same time, new salt warehouses were built in Lucija and Portorož.

The saltpans of Piran were divided in numerous private salt fields (integral units of salt production). Salt production, integrated with crop cultivation, was the main economic activity of the inhabitants of Piran until the 1960s, which permitted them substantial incomes. The salt workers were spending their summers in the saltpans, living in their saltpan houses and working on their salt fields. Salt was collected daily and relied on the salt-making knowledge passed on from generation to generation. After the 1960s the saltpans started to be gradually abandoned (Bonin 2006: 46). In 1990 the Sečovlje Salina Nature Park was proclaimed.

The saltpans of Sečovlje are located at the mouth of the Dragonja River, which divides them in two sectors: the still active Lera saltpans (on the eastern bank of the river) and the nowadays abandoned saltpans of Fontanigge (on the western bank), which comprise the ruins of saltpan houses and salt fields of different shapes and sizes (Fig. 51). It seems that it is in this area that the oldest saltworks were organized. The alluvial deposits of the river gradually buried the southern basins in Fontanigge, which the salters converted into fertile fields and they moved the salt basins further north towards the sea. The saltpans of Lera, as well as those of Strunjan, which previously constituted of numerous salt fields, were rearranged into one large saltpan

Fig. 51 Sečovlje saltpans (photo D. Podgornik, Bonin 2006).

under the Austrian rule in the early 20th century. They show an organized and uniform pattern, with crystallization basins that are assembled in a single place, for an easier transfer of salt. At the same time, the brine started to be moved between the basins with the aid of motor pumps, while in the small salt fields this was done with two wooden devices (see below) (Koludrović, Franić 1954: 139-141; Bonin 2006: 44-47).

The Fontanigge area is hosting the Museum of salt-making, which is part of the Sergej Mašera Maritime Museum in Piran. The salt museum, which includes several rebuilt saltpan houses, with channels and salt fields (Fig. 52), was opened in 1994. It holds an ethnological collection. Salt is still being produced in the salt fields of the museum.

Fig. 52 Sečovlje saltpans: Museum of Salt-making in two reconstructed saltpan houses next to the salt fields (photo of Gregor Bernard, http://bernardfreebirds.blogspot.com/2010/10/secoveljske-soline.html, 25/08/2022).

The saltpan houses "salari" date presumably to the second half of the 19th and the first half of the 20th century, but they could be older as they were adapted to the work on saltpans and did not change much over time. They were built on the embankments in between the navigable channel and the salt field. They had a rectangular plan, with a salt warehouse (and storage room for tools) on the ground floor and the living spaces of the salt workers' families on the first floor, comprising a kitchen and two bedrooms (Bonin 2006: 53). In the first half of the 19th century, there were 440 saltpan houses in Sečovlje, 35 on the Fazan saltpans in Lucija and only 17 in Strunjan. Similar temporary houses were also present in the saltworks of Koper and Muggia, although less frequent, because they were located closer to the towns (Selva 2007: 182).

Most salt workers in Sečovlje (owners and leaseholders of salt fields) were from Piran. Every year on the day of their patron S. George (April 23rd), they moved to the saltpans and stayed until S. Bartholomew's day (August 24th).

In Istria, the term "stabile" or "fondamento" traditionally referred to the salt field or entire structure in which salt was extracted. More salt fields together created an "azienda salifera" or "plaga salinara" (salt company). Each "fondamento" was connected to a channel for the inflow of seawater and it was surrounded by large embankments, "arzeni", which served to protect it from the runoff waters and, towards the sea, from the demolishing action of storm surges. The embankments built close to the sea were called "principali o barriere" (main or barriers) and were built with stones, while other dikes were "secondari" (secondary) and were in clay. The salt fields were internally subdivided in several compartments, arranged around a series of channels called "cavane", through which seawater was let in the salt field, but at the same time it served as access route by boat. Every three or four days, during high tide, the seawater, flowing through the "cavane", entered through the main sluice gate called "calio" in the ditches "fossi" or "fossadi" of the individual salt companies. The ditches had a depth of about 50-70 cm and retained the water with the original salinity of 3.5° Baumé (Bé) for a few days, where it acquired a greater concentration and deposited the first impure substances. The salt worker closed the "calio" by lowering two large boards, the "tresse", into the grooves of the stone jambs and filling the gap with clayey mud that made the closure waterproof.

The salt field was divided in several compartments by small earthen dikes, called "verghe". There were four main successive compartments: "morari" or first stage evaporation basins, "corboli" or second stage evaporation basins, "servidori" or final stage evaporation basins and "cavedini" or crystallization basins. The number of "cavedini" determined the production capacity of the salt field. The first evaporation basin was called "moraro alto" or "di fosso". This was placed at a higher level than that of the sea during high tide, and the brine reached it passing through a sluice gate called "bocco (mouth) of the moraro del fossado".

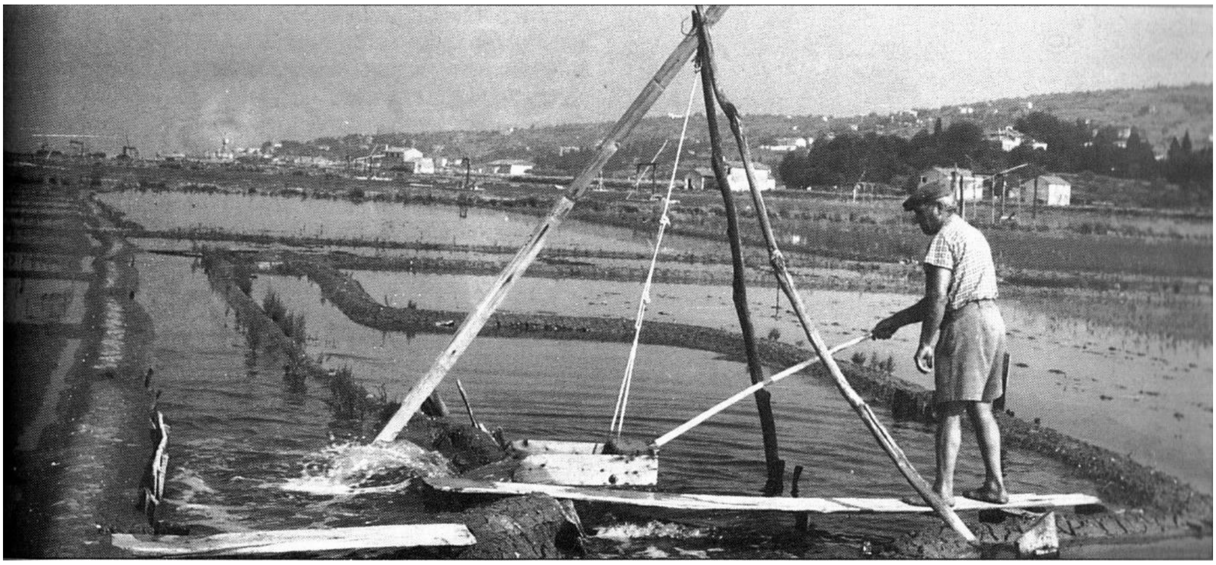


Fig. 53 Zorno in the Sečovlje saltpans (photo of Josip Rošival, 1961, from Žagar 1995).

Brine was transferred from one basin to another also with two wooden devices, the "zorno" (Fig. 53) and the "machina" (Fig. 54). The first was made of thin boards, open at the top and on the front side, like a large shovel, equipped with a long handle and suspended by a rope, the "bragheta", towards a support formed by three poles, the "travache", planted in a pyramid shape. The salt worker oscillated the "zorno", pouring water from the canal into the first "moraro": this operation was called "zornar" (Selva 2007).

The "machina" was a large wind pump, which could be fixed with a semicircular frame, "rondon" or "pompa granda" (big pump), or transportable "careto" (see Bonifacio 2005).

After a few days the brine from the "moraro alto" (high moraro) was made to flow into the second evaporation basin, called "moraro de meso" (central moraro), located about ten or twenty centimeters lower, and from there it ended in the third basin, called "moraro basso" (low moraro) or "soracorbolo". In each of these basins, twenty to thirty centimeters deep and separated from each other by a dike, the "mesarola", the water concentrated for one or more days. From the "soracorbolo" the water was collected in a rectangular pit called "fondon" or "vasca", from where it was lifted in the collector channel "lida" to feed the "corboli", the "servidori" and, finally, the "cavedini". The latter had a very smooth bottom in compacted clay.

Fig. 54 The "machina" in the Sečovlje saltpans (photo of Dušan Podgornik, from Bonin 2009).

When it reached the "cavedini", the brine had a degree of salt concentration equal to c. 25° Bé and, after a day left exposed to the sun and winds, the liquid evaporated leaving salt crystals. In order to favor the crystallization process, the salt workers used to throw large handfuls of salt into the "cavedini" in the morning: this procedure was called "somina" or "semena". Salt was collected from the crystallization basins with a scraping tool, the "gavero", and piled up on the lateral dikes, the "mesarole". When salt was dry it was loaded with two wooden ladles, the "palmoni", in the troughs "conche" or "alboli" and carried on the shoulder (from the 20th century on trolleys on rails) to the warehouse, "canova del salaro". Wooden clogs or "taperini" had to be worn while stepping in the "cavedini", not to damage the layer of "petola" at their bottoms (Starec 1996).

If the weather was helpful, salt was harvested daily during the three summer months. It could be harvested every two days in May and September (Selva 2007). In the case of rainfall, the salt workers put the highly concentrated brine "mora" inside three small pits "fosse dei cavedini", dug at the three corners of each crystallization basin. Rainwater was eliminated from inside the salt field through channels called "lide", which directed the water into the "libador" or drain collector and from here into the sea. When the rain stopped the "mora" was poured back again in the "cavedini" with a vessel set on a long handle called "botaso".

Ordinary maintenance work was very important in the saltpans, especially at the beginning of the season, when the canals were dredged, the embankments raised and strengthened, the basins leveled. However, some interventions were also essential during the winter months, particularly when it was necessary to constantly keep the salt pools covered with seawater to avoid their drying, cracking and desalination.

Special attention was provided for the crystallization basins, where the layer of "petola" was prepared. This work had to be carried out at the end of the season, when all the salt had been removed and the bottom of the "cavedino" had to be leveled, by either lowering or raising its bottom. To lower it, it was necessary to divide the bottom into twenty to thirty cm wide strips, and then remove with special metal shovels, the "badili", a layer of clay three to four cm wide and fifteen thick. After this intervention, the bottom of the "cavedini" had to be compacted with a special tool called "pestone": the layer obtained in this way was then smoothed with the "rodolo" (stone roller). If the bottom of the crystallization basin had to be raised, a small quantity of seawater was introduced and sprinkled with “dry” mud. When the latter was completely soaked, the excess water was released and the "cavedino" was subjected to a new smoothing and refill of seawater. Salt workers often decided to “fertilize” the "cavedini": they coated them with mud, filled them with fresh seawater and let it stay for a period of 20 days, in which the "petola" microbial mat formed (Žagar 1995).

It was also necessary to keep the other evaporation basins ("morari", "corboli" and "servidori") in good condition, since the water could evaporate quickly only from well-smoothed surfaces. For this reason, the salt workers worked hard to eradicate the "sburjon" or *Salicornia* (glasswort) from their bottoms – a halophyte plant that grows in hypersaline environments, damaging the seabed. The salt workers could empty the entire basin to get rid of it.

More about the saltpans of Piran can be found in the rich bibliography (Nicolich 1882; Danielis 1930; Koludrović, Franić 1954; Hocquet 1978; 2012; Žagar 1995; Mihelić 1996; Starec 2001; Bonifacio 2005; Lusa 2005; Neves *et al*. 2005; Zudič Antonič 2005; Bonin 2006; 2009; 2016; Selva 2007; Žitko 2009). Useful drawings of all mentioned tools used in the saltpans can be found in Žagar 1995 and Lusa 2005. Photos of some objects from the Salt-making Museum can be found on the webpage of the Sergej Mašera Maritime Museum from Piran (https://pomorskimuzej.si/sl/digitalne-zbirke/muzej-solinarstva).

Pag

Fig. 55 Saltpans of Pag (M. Grisonic).

The Pag saltpans, the biggest in Croatia, are located on the southern edge of the Gulf of Pag, in the dried-out Solana Bay, separated from the Gulf by a narrow isthmus called Prosika (Suić 1953: 10). Nine salt warehouses (three from the Venetian and six from the Austrian period) still stand on the isthmus. Pag has the best natural and climatic conditions for salt production of the entire Dalmatian coast, thanks to the big shallow bay of about 6 x 1-2 km, with abundant impermeable clay sediments, the summer winds (the daily NW *maestral* and the N-NE *burin* that blows at night), the extremely rare rains, the higher salinity of the closed Gulf of Pag, in which numerous varieties of shells concur to purify the sea (Vidas-Posedel 1960: 74; Usmiani 1984: 154). Today's saltworks are the result of the Austro-Hungarian modification before the beginning of World War I. In 1980 the saltpans were modernized and a production facility was built. Solana Pag is now a large-scale business of 225 ha and Croatia's leading producer of kitchen salt. It produces 20,000 t out of the total 21,000 t of salt produced in the country per year.

Unlike the saltpans of Sečovlje (parts of which belong to the Sergej Mašera Maritime Museum in Piran), which have been widely studied and where the tradition of salt making still persists in collective memory, with a strong will to preserve the traditions of the ancestors, the saltpans of Pag are surprisingly much less notorious. The most complete historical study on the saltworks of Pag was provided by Š. Peričić (2001), ampled by different contributions in the monography on the island of Pag *Toponimija otoka Paga* (Skračić 2011). At the same time, the rich history of the saltpans of Pag almost died down, if it had not been for the work of single citizens, first among them Mate Donadić, who collected ancient photographs, tools and other materials used on the saltpans in previous decades and interviewed elderly people, who had worked on the saltpans. Thanks to these deserving citizens, a permanent exhibition of salt production exists in one of the nine salt warehouses of the Town of Pag since 2009. Because of all this and the enormous historical importance that the saltpans of Pag had in Dalmatian history, the ethno-historical data of these saltworks will be particularly emphasized in this work.

The saltpans of Pag caused copious, centuries-long fights between the main political forces, including local population of Pag, the Zadar Commune, Rab, the Narentine pirates, the Republic of Venice and later the Habsburg Empire (Koludrović, Franić 1954; Hocquet 1978; 2012; Čolak 1963; Raukar 1970; 1977; 1981; Usmiani 1984; Peričić 1988; 2001; 2007; Pederin 1988; Zaninović-Rumora 1988; Grgin 1996; Piplović 2003; Granić 2011; Dokoza 2015). They are attested from the Early or High Middle Ages, but according to numerous scholars, they might have already developed in Classical Antiquity (Juras 1910: 41; Suić 1953: 14; Zaninović 1991: 261; Kurilić 2011: 51; Granić 2011: 181; Oštarić, Kurilić 2013).

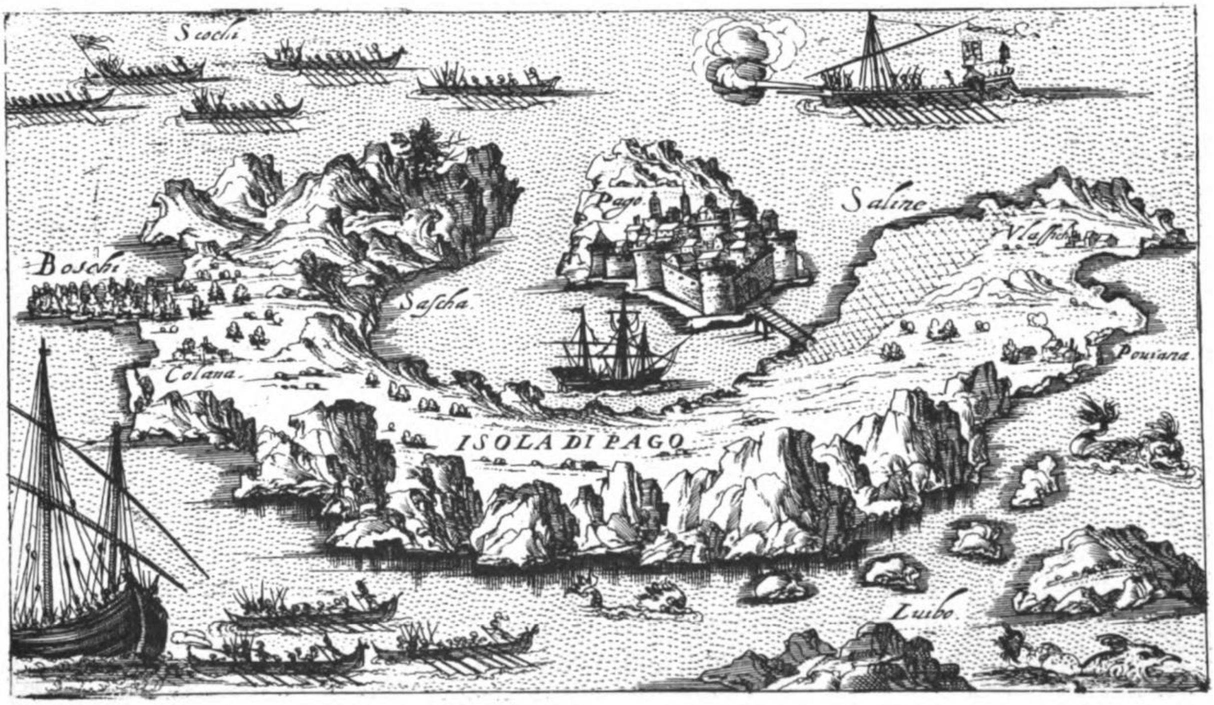


Fig. 56 Saltpans of Pag (Rosaccio 1598: 11).

How much income the production and trade of salt brought to the people of Pag is shown from the fact that in the 15th century they had enough funds to literally move the entire town from its old location, Stari Pag (Old Pag), to the present location of the town of Pag, 2 km north. They built a completely new town, designed for the most part by the famous architect Juraj Dalmatinac (also known as Giorgio da Sebenico), in a more sheltered location, better protected from the extremely strong northeastern *bura* wind and the attacks from the sea. At the same time, the new location offered a more suitable harbor and enough space for further enlargements of the town (Hilje 2011: 147).

The importance of the saltpans of Pag is evident also from the *paški asignat* – the first assignat or paper money in the territory of present-day Croatia and the wider region, issued from 1778, when it was still under the Venetian dominion. Because the value of the produced salt in Pag was so great that it became impractical to transport the required amount of coins, the city authorities started issuing the assignats on paper, whose value was expressed in salt. The assignats were receipts that the Pag judges had previously ordered from Venice. They signed them on behalf of the Pag Commune and through them ordered to the treasurer to pay the written amounts to whom the assignat was addressed (Kolar-Dimitrijević 2013: 34).

The origin of the saltpans of Pag is unknown. The continuity of exploitation of salt in the Valley of Pag from the Liburnian or Roman period, stressed by several authors (Juras 1910: 41; Suić 1953: 14; Zaninović 1991; Oštarić, Kurilić 2013), can at present only be insinuated. It will be discussed more widely in the section about the Roman fish-processing sites in Dalmatia (Ch. 3.7.1), beacuse some indirect evidence from the site of Caska on the northern part of the Gulf of Pag might hint to the fact that considerable amounts of salt were needed for the preservation of tuna fish and derived products.

The origins of salt production on the island of Pag are connected with a legend from the Early Middle Ages. In one of his manuscripts,[22] the notary and historian of Pag Marko Lauro Ruić (1736-1808) passed on a local tradition about the bishop of Zadar Donat (end of the 8th century-AD 811), according to which he introduced the saltpans on Pag, showing to the local people the place where to build them on clay ground:

"Da remotissimo tempo si crede esser stata introdotta la fabbrica delle saline nell'isola dai Zaratini, sin da quando San Donato vescovo di Zara, circa la fine dell'ottavo secolo, approdato a Pago, n'aveva agli abitanti insegnata erezione su certe fondamenta argillose, da lui riconosciute buone a tal'uopo." (Ruić, *Delle riflessioni*, 1. 162, from Nikolić 1907: 9).

Ruić did not agree with this tradition, but he stated that such a vital economic activity like salt production must had started much earlier, in the coves that were suitable for it and that Donat only instructed the inhabitants of Pag how to ameliorate the already existing production process (Peričić 2007: 443). If something of this is true, Donat could have gained knowledge about salt production while travelling in the Mediterranean as an envoy of Charlemagne and the city of Zadar (Čolak 1963; Peričić 2001). The tradition of the bishop Donat is anyway connected with the changing political situation on the island of Pag, which was not included in the Byzantine Theme of Dalmatia, but in the Dutchy of Croatia (AD 800-925), the vassal state of the Franks,

[22] Manuscript n. 34: *Delle riflessioni storiche sopra l'antico stato civile et ecclesiastico della città et isola di Pago ò sia dell'antica Gissa, estratte da diversi autori, diplomi, privilegi et altre carte si publiche come private e scritte da Marco-Lauro Ruich* (1779-1781). It is preserved in the State Archives in Zadar. Marko Lauro Ruić produced numerous manuscripts in which he recorded the history of his town and the whole island. He transcribed, translated and drew information from old documents that were kept in the Pag City Archive, many of which were later lost. Ruić's manuscripts are considered a reliable source of information from many older lost documents (Katić Piljušić 2004).

which had one of its seats in the nearby Nin (Čolak 1963: 483). The changing political situation might also had been reflected in the salt production techniques.

The oldest known documents that expressingly mention the saltpans of Pag are from the 13th century, when Zadar and Venice were fighting over their sovereignty. The saltworks of Pag included many little saltpans or separate entities that had its own production process and were completely independent from what was happening on the neighboring property (Usmiani 1984). The saltpans were possessed by few noble families and other citizens from Zadar and the surrounding towns. Only some of them were owned by the citizens of Pag. The documents show that saltpans were sold, hypothecated, bought, donated and leased.[23] 1/3 of the collected salt belonged to the tenants and 2/3 to the owners (Peričić 2001: 47). The preserved archival documents show that there were at least 46 saltpans in the Valley of Pag and at least other 43 in the neighboring coves of Dinjiška and Vlašići (Čolak 1963: 512). The term used in the documents to indicate the saltpans (*salinae*) has the dual meaning of saltpans – the whole area with numerous salt basins – but it also indicated a single salt basin (Dokoza 2015: 87), which complicates our understanding on the effective areas and hypothetical quantities of salt production. It is not sure if the *salinae* from the medieval documents have the same meaning of the 19th century "partinence/pertinenze" or smaller private saltpans, which were independent units of production (see below).

In the 14th century the island of Pag was under the sovereignty of Venice, but it was divided between the Communes of Zadar and Rab. This administrative division is evident still nowadays. The northern part of the island, which was under the Commune of Rab, is nowadays included in the municipality of Novalja and encompassed in the Lika-Senj County, while the southern part of the island with the town of Pag is comprised in the Zadar County. During the 14th century Pag became almost a colony of Zadar and repeatedly tried to free itself from its

[23] In 1237, Črne Karbonov (Cerne Carbonis) sold to Radovana, widow of Ivan Ragna from Zadar, his six saltpans located in the valley next to *Murvilla* on Pag Island (Murvica in the Valley of Pag or in Vlašići, cf. Čolak 1963: 485 and Brgles, Brozović Rončević 2011: 486). These saltpans were not isolated, but were bordering with those of *dominus Sauçadeo* (CD IV, 35; Čolak 1963: 485; Hocquet 1978: 105, n. 53). In 1274 the nobleman Andrea de Ragno from Zadar bought four saltpans in the Valley of Pag from a local widow: they were located below some ancient ruins called *Padibudi* (CD VI, 75; Čolak 1963: 485). In the same year, the Zadar nobleman Barti de Slorado sold his saltpans to another nobleman from Zadar: these saltpans were bordering with those of the Zadar nobleman Andrea da Cotopagna and those of Radoš from Pag (CD VI, 91). Other documents that mention the saltpans of Pag are preserved in the State Archives in Zadar (DAZD) (see Čolak 1963: 485-486; Hilje 2011; Dokoza 2015). More documents that testify the rent of saltpans of Pag: CD VI, 162 (1276); CD, VII, 105 (1292) and a lien: CD VI, 316 (1279).

domination, with the result that it was heavily destroyed. Fights lasted the whole century (see Čolak 1963: 491-492). 14th century archival documents concerning the saltpans of Pag are much more numerous than those of the preceding century,[24] although even this evidence is very fragmentary. The only 14th century archival fonds that is fairly complete is the one of the notaries of Zadar: out of 69 notaries, only the documents of 23 of them survive to present (Dokoza 2015: 88). Again, most saltpans' owners were from Zadar, but those from Pag were becoming more and more numerous (Čolak 1963: 495). Some monasteries and churches also owned saltpans (the monastery of S. Margarita and the churches of S. Marija/Mary, S. Jakov/James and S. Frane/Francis, all of them from Pag). The preserved archival documents from the 14th century show that there were at least 136 saltpans on the island of Pag, most of which were in the Valley of Pag (Čolak 1963: 513). At the same time, salt merchants from Venice and Senj appeared in Pag. As stated in the 1349 contract between Venice and Pag, the Venetians bought half of the salt produced on Pag, which they then sold on the Italian Adriatic coast, while the other half remained to the saltpans' owners. The owners could sell their salt anywhere, but previously had to pay the duty of 5 ducats for every 100 *modii* (1 *modius* of Pag = 81.5 kg) of salt that was exported from Pag and Zadar. Salt was exported to the coastal Adriatic cities – mainly Karlobag and next Senj, Bakar, Rijeka and Obrovac, from where it was transported towards the interior of the Balkan Peninsula (Peričić 2007: 445). It was also traded with Dubrovnik, reaching the port of Lezhë in Albania (Gecić 1955) and some amounts of salt were shipped to Marche on the western Adriatic coast. Besides the harbor in the Gulf of Pag, the inhabitants of Pag also used to transport their salt to Košljun, the closest harbor on the

[24] The most frequently mentioned location of the saltpans is the Valley of Pag (Paška vala) (CD XII, 350 from 1356; CD XV, 236 from 1376; CD XV, 345 from 1378), where saltworks are still situated today. Many other microtoponyms are attested, mostly located in the Valley of Pag. The noble Mihovil de Rosa from Zadar had saltpans in three different places on the island: in Zamet, 13 in Gilovce and 37 in Kandeva ograda (= the fence of Kandeva) in the Valley of Pag (CD X, 377; Čolak 1963: 492). The saltpans in Zamet are attested also in a document from 1348 (CD XI, 481; Čolak 1963: 493). In 1321, Ivan Pogančić and his wife Milica from Pag gave to the newly founded women's Benedictine monastery of S. Margarita in Pag five saltpans *in insula Paghi in loco vocato Babin potoch* (Babinpotok), nine salpans *in valle Paghi in confinio Sancti Andreae* and nine saltpans *in valle Paghi in loco vocato Capellane* (CD IX, 24-25; Hocquet 1978: 105, n. 53; Hilje 2011: 131, n. 234). All these saltpans were bordering with other saltpans, which had different owners. In 1333, eight saltpans are attested in the valley of Studeno on Pag Island (CD X, 96; Čolak 1963: 493). In 1348, other saltpans are attested in Zamet (CD XI, 481). In 1367, ser Marino de Matafaro sold twenty saltpans on Pag Island to ser Cosa de Begna: sixteen of them were *in valle Paghi in loco dicto Belvidir (et in confinio ecclesie Sancte Eufemie)* and four *in valle Paghi ad Jezera (in confinio ecclesie Sancti Michaelis)* (CD XIV, 89-91; Hocquet 1978: 105, n. 53). These saltpans bordered with those of other owners, among which there were those of the Grisogono and Ljubavac families. In 1370, Mauro de Grisogonis left in a will the saltpans in Jezero close to the church of S. Mihovil to ser Miha, a noble from Zadar (CD XV, 102). In 1376, other saltpans were sold in Jezero in the Valley of Pag (CD XV, 195-197). A document from 1388 attests that saltpans were located *in Valle Pagi in loco uocato Iellauaç* (Hilje 2011: 134, n. 253).

western coast of the island, on the eastern Adriatic seafaring route. Salt contracts between Venice and Zadar and Venice and Pag were refined in 1352: Venice purchased 3/4 of the salt produced at a very advantageous price and banned the export of the remaining 1/4 of salt by sea.

After the peace treaty signed in Zadar in 1358, the Republic of Venice renounced to its Dalmatian territories. Dalmatia and Pag came under the rule of Louis I of Hungary from the Capetian House of Anjou, who appropriated of the monopoly on salt trade. He removed the previous contraints that Venice had imposed, which lead to a flourishing period of salt production and trade in Pag (Peričić 2001: 48, 69-70; Dokoza 2015). Salt producers privately sold minor quantities of salt to the merchants of Zadar and Firenze, who traveled to Pag. Thanks to the mediation of the merchants from Zadar, big quantities of salt from Pag were sold to Kotor in Montenegro and to the merchants of Dubrovnik, who shipped it to the mouth of the Neretva River, from where it reached Bosnia and other internal regions of the Balkans. Zadar, whose nobles and later also enriched merchants greatly based their wealth over salt exploitation and sale, became one of the main centers of salt trade on the Adriatic. The implication of the Zadar noble families in the trade of salt from Pag can be deduced also from the fact that they possessed salt warehouses next to their saltpans, which indicates that they produced bigger quantities of salt intended for trade (Dokoza 2015: 95). In Angevin Dalmatia, the Commune of Zadar supervised all the salt trade. From 1405 it was taken over by the Prince of Zadar (Peričić 2001: 71-72).

In the 14th century, the saltpans of Pag were more advanced than those of Piran and were known for their white salt, which was produced on the "**petola**", the characteristic bottom layer manually applied in the crystallization basins, which the salt workers of Pag also introduced in Piran (Žagar 1995).

Salt warehouses were really numerous in Stari Pag, where they stretched over whole parts of the town near the two piers along the coast and on the isthmus of Prosika (Hilje 2011: 164), where later the Venetian and Austrian warehouses were built. Their dimensions exceeded those of the other buildings of Stari Pag. A document from 1395 indicates a warehouse with dimensions of 22 x 9.5 m.[25] Most owners of salt warehouses were Zadar nobles, who also owned most saltpans. The warehouses (sing. *magaçeno, magacenum, magancenum, magazenum, magazen*) are often mentioned in purchase and sale contracts from the second half of the 14th and the beginning of the 15th century, which also refer to their construction and repairs (Hilje 2011: 141-142). They were covered with roof tiles (*cupis coperto*) and with wooden planks (*planchis coopertum*) (CD XV, 195-197, 236, 346; CD XVIII, 427; Hilje 2011: 129, n. 214; 134, n. 253; 144, n. 354; 138, n. 289, n. 299). Some warehouses did not have a roof (*magazenum discopertum*) (Hilje 2011: 138, 299). In 1387 Blaž from Pag pledged to replace the ruined roof of a salt warehouse: he would put new wooden planks, cover them with roof tiles and impermeabilize the whole warehouse with mortar (Hilje 2011: 141, n. 335).

From 1409, the saltpans of Pag were included in the dominion of the Venetian Republic, under which they remained until the fall of the Serenissima in 1797. The Venetian Republic held the monopoly on salt production in the Adriatic for centuries and banned all the saltworks on its eastern coast, except for those in the Pag Valley and in nearby Dinjiška and Vlašići coves (Peričić 2001: 48, 72). Again, Venice purchased 3/4 of salt from Pag and sold it mainly in Marche. The remaining quarter was exported to Zadar, Šibenik, Senj, Rijeka, the mouth of the Neretva River and Obrovac, where conspicuous quantities of salt were being smuggled. To avoid these situations, already in 1414 the Venetian authorities obliged the owners of the saltpans in the Zadar area to bring all produced salt to Zadar until the end of October.

The production of salt in Pag oscillated very much during the centuries, due to political and climatic factors (see Usmiani 1984; Peričić 1988; 2001; Piplović 2003). From the preserved documents it can be inferred that in 1429-1430 the saltpans of Pag produced the same amount of salt as in 1952, about 23,000 t (the present-day production is 20,000 t), while in the middle of the century they produced only 1/10 of salt compared to earlier decades. Around 1500 the humanist Palladio Fusco wrote that Pag had beautiful and generous saltpans from which the Venetians collected abundant taxes (Peričić 2001: 49). The 16th century was the period of the Ottoman threat and the instability caused by the pirate attacks of the Uskoks, which reflected in the quantities and quality of salt produced. The quarter of salt that remained to the owners of the saltpans in Pag was shipped to Marche and to the ports at the mouth of the Neretva and

[25] State Archives in Zadar: DAZd, ZB, Petrus de Serçana, B III, F 54, fol. 15' (Hilje 2011). The dimensions of the medieval warehouse excavated on Cape Soline in Privlaka close to Zadar are 26.5 x 8.5 m (Šućur, Mustać 2019: 72), while the dimensions of the presumed warehouses in Makirina Cove are 40 x 13 m (see Ch. 4.1).

Makarska, where Ottoman merchants further traded it with Bosnia and other Ottoman lands. In 1527, when Obrovac fell under the Ottomans, salt became the main trading good, which was exchanged for wheat and other goods from Bosnia. At least one Venetian war galley accompanied the ships loaded with salt from Pag to Obrovac. The merchants from Pag, who did not always have appropriate ships, often resorted to the ships and sailors from the northern Dalmatian island of Silba. Salt from Pag also reached the islands of the Zadar archipelago and the central Dalmatian islands of Hvar and Vis, where it was employed for the salting of fish and namely sardines (Peričić 2001: 75-76).

The Ottoman-Venetian wars in the 17th century caused a shrinkage of salt trade towards the Ottoman Bosnia and consequently a decline of salt production and work force in Pag. Many salt workers started to work as sailors and left the salt fields. Many who continued the centuries-old tradition of salt making smuggled salt to Obrovac and other markets. At the end of the century, salt was exported mainly to Senj, but suffered the competition of the salt imported from southern Italy (Peričić 2001: 77).

When Austria came into possession of the Pag saltpans, it imposed its salt monopoly: first the whole quantity of salt was sold to the State at a defined low price. Later, they re-established the Venetian practice according to which 1/4 of the salt produced could remain in Pag for local consumption and for trade. The government shipped the purchased salt of Pag to Veneto and Boka Kotorska in Montenegro, and to a lesser extent to Senj and Bakar on the Croatian Littoral. The Habsburgs privileged Istrian salt from Piran over the saltpans of Pag: Piran had the right to sell its salt in northern Italy and on other international markets. From 1866, when Austria lost its northern Italian territories, the salt of Piran replaced the salt of Pag in the markets of the Croatian Littoral. The salt merchants from Pag were allowed to sell their salt only in Dalmatia, where it was intended mainly for fish salting (Peričić 2001: 81).

At the beginning of the 19th century, the saltpans were divided into 134 smaller saltworks ("partinence/pertinenze"), located at 12 different sites ("contrade") inside the Pag Valley. The sales contracts of the time mention only the crystallization basins "kavedini", which were also called "soline" (in fact, one "solina" was one pool on the saltpans). The dimensions of the "kavedini" were c. 14 x 8.3 m or 116 m^2. As shown in the 1808 cadastral map of the saltpans of Pag produced by the chief engineer of Dalmatia Frane Zavoreo,[26] the "kavedini" were 2,000, which makes a total of 230,000 m^2 (Usmiani 1984: 155; Faričić 2011: 558). All the owners of the "kavedini" located inside a "pertinenza" shared the same evaporation basins, which did not have standard dimensions. The owners were richer families from the town of Pag, while the about 460-500 salt workers were the peasants from the neighborhood, who worked on the saltworks just three months per year. Among them there were also some women and children. The owners and the workers united themselves in a consortium (Peričić 1988: 35-36). These salt fields independently produced and sold salt, although in the framework of the Habsburg (1797-1809 and 1813-1918) and French (1809-1813) monopolies on salt.

Fig. 57 Saltpans of Pag: view towards the Gulf of Pag (M. Grisonic).

The bottom of the "kavedini" was usually repaired starting from March. Seawater was let in the saltpans at the beginning of May or June. On the salt fields, there were five successive

[26] In the State Archives in Zadar: HR-DAZD-6, Mletački katastar, Mape Grimani, br. 295 – Pag, 1808. Zavoreo used the Italian language, still employed in public administration. This map can give an idea of how the saltpans in the Valley of Pag looked like before the Austrian modernization interventions. Detailed pictures of the map can be found in Faričić 2011: 599-605.

evaporation stages, with basins called "kvasilo", "dobac/dolac", "talla/tale", "žljib/sglibo/zibi" and "rabizza/rabac". Bigger "pertinenze" could have had more than one of such basins. All the evaporation basins together were called "arnaži/arnasi" (Usmiani 1984: 156). The documents reveal that the first three evaporation basins were located above sea level and at progressively higher ground; the workers moved the brine from one basin to another with the aid of showels, the brine reaching their knees. The brine flowed in the next basins following the slope of the terrain (Usmiani 1984: 172). When the brine reached the crystallization pools "kavedini", salt was harvested with wooden tools called "grebulje" every two to three days from May until the end of September. Salt was accumulated in heaps, which were left to dry for about eight days, before it was transported in the State warehouses. The places where salt was let to dry in mounds were called "solar/salaro" or "aja". One "pertinenza" would produce daily about 80 kg (1 *star*) of salt (Peričić 1988). The big embankments, which protected the singular saltpans from the sea were called "arđin/argine" (nowadays the Croatian word "nasip" is used): they were dry stone structures built with two rows of blocks, bound together by clay (Usmiani 1984). The drainage channels "opusti", about 102 cm wide, collected rain and runoff water and brought them to the sea. They protected the saltpans towards the mainland. Bigger saltpans or smaller ones together had a common navigable channel "tir" for the boats that loaded salt, which entered deep inside the saltworks. The small embankments between the salt pools, about 34 cm wide and high, were called "stradele" (nowadays "arđine"). These were made out of clay, sustained by larch planks, which were imported from Venice. Ten poles "palini" of spruce wood kept each plank in place. The wood for the poles came from the Zadar archipelago (Usmiani 1984: 157).

Fig. 58 Sluice gates in between the salt evaporation pools on the saltpans of Pag (M. Grisonic).

The saltpans were all concentrated at the edges of Solana Bay. Most of them were located at its bottom, where it was most shallow, at the mouth of a seasonal stream. Many saltworks occupied the whole NE side of Solana Bay, while they were less numerous in the SW part (Piplović 2003: 311). The central part of the bay was occupied by the 1364 m long navigable channel "fuza/fusa" for the transport of salt to the warehouses and to allow the flow of fresh seawater to the most distant basins. The lower part of the saltpans had another "fuza", which was 1320 m long. In 1808, Zavoreo designed a third 1276 m long "fuza" for the upper saltpans. The channels needed to be cleaned every three years. The harbor in front of the salt warehouses was called "kavana", later "kava".

Šime Rossignoli, a salt worker and engineer from Piran and his family worked on the reconstruction of the saltpans of Pag in the 1820's. The drainage channels served at the same time as navigable channels for the "bracere", the boats on which salt was loaded and transported to the warehouses. They had a capacity of c. 12 t or 150 *stara* (1 *star* = c. 80 kg). They were about thirty and it was possible to use eight of them at the same time (Peričić 1988). In the second half of the 18th century, different "gondole" started to be used instead of the "bracere". They were more efficient for loading salt on cargo ships and could more easily pass on the navigable channels in the saltpans.

The division of the saltworks of Pag in numerous privately owned "pertinenze" lasted until 1907, when the Austro-Hungarian Monarchy purchased the different private saltpans, which were in decay, and united them in one big one (Peričić 1988: 33). The modernization works lasted from 1909 to 1911 (Koludrović, Franić 1954: 142). The saltpans were divided in two fields with a total surface of about 113 ha: they had 13 evaporation and 176 crystallization basins. Two sluice gates were added to close the whole Solana Bay, which increased the salinity of the first evaporation basins. The traditional method of moving brine to successive basins with the aid of shovels was replaced with pumps. At the same time, the quality of salt improved from yellow and gray to white (Peričić 2001: 64-65).

The harvested salt was collected in wagons and transshipped on boats that sailed on the navigable channel to the salt warehouses (Fig. 59). These are still located northwest of the saltpans, on the isthmus of Prosika, next to the town of Pag. They are nine, built with massive blocks partially taken from the city's medieval walls and towers. Each one of them has an internal surface of about 500 m^2, while all of them together have a capacity of 20,000 t. The three warehouses from the Venetian period were called S. Marc, S. Peter and S. Paul. Other six warehouses were built in the 19th century: Ferdinand I, Frane Karlo (Franz Karl), Frane Josip (Franz Joseph), Ivan Krstitelj (John the Baptist), Ludovik (Karl Ludwig) and Ferdinand Maksimilijan (Maximilian I). At the same time, the two nearby churches of S. Frane and S. Ante served for the same purpose (Peričić 1988: 43). The dimensions of the warehouses were 41.5 x 11.3 x 5.6 m. All they together could store 22,000 t of salt.

Fig. 59 Salt warehouses in Pag (M. Grisonic).

Within its monopoly on salt, the Habsburg government bought the whole quantity of salt of Pag and paid the saltpan workers. The price of salt was very uneven from year to year (Peričić 1988: 46). Cops or soldiers surveyed the saltpans, because salt was frequently stolen. Nevertheless, if bigger quantities of salt of the established ones were produced, they had to be thrown into the sea (Peričić 2001: 62).

The salt workers carried the heavy sacks filled with salt in pairs on their backs to and out of the boats, which were used for the transport of salt to the warehouses until 1950. All the boats were built in the shipyard of the Pag saltpans. In 1950, the navigable channel in the central part of the saltpans was closed and replaced by the 5 km long railway, the only one on the Adriatic islands, which was in use until 1980. It reached the southernmost crystallization basins, located next to the abandoned Crvena kuća (Red House), where the German prisoners were kept for few months in 1944 and forced to work on the saltpans (Fig. 60).[27] Usually, 300-400 salt workers seasonally worked on the saltpans. When salt was ready to be gathered, movable rails were put as close as possible to the crystallization basins and were then removed. The wagons, which were wooden and later metal, were pushed manually on the rails towards the warehouses.

Fig. 60 The Red House on the saltpans of Pag (M. Grisonic).

The whole area of the saltpans of Pag preserves interesting artifacts. Most of them belong to the previous century, while some could be older. For the levelling of the salt pools and the embankments between them ("stradele" or "arđine"), stone and later concrete cylindrical rolls (Cro. sing. valjak, pl. valjci) were used. Three concrete rollers were found during the first visit of the saltpans (Fig. 61): the dimensions of two of them are 78 x 30 cm, while the third one is

[27] I am grateful to Josip Ćapin, the director of Solana Pag, Antonijo Bakać, Rinaldo Bukša and the whole team working on the saltpans, as well as Mate Donadić from the Permanent exhibition of salt in Pag, who kindly showed me the saltpans and the salt exhibition, providing valuable information on current and past salt exploitation on the island.

60 x 36 cm. The rollers had a metal handle, which is preserved on one of them. Remains of a metal handle that probably belonged to another roller were spotted on the ground. Not far from this spot, two fragments (the largest one is 36 x 24 x 41 cm) of a stone artifact with three 3.5 cm large grooves were found (Fig. 62). These elements probably held the sluice gates, which are normally 3 cm thick. The grooves needed to be somewhat thicker, because the wood of the sluice gates swelled with moisture.

Fig. 61 One of the three rollers in concrete found on the saltpans of Pag (M. Grisonic).

The bottoms of the salt pools were whitewashed with slaked lime. The "žgribači" (literally "those who collect salt") entered with wooden slippers called "nanule" in the crystallization basins and scraped ("raščati") the thin layer of salt that formed daily. To do so, they used wooden tools with a flat ending (in Piran they were called "gaveri") and metal shovels. Before the harvest of salt, the "lužina" or the remaining water in the crystallization basins was expelled (Donadić 2022: 10). If all the water would had been left to evaporate, even the “bad salts” would had crystallized and given a bitter taste to the final product. Salt was put in wooden boxes with four handles called "mašure" and then in wheelbarrows "karijole", some of which were also provided with stone rollers of smaller dimensions. One of these rollers, measuring 52 x 20 cm, was found during the inspection of the saltpans (Fig. 63).

Fig. 62 Stone artifact with grooves recovered on the site (M. Grisonic).

Salt was gathered ("žgribati") in mounds, where it was let to dry and release the unwanted “bad salts” for three to four days, before being transported in the warehouses.

Fig. 63 Stone wheelbarrow roller found in the saltpans (M. Grisonic).

In the present-day saltpans of Pag, which have 93 employees, salt is produced through a combination of natural factors and industrial processes in the plant (Fig. 64). The saltpans have three pumping stations. First, seawater enters three stages of evaporation pools, where it evaporates thanks to the action of the sun and the wind. The surface of the saltpans is divided in three evaporation stages. The first evaporation stage, located in the northwestern part of the saltpans, takes c. 50 % of the entire surface of the saltpans. Here the seawater evaporates the fastest, reaching the concentration of 7° Bé and at 5° Bé calcium carbonate ($CaCO_3$) precipitates. The basins of the second evaporation stage, where the brine concentrates to 14° Bé, are located in the western and southeastern part of the dried-out Solana Bay. In this stage, at about 14° Bé, the iron oxide (FeO) precipitates and various microorganisms die (Donadić

2022: 8-9). The third evaporation basins, where the concentration of salts reaches 20° Bé, are located next to the modern road Pag-Zadar, at the eastern side of the bay. This area, also called Gornje Soline (Upper saltpans) has eleven "opusti" or channels for the drainage of rain and runoff water that are located in the middle of eight salt basins. In the basins of the third evaporation stage the gypsum or calcium sulfate ($CaCO_4$) precipitates, all the way until the beginning of crystallization. The evaporation basins are filled with 7-10 cm of seawater. Seawater is let in the saltpans in April and it takes up to 40 days to saturate in the final evaporation basins. The salt season usually ends at the beginning of September. The density of water in the different salt pools is measured with the hydrometer, while raw potatoes were used for the purpose in the past: when they floated it meant that the concentration of salt had reached 18-20° Bé (Donadić 2022: 12).

Fig. 64 Solana Pag factory (M. Grisonic).

When about 90 % of the water has evaporated in the third-stage evaporation basins, reaching the concentration of 24-25° Bé, the resulting saturated brine is first transferred to 3-4 m deep open storage basins, where possible impurities deposit, and then it is pumped into vacuum boilers inside the factory, where the remaining water is thermally evaporated passing through four stages. At the end of the crystallization process, which is the only one that occurs inside the factory, pure salt is obtained. In this way, both the natural advantages of the environment and the modern technologies concur to obtain most of profitability. Salt production is now possible throughout the whole year, because the brine produced during the summer is deposited in large and deep open storage basins, where due to the big difference in specific gravity, brine remains at the bottom, while eventual rainwater stays on the surface and can be easily expelled (Donadić 2022: 11-12). 1 m^3 of this higly concentrated brine can give more than 200 kg of kitchen salt. The advantage of such system is also the quality of salt, which is pure white, while before women had to painstakingly remove the clay fragments called "poplati" or tiny stones, after some of the salt pools had been asphalted. The modern saltpans of Pag produce their own fine kitchen salt and flower of salt, which is harvested manually with fine nets from the surface of condensed seawater in special basins. The saltpans import salt from Tunis and other coutries to produce industrial and road salt.

The sluice gates on the saltpans are called "vratašca" or "purtele" (Cro. vrata, It. porta = door). Their internal sides need to be additionally sealed with clay to avoid the unwanted flow of water from the salt basins, before the brine has condensed enough to be moved to the next stage. For this purpose, heart-shaped shovels are used that smooth the clay. Today the channels are not cleaned as often as in the past, while the wooden planks and poles, which coat the sides of the earthen embankments between the salt pools called "arđine", must be regularly changed.

In some channels and salt basins the small fish “solinarke” (*Aphanius fasciatus*) live: while the seafish usually stands 3.5 % of salinity, “solinarke” can live in waters that reach a salinity of 15 %. They were brought to the saltpans of Pag from Slovenia during the 1920s, because they eat mosquito eggs, which were causing malaria.

Nin

The saltpans of Nin (Ital. Nona) are located in the lagoon of the Bay of Nin, 20 km north of Zadar (Fig. 65). Nin is considered as one of the most important healing mud locations in Croatia (Bosna, Miletić 2016). The present-day saltworks were built in 1955 after a major redevelopment of the area, carried out by the Habsburg Empire at the beginning of the 20th century (Vujčić-Karlo 2012). From 2002, Solana Nin is a private company that continues the traditional production and harvest of salt, offering guided tours, birdwatching and the possibility to visit an interesting salt museum.

The saltpans of Nin appear in the documents from the 13th century. Salt exploitation was one of the main economic activities in the town and there was an important salt market frequented by the Croats, Hungarians and Bosnians (weekly journal *Glas Zadra*, br. 225, god. VI, 08/10/1955; Hocquet 1978: 84; Fanfani 1981: 166). It is believed that they existed already at the time of the Croatian Kings (925-1002) and later the Hungarian Kings of Croatia (1102-1527). King Ljudevit's decree from 1371 attests that special taxes on the sale of salt from Nin had to be applied. This lasted until the Venetians bombarded Nin from the sea, destroying the town and its saltpans in 1423 (Koludrović, Franić 1954: 137; Fanfani 1981; Vujčić-Karlo 2012).

Present-day Nin saltpans have a total area of 550,000 m² and about 120 salt pools. Salt is produced by solar evaporation of seawater, channeled in successive basins that belong to four evaporation stages, before they reach the crystallization basins (Vujčić-Karlo 2012):[28]

T. 4 Present Nin saltpans

Stages	Surface	Water density	Quantity of evaporated water
sea		3.5° Bé	
1st evaporation	230,000 m²	3.5-7° Bé	50 %
2nd evaporation	146,000 m^2	7-14° Bé	25 %
3rd evaporation	85,000 m^2	14-21° Bé	18 %
4th evaporation	47,000 m^2	21-25.6° Bé	7 %
crystallization	42,000 m^2	25.6-29° Bé	almost all

[28] I am grateful to Josipa Šalov from Solana Nin, who kindly gave me all this information and showed me the saltpans with the salt museum.

Fig. 65 Saltpans of Nin (© Archaeological Museum Zadar).

In the saltworks of Nin the concentrated brine is moved from one basin to another simply with the sluice gates and not with the aid of channels. The pools have different slopes: the first evaporation pools, where the sea enters after the main sluice gate has been opened, are set on highest ground, while pumps are used for all other phases. From the first evaporation stage, the brine is pumped for about 8 hours and transferred to the basins of the second evaporation stage. To reach the fourth evaporation stage it is pumped for about 3 hours. Numerous dikes, which encircle the single salt pools, and a total of 495 sluice gates are used to regulate the brine level in the basins. The gates are raised and lowered depending on whether the sea/brine needs to be brought into a certain basin or whether it needs to get out. The process of releasing seawater into the pools begins in May. It lasts until July, and if the weather conditions are favorable, the first harvest can take place ten to fifteen days after the beginning of July. In one season, three to four salt harvests can take place. When the higly concentrated brine is let in the crystallization pools, the remaining water is released and salt is harvested after maximum ten days.

Fig. 66 Saltpans in Nin (M. Grisonic).

At the bottom of the evaporation basins there is healing mud of the liman type,[29] surmounted by "petula" (petola). Contrarily to the saltpans of Piran, where this microbial mat is manually cultivated only at the bottom of the crystallization basins (Glavaš *et al*. 2018), in the saltpans of Nin petula naturally forms at the upper bottom layer of the evaporation basins. In both cases, it prevents the mixing of mud with salt, contributing to its purity and acts as a biological filter, which helps incorporate the numerous minerals present in the "petola" (including natural iodine) in the final salt.

In the crystallization pools, which are paved in concrete, sea salt crystallizes and settles at the bottom. To get 1 mm of salt, it is necessary to evaporate 8 mm of saturated water. In Nin salt is collected several times during the summer season. The first harvest can commence when a layer of 15-20 mm of salt forms, after 120-160 mm of saturated water have evaporated. Before salt

[29] Limans are ‘narrow bays cut deep inland, which formed along previously existing river valleys as a result of coastal plain submergence by transgressional seawater’ (Shuisky 1982).

is harvested, the remaining brine is ejected and salt is collected in piles, where it is left to dry for a certain time before it is transported to the warehouse. When the saltpans of Nin reopened, salt was transported in wooden barrows called "karamace" and then loaded on wooden wagons. They later used the steel mining wagons, which the salt workers needed to push. Today, modern tractors and trucks are used for the purpose. Salt is still gathered with traditional wooden scrapers, rakes and metal shovels. Instead of the traditional wooden sandals, modern boots are worn for the work in the salt pools.

Fig. 67 Salt harvest in Nin (M. Grisonic).

The average production of sea salt in the saltpans of Nin in the last ten years was 3,200 t. 1 m^2 surface in the crystallization basins produces 76.2 kg of salt. The saltpans of Nin also produce the flower of salt (up to 20 t), which crystallizes on the brine surface in the crystallization pools. It is collected with shovels provided with sieves and it is deposited on other sieves, where the crystallized salts naturally lose a certain amount of moisture. Flower of salt is collected in early morning hours and late in the evening, when there is no wind. It can be collected every day. This type of salt is enriched with magnesium and calcium and it is sold unprocessed. Nin saltworks also produce salts used in the fishing industry and technical salt for industrial uses.

Due to the shrinkage of natural wetlands in the whole Mediterranean basin for agricultural and industrial purposes, artificial wetlands like the saltpans of Nin constitute very important ecosystems for faunal and floral species, many of which are endangered (Bosna, Miletić 2016). Up to 120 different types of birds can be observed on the saltpans of Nin, including breeding, migration birds and birds from the surrounding areas that come to the saltpans to feed (see Vujčić-Karlo 2012). The most frequent animals living in the salt pools are a species of small fish and a species of shrimp. The fish *Aphanius/Cyprinodon fasciatus* or Mediterranean Toothcarp/ Killifish (Cro. obrvan, It. nono) is 4-6 cm long and has a body with vertical bands. It lives in the saltpans, in the pools next to the sea and at the rivermouths. It eats small crabs and the larvae of insects, mainly those of mosquitos. It is for this reason that in the previous century it has been brought to the saltpans of Pag and Nin from Slovenia, where it is native. It can live in the salt pools up to the second evaporation stage. The Brine Shrimp *Artemia salina* (Cro. račić slaništar) is max. 1 cm long and can be found in the fourth evaporation stage. It feeds on tiny unicellular algae, among which there is the *Dunaliella salina* and the *Cyanobacteria* or green-blue algae. Their eggs can survive many years under the mud without water.

The saltpans of Nin house the so-called Roman floodgate/sluice gate (Fig. 69), which has been found inside the area of the saltworks during their construction in the 1950s. The structure is composed of two massive blocks laying horizontally on a lower pedestal built with two parallel vertically positioned calcareous blocks, placed at the distance of 70 cm one from the other. The two massive blocks on top of the structure, which are clearly Roman, were held together with three metal clamps (Fig. 68b). One of the two blocks has a 80 x 12 cm rectangular opening, placed right on top of the two grooves of the underlying calcareous blocks (Fig. 68a). The latter are provided with three rectangular grooves each, meant to hold wooden boards of sluices. It seems that the whole structure really served as a sluice gate. The question is: in which historical period was this structure in use?

Fig. 68 The so-called Roman sluice gate on the saltpans of Nin: details (M. Grisonic).

Fig. 69 The so-called Roman sluice gate on the saltpans of Nin (M. Grisonic).

Unfortunately, the exact contex of finding is not known and currently we do not have direct comparisons with possible similar structures from Classical Antiquity. In medieval, modern and still-working traditional saltpans, vertically positioned cornerstones provided with grooves for the wooden sluices can be found in the embankments at the very entrance of the seawater in the first evaporation pools (in the saltpans of Piran this main sluice gate is called "calio"), but also in other parts of the saltpans that are more solicited and need to have sluice gates of bigger dimensions. Two fragments of a possible cornerstone for the sluice gates, probably from the Modern period, have been discovered during the survey on the saltpans of Pag. The calcareous blocks with grooves in Nin look quite similar and are carved in the same kind of stone. At the same time, there is a visible difference in the stones of the pedestal and the two Roman blocks put on top of the structure, which leads me to conclude that the massive Roman blocks were probably brought from *Aenona* and reused in the area of the saltpans in later periods. Originally, the block with the draining opening might had served as a manhole.

It is not known where in the Bay of Nin the possible Roman saltpans could have been located. The majority of scholars excludes the area of the present saltpans, which was flooded by the local river, before its course was deviated further northeast during the Austrian rule. Numerous tombs dating from the Early Iron Age to the Late Roman period were found in the wider area around the present saltpans (Solana/Blato) before the eastern entrance of *Aenona* (Dubolnić Glavan 2015). At the present state of research the identification of possible Roman saltpans on the territory of Nin remains unsolved. As discussed below (Ch. 3.7), all neighboring bays, which were included in the *territorium* of *Aenona*, produced salt during the Middle Ages.

Ston

Ston (Ital. Stagno) is located at the southern beginning of the Pelješac (Sabbioncello) Peninsula, also called Stonski Rat, in present Dubrovnik-Neretva County, about 40 km NW from Dubrovnik. The first mention of Ston as *Turris Stagna* can be found on the Tabula Peutingeriana, while Constantinus Porphyrogenitus named it *Stagnon*. *Stamnum – Stagnum* means salt marsh, pond, standing water (see Ch. 2).

Fig. 70 The saltpans of Ston (from Krsić 2009).

Ston, a territory of the Dubrovnik Rebublic from 1333 until its end in 1808, was one of the main producers of salt on the eastern Adriatic coast (Koludrović, Franić 1954; Hocquet 1978; 2012; Peričić 2005; Krsić 2009). Today's saltpan has an area of 450,000 m^2: it is a solar evaporation saltpan, where salt is produced by evaporation of the progressively concentrated brine, thanks to the action of the sun and the winds. The saltpans of Ston are a private company, which continues the traditional harvest of salt almost exclusively for touristic purposes. They can produce up to 2,000 t of salt per year and make flower of salt.

The Commune of Dubrovnik paid rent to exploit the saltpans of Ston to the Ban of Bosnia and the King of Zahumlje until 1333, when the Ragusans bought the almost abandoned saltpans and annexed the Pelješac Peninsula (Gecić 1955: 102; Peričić 2005: 140-141). The Ragusans immediately built two castles to protect the access to the saltpans (Hocquet 1978: 87), founding medieval Ston on the spot of a previous Roman settlement (Zaninović 1970; Di Vittorio 1981: 292-293), together with the harbor of Mali Ston (Little Ston), c. 1 km to the NE. They connected them with a fortification of monumental walls, which can still be admired today and which were protecting the saltpans. Ston was the seat of a permanent garrison (Gudelj 2011: 102). The new saltworks were constructued on the spot of the old ones, following a well-planned scheme. Soon later salt trade represented more than one third of the income of Dubrovnik. The Republic (1358-1808) had the monopoly on both the production and trade of salt. Salt from Ston was mainly sold in the hinterland, to the Ottoman (1463-1908) lands of Bosnia and Herzegovina (an Ottoman *emin* supervised the salt trade in Dubrovnik and Ston), while on the coast from Neretva to Bojana/Buna Rivers it competed with the salt produced on the Venetian territories, including Piran, Pag and Šibenik. Salt from Ston was shipped to the Neretva markets on low-draft boats for shallow water called “pelješke solarice” (= salt boats from Pelješac), managed by the inhabitants of Trpanj, and with “gripi”, which were usually escorted by armed forces (see Peričić 2005: 154, n. 83, 157; Marinčić 2009). However, most salt traded by the Dubrovnik Rebuplic was imported from other eastern Adriatic saltpans (Pag, Zadar, Šibenik), the Western Adriatic and other parts of the Mediterraean.

While the other saltpans on the eastern Adriatic coast consisted of numerous indipendent private saltpans, the Republic, the only owner of the saltpans of Ston, built them according to a unitary plan. The salt workers of these saltpans were the inhabitants of the surroundings, to whom the Republic leased them, together with the tools and houses for a period of five to ten years (Taljeran 1935: 90). It seems that when the saltpans were not leased, the surrounding inhabitants were called to work on them as part of their corvée (cf. Taljeran 1935: 90; Peričić 2005: 159-161).

The basins were called "guvni" or "kavedini" and "palate". Some of them were already paved with granite slabs (Peričić 2005: 141). At the end of the 14th century, the saltpans had 13 "guvni" (Gecić 1955: 104-105). A constant problem of the saltpans in Ston were the infiltrations of fresh water from the nearby stream, because the people ruined the embankments between the salt pools while catching fish in some of them. For this reason, in 1434 the Senate had to ban all fishing activities from the saltworks (Čolak 1962: 412) and stronger embankments were constructed to protect the salt pools from fresh water. The work on the saltpans began in early April, when the rainwater that accumulated during the winter was expelled to the sea, and ended up at the end of September. Again, the quantity of salt produced varied a lot from year to year (see Peričič 2005: 142, 144-145).

Fig. 71 Saltpans in Ston: one crystallization basin (M. Grisonic).

The saltpans are comprised inside an area, which is delimited by the stream Briega to the north, the stream Palada to the west (Piplović 2003: 315, 324) and the sea to the east. The salt pools date back to the time of the Republic of Dubrovnik. There are 53 evaporation basins (službenice) and 9 crystallization pools. Each salt pool has its own name and some of them are carved on stone slabs from the time of the Dubrovnik Republic; all have names of saints (S. Vlaho/S. Blaise - the protector of Dubrovnik, S. Frano, S. Nikola, S. Baltazar, S. Josip, S. Ivan, S. Marija, S. Lazar, S. Klementin, SS. Petar i Pavao), except for one pool, which is called Mundo (= world in Spanish). As the locals explain, the salt from this pool was apparently distributed to the poor families living on the territory of the Dubrovnik Republic for free.

The salt workers were both men and women, who harvested salt, transported it to the four warehouses and loaded it on ships in Mali Ston, c. 1 km NE of Ston, to avoid the long navigation around the Pelješac Peninsula towards the north. From Mali Ston the central Dalmatian ports and the delta of the navigable Neretva River, going far into the mainland, were easy to reach. Great quantities of salt were transported on the river to the the fluvial port of Metković in Croatia and nearby Drijeva (*Forro Narenti* or present Gabela), the medieval and modern era customs town and marketplace on the Neretva Delta in present Bosnia and Herzegovina, where salt was traded with the Ottoman Empire (Piplović 2003: 316, 319). In 1673, the Dubrovnik Republic lost its monopoly on salt trade and its warehouses in Drijeva, which were taken over by the Venetian Republic (Marinčić 2009). Another salt market where the Dubrovnik Republic traded its salt was in Sveti Srđ (San Sergio) at the mouth of the Bojana/Buna River south of the Skadar/Shkodra Lake, at the present frontier between Montenegro and Albania, which was active at least since the Middle Ages. The Republic also traded salt in Dubrovnik itself and in Slano. Smaller quantities of worse quality salt were sold to the Dalmatian fishermen for fish salting, namely tunas and sardines (Peričić 1983: 262-264; 2005: 159).

Fig. 72 Wagons for the transport of salt to the warehouses (M. Grisonic).

In 1815, after a short period of French administration (1808-1814), the saltpans came into direct possession of the Habsburg monarchy, in a period when other Dalmatian saltpans were still divided into numerous privately owned salt fields. Because of this, there were no restrictions of the quantities of salt produced in Ston and the harvesting season was enlarged from May to October. The saltpans of Ston produced one third of the quantities of salt produced in Pag, but quite more than the other Dalmatian saltpans of Rab and Dinjiška (see Peričić 2005: 148). Salt workers who were permanently employed on the saltpans were not numerous, most of them were seasonal workers.

At the end of the 19th century the saltpans were abandoned and created serious health problems for the local population. After being owned by the Yugoslav government, present Solana Ston is a private enterprise.

The specificity of the Ston saltpans is that the salt basins have bigger dimensions than usual and that the bottoms of some of them are paved with granite blocks (Fig. 71). Ston is less windy compared to other Adriatic saltpans and the fact that the crystallization basins are so big slows down the evaporation and crystallization of salt (Peričić 2005: 147). The length and width of each crystallization basin in Ston are 55 m to 63 m, for an internal surface of c. 30,000 m^2. In the 19th century, 12 "kavedini" from Ston had the same area of 324 "cavedini" from Piran. The salt collected from the less numerous paved basins was pure and white (sal bianco), while the salt obtained from the most numerous basins layered with *terra rossa* was coarser and reddish (sal rosso), as the friable clayey soil mixed with the salt crystals (Peričić 1983; 2005; Krsić 2009). Even today, the salt obtained from the basins paved with granite slabs is pure white and it is not bitter. According to the locals, salt from one of these basins, called S. Lazar, was collected only for the Emperor Franz Joseph I of Austria and the court in Vienna. The basins that were paved with clay started to be asphalted starting from the 1870s (Peričić 2005: 150), with the consequence that fragments of asphalt were present in the final salt, a problem that has nowadays been resolved.

The advantage of the saltpans of Ston was that its warehouses were located at its very edges (Peričić 2005: 153-154). In the 18th century their names were: “Od tramontane”, “Od ponte”, “Od tornja”, “Slanac na levantu”, “Drvarica”, “Duboka”, “Tabor” and “Pakljena” (Marinčić 2009).

Salt from Ston is harvested manually from July to September with wooden scrapers (although using boots, not the traditional wooden sandals) and shoveled directly into wooden wagons (with a capacity of 1 t), set on movable rails put the closest possible to the crystallization basins (Fig. 72). The wagons are pushed towards the small train, which brings them closer to the warehouses, once called "slanice", where salt is brought directly and not let to dry outside in heaps.

Even if for the moment we are lacking direct archaeological evidence, salt production in Ston is thought to have commenced already in Classical Antiquity, if not even earlier (Zaninović 1970: 492; 1991: 263; Peričić 2005; Krsić 2009). The discovery of the boundary of the *ager centuriatus* in the Ston Field, which belonged to the colony of *Narona* and is located inside the present Ston saltpans, together with its presumable relationships with Roman salt production, will be discussed in depth below, in chapter 3.7.1.

Fig. 73 Saltpans in Ston: detail of the embankments (M. Grisonic).

3.5. Toponymy

Toponymy is a linguistic discipline that studies the toponyms, or names of places and geographical features, and connected questions of their meanings, origins, use and typology. Toponyms are very conservative and can survive historical turmoils and changes; because of this, also when there are no other written evidences, they can reveal different linguistic processes, and also language changes (Mastrelli 2009: 19-20). Toponyms reflect the history of a certain territory, the changing political situation, the presence of animal and plant species, particular geophysical shapes, anthropic characteristics, and social, cultural and linguistic dynamics that took place in a specific location over time (Selva 2009: 31).

Places of salt production, but also those where salt exchange and trade took place usually mantain their salt-related toponymy, which shows the enormous importance that salt had in history (Tašić 2000: 35; Hocquet *et al*. 2001: 15). The most important examples are Salzburg, Salisbury, Hallstatt, Halle, Hallein, Tuzla. *Slatina*, a very common toponym in Eastern Europe, is another example (Perić 2012), although it can also indicate a natural pond with stagnant water, both on the coast and on the continent (Brozović Rončević *et al*. 2011: 662, n. 168).

Salona or *Salonae* (present Solin north of Split) was the capital of the Roman Province of *Dalmatia*, built at the mouth of *Salon*, the present Jadro River (the locals call it Rika), after which the city was named. *Salona* is a pre-Roman and non-Latin toponym (Skok 1950: 157; 1971; Šimunović 2013) of uncertain etymology. It is one of the eastern Adriatic toponyms which end in -ŌNA and were then replaced by the Slavic -ĪN, such as *Flanona* > *Plomin, Aenona* > *Nin, Promona* > *Promina, Scardona* > *Skradin, Stelpona* > *Stupin, Narona* > *Norin*. The toponyms ending in -ŌNA occur in the Liburnian and Delmatic areas. It would follow that *Sal-* in *Salona* is some non-Latin, native root, just like *Flan-, Prom-, Skard-, Stelp-, Nar-*, etc.[30] Therefore, the toponym *Salona* cannot be used as an indirect indicator of salt exploitation, like some authors (Čolak 1963: 478, n. 2a; Selva 2007: 174) have suggested. For the possible origin of the toponym *Salona* see Skok (1971: 304-305).

[30] I would like to thank prof. Nikola Vuletić and Željko Miletić from the University of Zadar for their help in these matters.

Toponymy based on the use of the Latin radical –*sal*– or the Slavic –*sol*– is wide spread on the eastern Adriatic coast and namely in Dalmatia (Skok 1971), whitnessing this intense activity in the past (Hocquet 1978: 83). This data can be often compared with archival texts, which attest the presence of saltpans on these locations.

The wide spread toponym *Soline* derives from lat. *salinae*. The transition from the protonic, Dalmatic /ă/ into the Croatian /ŏ/ occurred in the 8th century AD, when the /ă/ did not yet exist in ancient Croatian (Šimunović 1986: 63; Vuletić 2010: 339). In Dalmatia, the word *solina* or *salina*, as indicated in the 13th-15th century archival documents from Zadar, also meant salt pool (Čolak 1963: 485, n. 23; Raukar 1977: 211; Usmiani 1984: 155, n. 6; Dokoza 2015: 87).

The continuity of exploitation of the same coves for salt production from Classical Antiquity to the Middle Ages based on toponymy has already been evoked by numerous scholars (Skok 1950; Zaninović 1991: 261; Matijašić 1998: 353-354; Šimunović 2005), as well as their installation in the same locations through centuries (Čače 1985: 486; Traina 1992: 377; Zaninović 1991: 255, 259, 261; Dokoza 2015: 89; Auriemma 2016: 475; Felici 2018: 139). One of the most significant examples of exploitation of marine resources from Classical Antiquity until the Modern era is Fizine on the Slovenian coast, in between Piran and Portorož, where a Roman settlement and fishpond are located next to the 19th century salt warehouses (Gaspari *et al*. 2007; Auriemma 2016: 491).

Toponyms with the Slavic radical –*sol*– are often found also on the continent, far from the sea. In this case, they can indicate the presence of salty sources, a market where salt was sold and exchanged with other goods, or simply the locations where salt was given to the livestock. Examples of the latter are the toponyms *Soline, Solenica, Solenik, Solenjak, Solevac* (Orbanić, Žigant 2013: 36, 796). According to the State geodetic administration of the Republic of Croatia, the toponym *Soline* appears 61 times in Croatia: most of the times it denotes locations along the coast (https://rgi.dgu.hr/rgigis/).

There are also other toponyms that are linked to salt exploitation, as *lokunja*, which derives from. Lat. *lacuna* = puddle, pond, swamp, lake. It can indicate a saltpan or a spot where salt was being collected (Šimunović 1986: 83). In early medieval documents from Comacchio *lacuna* is the collection and first evaporation basin on the saltpans (Benati 1997). Lokunja is for instance a pond located NW of the saltpans of Pag, which was exploited for salt production at the time of the Venetian Republic (Usmiani 1984: 160, n. 22).

Another interesting toponym is *jaz* (pl. *jazi*): it is a marine shoal, usually located in the most protected, internal parts of the coves, where the minute material washed off from the surrounding lands accumulates. With further marine activity silt is created out of these sediments (Faričić, Magaš 2007: 11), constituting a base for the implantation of saltpans. Therefore, *jaz* most often designates the muddy end of the cove, which itself bears another name, but sometimes the entire cove can be called *Jaz*. Other variants of the name refer to large or small *jazi*: *Jazina, Jazine, Jazići* (Skračić 1996: 284). These toponyms are very frequent mostly on the Dalmatian coast, appearing several dozens of times.

Another toponym that indicates salt production is *Kvasilo*, which is the first evaporation basin inside the saltpans, and *Talina*/*Taline* (Magaš 2011: 43), which derives from "talla/tale", the third stage evaporation basins on the saltpans of Pag and in the northern Dalmatian area in general. The toponym *Magazin/Magazini* next to the saltpans refers to salt warehouses. There are also toponyms that indicate salt markets, where customs duties on salt were applied, like *Gabela* on the Neretva River (from *gabella de sal*).

Nevertheless, the toponyms *Slana, Slatina, Soline, Slatkovići* and *Šipnate* can also indicate salty, sweet and brackish springs (Brozović Rončević *et al*. 2011: 653, 662 n. 168). *Soline* and *Slatina* are therefore also hydronyms, which indicate a natural pool with stagnant water. In Dalmatia, *Slatina* appears countless times along the coast (Skok 1950: 52).

The toponyms *Polačine/Polačina* derive from Lat. *palatium* and usually indicate the presence of an ancient building, not necessarily from Classical Antiquity (Vuletić 2011: 688).

Toponyms that indicate fishing spots and activities near possible saltpan locations increase the probability of the existence of salt-making sites. The need of abundant quantities of salt that would guarantee the preservation and trade of fish would justify the establishment of saltworks. There are numerous toponyms that are connected to fishing activities: *Ribnjak*, *Ribarica, Oštrigera, Piškera, Šćuza, Tunjarica, Tunarica, Tonarica*. The majority of these toponyms indicates a traditional fishing technique, which is still in use in Tarska Vala in Istria: the coves were closed with a large fishing net and smaller nets were then used to pull the fish on the shore by fishermen themselves or with the aid of bulls (Orbanić, Žigant 2013: 46).

The toponyms *Tunjarica*, *Tunarica, Tonarica* indicate tuna fishing (Orbanić, Žigant 2013: 46). Fishermen used to mount on special lookouts – sing. *tunera*, pl. *tunere* – to observe the arrival of shoals of tuna. Most *tunere* were leaning wooden ladders, which can still be seen in the Kvarner region, while in some cases they could also have been built in masonry, as the Tunera in Caska (Fig. 74). In the past, the term *tunera* used to indicate different elements connected to tuna fishing, like the tuna fishing spots, night sentries, fishermen's shacks, fishing nets and locations where tunas were pulled on shore (Krnjak 2016: 284-286).

Fig. 74 Caska in the northern part of the island of Pag: the Tunera tuna watching tower and the Gulf of Pag (the saltpans of Pag are located in the background at the opposite side of the Gulf) (M. Grisonic).

Tuna fishing was a seasonal occupation that involved fishermen, sometimes joined by peasants (Orbanić, Žigant 2013: 46). Usually, the tuna fishing season started at the beginning of August and lasted until mid-October, while in Pula there was a single fishing season, in August and September (Krnjak 2016: 286). Tuna is one of the most renown fish, which was often conserved by salting. For the preparation of *garum*, mackerel and tuna meat were used.

3.6. Eastern Adriatic salt in ancient written and epigraphic sources

Salt exploitation along the eastern Adriatic shore held a key role not only for the inhabitants of the coastal settlements, but also for the farming populations living in the interior of the Balkan Peninsula. Salt was an important bargaining chip when traded with inland populations, who did not have a direct access to salt sources (Grisonic 2022). According to Cristina Carusi, it is not a coincidence that among the very few ancient literary sources mentioning salt, some of them specifically mention the trade between the coastal populations and those of the hinterland. Such a commerce must have been more lucrative than the salt trade in the coastal markets, where the ready availability of salt probably lowered its value (Carusi 2008: 173-174, 249; 2018). As it was the case on the Italian Peninsula with the saltpans at Ostia and the development of the salt trade along the *via Salaria*, the Balkan farming populations needed a great amount of salt, primarily for the cattle and sheep on which their economy was based. Salt trade among the Adriatic coastal settlements and the populations living in the interior of the continent must have developed on similar salt routes. In southwestern and central Bosnia, several toponyms "Solarski putovi" or salt paths have been preserved (Pašalić 1960: 21, 38; Zaninović 1970: 492). These paths passed along the same roads and trails that were used in Classical Antiquity and maybe earlier.

At the same time, in the internal part of the province of *Dalmatia* people learned how to extract salt from salt springs. Strabo (VII, 5, 11) and the Periplus of the so-called Pseudo-Scylax (c. 24) both mention the powerful *Autariatai*, who disputed with the *Ardiaei* about the ownership of the salt sources along their shared border, somewhere in the upper Neretva Valley near present-day Konjic in Herzegovina, where there is a large hillfort (Wilkes 1969: 6; Zaninović 1991: 258; Carusi 2008: 147; Grisonic 2022). Strabo wrote that they gathered the salty water, which flew during springtime and exposed it outside: in this manner salt crystallized in five days. Both Illyrian populations decided that they would take turns to exploit the salty sources, but because they were not respecting the agreement, they were fighting among themselves (Carusi 2008: 146). The pseudo-aristotelic *Mirabilia* ([Arist.] *Mir*. 138) specifies that salty water was kept in a covered space during daytime and brought outside during nighttime. The same ancient source adds that the *Autariatai* and *Ardiaei* were obtaining salt from their springs rather than importing it from the coastal areas, which were too far and they were not mixing with other populations. These tribes used to give the majority of salt to their livestock, and twice a year, otherwise the animals would have died (Carusi 2008: 146-147). Carusi estimates the episode dates from the first half of the 4th century BC or earlier. In addition to salt springs, the populations living in the interior of the Balkan Peninsula also extracted salt from salt mines, for example in Tuzla in northeastern Bosnia, where in Roman times the settlement of *Salinae* developed (Skok 1971; Zaninović 1991: 258; Tašić 2012: 215; Grisonic 2022).

Strabo (V, 1, 8) states that in Aquileia the Illyrians bought wine and products from the sea (τὰ ἐκ θαλάττης) in exchange of slaves, leather and cattle. Among the products from the sea he might had referred not only to salted fish, but also to salt itself (Carusi 2008: 145-146).

Roman authors give no information about the production of salt on the eastern Adriatic coast (Carusi 2008: 145). Nevertheless, Pliny the Elder cited the Dalmatian *muria* as one of the most renowned products of his time (*Nat. Hist*., XXXI, 94). Additionally, in the 6th century Cassiodorus whitnessed the existence of *garismatia plura* or numerous *garum* workshops[31] in *Histria* and plentiful fishponds (*numerosae piscinae Neptuniae*) (Cass., *Var*., XII, 22, 3-5; Zaninović 1991: 260). It seems that in the Early Bizantine Empire *Histria* was one of the most important exporters of grain and other goods towards Italy (*annona*), among which there could also have been salt (Adshead 1992: 63). According to the hypothesis of Saria (1956, coll. 33), accepted by Wilkes (1969: 425), the *tribuni maritimi* to whom Cassiodorus referred in two of his letters (*Var*., XII, 22 and 24), might had administrated the sea transport, fishing and also saltpans. They were civilian officials in charge of ports and settlements or generally local administrators of the towns in *Histria* and *Venetia* (Giardina *et al*. 2015: 291).

Epigraphic monuments

The epigraphic sources from *Histria* and *Dalmatia* that are known so far are not particularly concerned with salt. Only two epigraphic monuments from *Dalmatia*, one from Zadar and the other one from Trogir, indirectly relate to salt matters. Both were found in secondary context. The first one might allude to the fact that the dedicant was involved in salt production and/or trade, while the second inscription is dedicated to the goddess Salacia.

[31] Meaning in the TLL, which is in our opinion the most likely. For different opinions of the meaning of *garismatia* see Giardina *et al*. 2015: 290.

Inscription of T. Helvius Salinator from Zadar

In the church of S. Mihovil in Zadar, the epitaph of the father of the centurion of the VII legion with the *cognomen Salinator* was found (*CIL* III 2914 = HD060145 = EDCS-28400165; Wilkes 1963: 313; Nedved 1992: 236, 247; Fadić 1995: 11; 24, n. 3; Tončinić 2011: 35, n. 13):

T(ito) (H)elvio Sca(ptia) Marino / IIIIvir(o) Altini / T(itus) (H)elvius T(iti) f(ilius) **Salinator** / |(centurio) leg(ionis) VII patri / in fronte p(edes) XXX in agro p(edes) XXX / h(oc) m(onumentum) h(eredem) n(on) s(equetur)

"To Titus H(e)lvius Marinus, enrolled in the Scaptia tribe, quatrovir in *Altinum*. Titus H(e)lvius Salinator, son of Titus, a centurion of *Legio VII* to his father. In a length of 30 feet, in a width of 30 feet. This memorial shall not be inherited by the heir." (Tončinić 2011, with modifications).

The inscription, nowadays lost, can be dated prior to AD 42, when the *VII legio* became *Claudia pia fidelis* (*C. p. f.*). The two men were from northern Italy and probably moved to *Iader* in the first decades of the 1st century AD (Wilkes 1969; Tončinić 2011).

The same T. Helvius Salinator erected a funerary inscription for Acilia, maybe his wife (SupplIt, 24, 2009: 143-144) that was found inside a column of the church of S. Andrea in Treviso. It dates to AD 6-42 (*CIL* V 2113 = EDR097605):

Aciliae / C(ai) f(iliae) / Secundae / T(itus) Helvius T(iti) f(ilius) Salinator / centurio leg(ionis) VII

The *nomen gentilicium* Helvius or Elvius is mostly spread in northern Italy and southern Gaul, but they were quite numerous in *Liburnia* as well (*Iader, Burnum, Asseria*) (Alföldy 1969: 89; Fadić 1995). Interestingly, T. Helvius who erected the two monuments did not inherit his father's *cognomen* Marinus, but had the cognomen Salinator. Was this *cognomen* linked to his occupation (Kajanto 1982: 20)? Did he inherit it from his mother's or his larger family, or from a family tradition (Nuorluoto 2021: 168-169)? Was he adopted and therefore he took the *praenomen* and *gentilicium* of his adoptive father, preserving his own original *cognomen* (Edmondson 2015: 572)?

An interesting parallel might be provided by the two inscriptions that the *salinatores civitatis Menapiorum* (*CIL* XI 390 = EDR144693) and the *salinatores civitatis Morinorum* (*CIL* XI 391

= EDR144697) from the province of *Gallia Belgica* dedicated to Lucius Lepidus Proculus from *Ariminum*, centurion of the VI legion based at *Novaesium* (Neuss) in *Germania Inferior* in AD 69-70. The inscriptions might testify an important connection between the coastal salt exploitation sites on the North Sea and the Roman army settled on the Rhine River (Thoen 1975; Cabal, Thoen 1985). The *salinatores* dedicated the inscription to L. Lepidus Proculus because of his merits, likely in salt commerce (see Napoli 2007).

Was T. Helvius Salinator, the centurion of the VII legion based in *Tilurium* (present Gardun by Trilj) who dedicated a funerary inscription in *Iader*, involved in salt exploitation and/or commerce as well? We know that *Legio VII* probably arrived in *Dalmatia* to suppress the Great Illyrian Revolt (AD 6-9) and then stayed in the province, engaged in building roads and other infrastructures. The officers of the legion actively participated in the administration of the province (Tončinić 2011) and at the same time they must had invested in various economic activities, including salt production.

Altar of Salacia from Trogir

In Trogir (*Tragurion/Tragurium*), an altar dedicated to the goddess Salacia was discovered in 1985 (AE 2007, 1103 = HD056486 = EDCS-46600039; Demicheli 2007). This is the second votive inscription of Salacia known from the Roman world. The ara was reused to build a late antique structure and it is now preserved in the Trogir Town Museum (inv. n. 28). It was dedicated by Salvius Panus, freedman of Gaius in AD 171-230:

Salaciae / Aug(ustae) sacr(um) / Salvius / C(ai) l(ibertus) Panus

Salacia was Neptune's wife and Triton's mother. She was the goddess of salt and sea or seawater. Her name derives from *salum* (= deep sea) or *sal* (see Demicheli 2007: 73). Demicheli assumes that the dedicant, whose *gentilicium* alludes that he was most likely from northern Italy, sailed to *Tragurium* and dedicated the altar to honor the goddess after a lucky sea journey. But apparently Salacia (Venus Salacia) was also the goddess of prostitutes (Serv., *ad Aen.*, I, 720) and therefore this dedication could have a completely different explanation. Originally, the inscription must have stood in a shrine dedicated to Neptune or to Venus.

3.7. Archaeological evidence

Fig. 75 Map showing the main locations mentioned in the following text (see also the Maps at the end).

3.7.1. Various salt production sites

In the Roman world, salt was produced by urban settlements, villas and fish-salting facilities, primarily from solar evaporation saltpans located along the shore (Grisonic 2022). Some of them were public, subcontracted to *societates publicanorum*, while others were owned by the towns or private individuals (Carusi 2008: 252; Marzano 2013: 138-141). Salt was usually exploited in areas that had a nearby harbor or were easily accessible (Traina 1992: 369). It is widely known that in Classical Antiquity (and until the Industrial Revolution) maritime transport was much cheaper, faster and safer than the terrestrial one, also witnessed by the Roman agronomists, for example Cato the Elder (*De agr*., XXII, 3). At the same time, salt could be produced locally at small scale almost everywhere on the coast or by inland salty sources.

Salt producers: the urban settlements and their territories

Urban settlements needed quite wide spaces for the installation of saltpans to meet the needs of salt for their population. The majority of settlements on the eastern Adriatic coast had shallow clayey coves, which might have been used for salt production, located in the immediate or close vicinity of their ports. If salt could not have been produced locally, it needed to be imported from more or less distant markets. The quantities of salt produced greatly varied from year to year, mainly depending on climatic factors. Urban settlements were also centers of redistribution and trade of goods, including salt.

Aenona, present Nin in Zadar County, was an important salt production site, probably already in the Liburnian period (9th century BC to the end of the 1st century BC), and later at the time of the Roman *municipium* (1st to 6th centuries AD; Grisonic 2022). The rich Liburnian necropolis and the imposing architecture of the *Capitolium*, the largest Roman temple on the eastern Adriatic coast, show the prosperity of the town (Zaninović 1991: 261). Nin was one of the capitals of the Croatian Kingdom (c. 925-1102). During the Middle Ages the major salt trade route for the internal regions of Lika and Krbava (the region of the ancient Japodes) was passing through Obrovac, probably following the same salt paths used in Classical Antiquity and Prehistory (Zaninović 1991: 261-262).

We are still ignorant of the exact location of the Roman-era saltpans that developed somewhere in the shallow Nin lagoon. The present-day Nin saltworks, where salt is still being harvested in the traditional way, were built in 1955 after a major redevelopment of the area, carried out by the Habsburg Empire at the beginning of the 20th century (Vujčić-Karlo 2012). Uglešić (2002: 49) thinks that the biggest saltpans of the territory of Nin were located in the nearby Ljubač Bay, where they are attested in the Middle Ages (Raukar 1981: 152) and that the possible Roman saltpans of Pag were also part of the territory of *Aenona*. According to others, Nin had saltpans also in Plemići Bay (Brusić 2002), where a Roman ceramic workshop, which produced amphorae, tiles and loom weights, as well as a probable *horreum* and a harbor with two piers are attested (Parica, Ilkić 2017; Lipovac Vrkljan *et al*. 2018; Lipovac Vrkljan, Konestra 2018; Konestra *et al*. 2022). C(aius) Albucius C(ai) l(ibertus) Restitutus, a freedmen who enlarged the temple of Sirian gods in Podvršje, next to Ljubač (AE 2014, 1027 from AD 80-100) might had been sent here from *Salona* by his patrons, the *Albucii* (*CIL* III 1961), to manage a local business (Glavičić 2013b: 34; Bekavac, Miletić 2018). Maybe it had something to do with salt exploitation (Dubolnić Glavan 2015: 245) and/or with the ceramic workshop in Plemići Bay. Salt exploitation is for the moment only a hypothesis, but if it was true, it would mean that the *municipium* of *Aenona* probably sold or leased parts of its coastal territory for salt production to a powerful family in the province, with whom it maybe also shared the incomes of salt trade. Another possible Roman salt-making site close to Nin was located in Privlaka - Cape Soline (see Ch. 4.2), where the possible saltpans were subjected to the nearby *villa maritima* or to *Aenona* itself. The bays around Nin are all suitable for salt production: they are shallow, provided with abundant clay and exposed to frequent winds.

In central Dalmatia, on the northwestern coast of the Gulf of Kaštela, the Greek *emporion* of ***Tragurion*** (Τραγύριον, present Trogir) probably had its saltpans close to the Pantan wetlands (Zaninović 1991: 262; Grisonic 2022; see Ch. 4.2). ***Salona*** (present Solin),[32] the capital city of the province of *Dalmatia*, situated on the northeastern side of the Gulf of Kaštela, probably held its saltworks south of its port (Zaninović 1991: 262), not too far from the estuary of the Jadro River (Fig. 76).

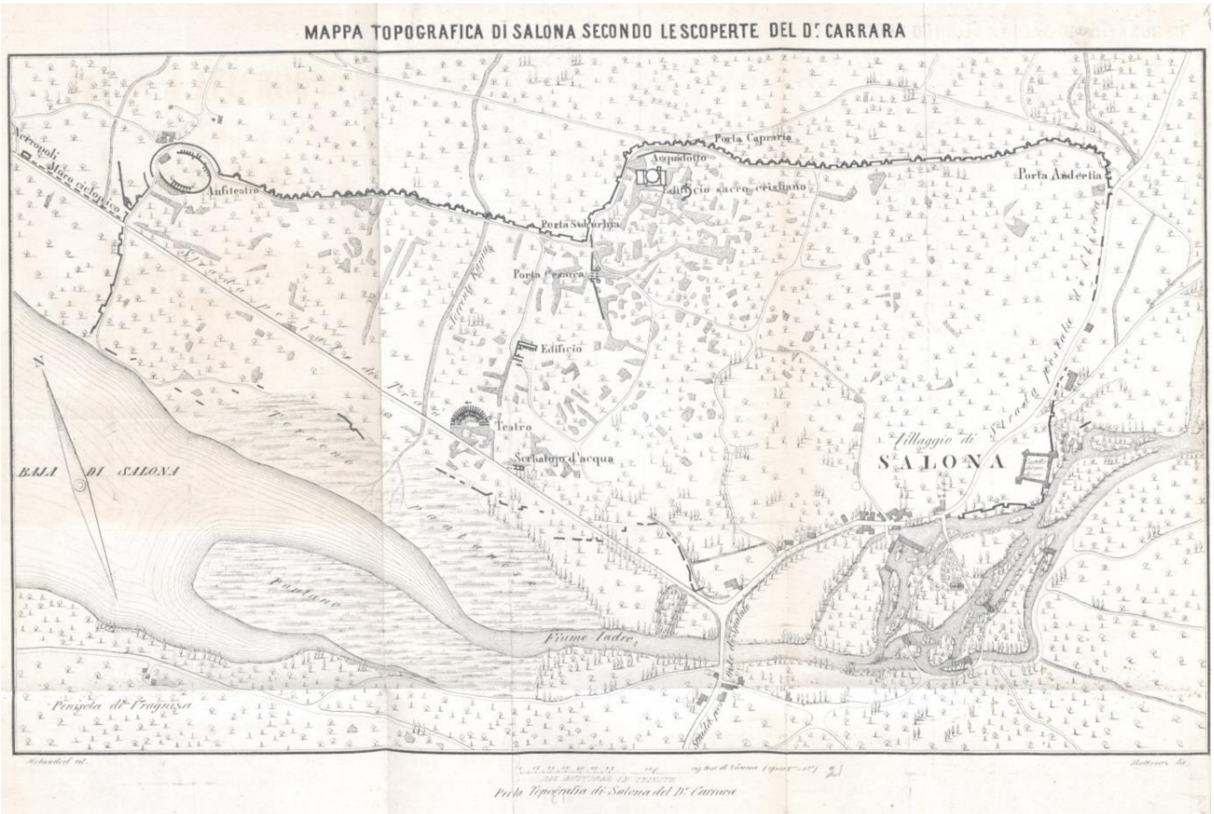


Fig. 76 Map of Salona of F. Carrara (1848) (https://www.flickr.com/photos/britishlibrary/11032543203).

[32] For the cartographic maps, pictures and history of the archaeological excavations of ancient *Salona* see https://salona.netlify.app/Salona.

Presumably, there must have been a flourishing salt trade between the coastal settlements in this area and the farming populations of the internal part of the Balkans, among whom there were the *Delmatae*. This trade traversed the Klis mountain passage, a highly strategic position on the homonymous mountain range located above *Salona* and the Gulf of Kaštela (Fig. 77). In medieval times, the town of Split used this same route to trade salt with its hinterland and with the Bosnian region (Zaninović 1991: 262). In Roman times, the roads connecting *Salona* with its hinterland presumably followed previous salt paths. We can imagine that salt production in the Gulf of Kaštela and its trade with the populations from the interior were a very important source of income for the capital of the province.

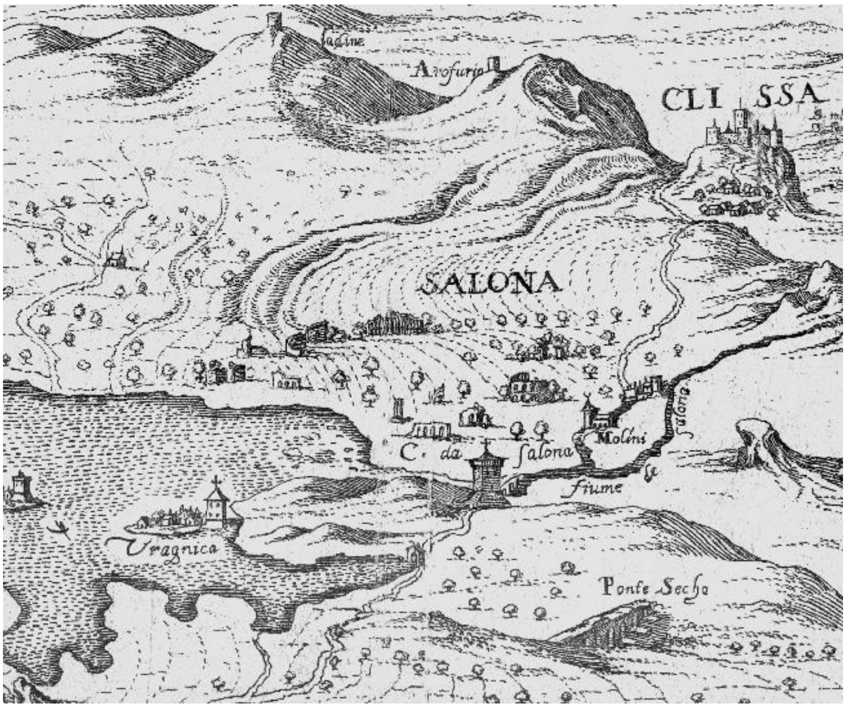


Fig. 77 M. Kolunić Rota, Salona around 1570 (Duplančić 2020: 92).

Epetion (Ἐπέτιον), present Stobreč, located on a small peninsula 5 km east of Split at the mouth of the Žrnovnica River, is first mentioned by Polibius (XXXII, 9, 1) as a settlement of the local population of Bulini and ally of the Greek colony of *Issa* on the island of Vis (Suić 1976). With their 3.3 m, the walls of the city seem to be the thickest of Hellenistic Dalmatia (Kirigin 2010). Very few archaeological excavations have been performed in *Epetium*, which is why its ancient history remains almost completely unknown. The ceramic finds recovered next to the preserved northern Hellenistic city walls date from the 3rd to the 1st centuries BC (see Ugarković, Konestra 2020). The settlement later developed in Roman *Epetium*, a *praefectura* inside the *ager* of *Salona* (Suić 1976: 34). The importance of the town in Roman times seems to have been essentially commercial, thanks to its favorable position on the Split Channel and on the coastal road leading from *Salona* to the mouth of the Neretva River (Enciclopedia Treccani). Interestingly, the Tabula Peutingeriana indicates *Epetio* with a vignette depicting *horrea* (Levi,

Levi 1967: 208, type 5; Magini 2003: 13; Carli 2013) of quite big dimensions (Fig. 78) and it expressively mentions *Port.(us) Epetius*, the harbor of the town, which follows to the east the *Port.(us) Calonitanus* (*Salonitanus*) (present Kaštela Bay), harbor of the capital of the province *Salona*.

Fig. 78 Part of the Tabula Peutingeriana, Weber, Seg. VI (https://www.tabula-peutingeriana.de).

The vignette of *Epetium* is much bigger than the one designating *Salona*. Probable smaller warehouses are depicted further to the east, where there is the settlement of *Inaronia* (= *Aronia*, present Makarska). It is important to note that although the Tabula Peutingeriana was created around AD 350, for *Histria* and *Dalmatia* it recalls a political and administrative situation present in the 1st century AD (see Bosio 1985: 44-45). Public *horrea* were located next to post stations and were destined to collect foodstuffs for the annona, the army, the population in case of famine or donations and for those travelling in the provinces on behalf of the State. *Horrea* were also collection centers for the payment of taxes in kind (Levi, Levi 1967: 133; Magini 2003: 13). *Salona* and *Epetium* were both settled in the biggest agricultural part of central Dalmatia. Like *Salona* with its Jadro River, the area of *Epetium* with the valley of the Žrnovnica River offered an important passage towards the hinterland. After these few remarks, in the absence of archaeological data, we can postulate the hypothesis that *Epetium* was an important commercial harbor, with warehouses that stored cereals and other goods, among which we can also enumerate salt. Possible saltpans could have been located in the shallow parts of Stobreč Bay at the mouth of Žrnovnica River (Zaninović 1991: 262), where they are attested from the 12th to the 16th centuries (Raukar 1981: 150; Hocquet 1978: 86; Nazor 2015: 227-230). The present-day area of Blato (= mud, marsh) along the river is called *Solline* on the 1831 cadastral map of the Habsburg Empire. In Classical Antiquity, minor quantities of salt could also have been imported from the central Dalmatian islands just in front, which preserve some toponyms that attest salt production, in connection with nearby Roman structural remains. They are less frequent than on the northern Dalmatian islands, because they were lacking larger exploitable surfaces for salt production. However, as their waters were abundant in fish that needed to be salted for its conservation and trade, several documents attest the attempts to build saltpans in later periods (Hocquet 1978: 87).

In southern Dalmatia, the former Greek *emporion* and later Roman colony of ***Narona*** (present Vid kod Metkovića), located in the valley of the Neretva River, was probably also an important salt trading site (Grisonic 2022). We can assume that salt was imported from Ston (Zaninović 1991: 263) and the neighboring coves, which were included in the territory of *Narona*. The still-functional saltpans of Ston are situated at the beginning of the Pelješac Peninsula, at the end of the deep Ston Channel. They held an enormous importance in the Middle Ages and at the time of the Dubrovnik/Ragusa maritime Republic (c. 1350-1808), when they constituted its second source of revenue after the shipping industry. At that time, salt was being exported mainly toward the estuary of the Neretva River, from where it was transported to the interior of medieval Bosnia, probably along the same routes already exploited in former times (Koludrović, Franić 1954: 146; Zaninović 1991: 263; Peričić 2005).

The **Ston Field**, although not very large (3 x 1.3 km), is with its abundant water sources a very fertile agricultural land, rare in this part of the Adriatic. At the same time, it is a very suitable location for salt production, with abundant clay ground, protected from the winds and a nearby harbor essential for the transport of salt. Salt production in Ston is thought to have commenced already in Classical Antiquity, if not even earlier (Zaninović 1970: 492; 1991: 263; Peričić 2005; Krsić 2009). According to Strabo (VII, 5, 7), the coastal area from the Neretva River until the Bay of Kotor was inhabited by the Illyrian community of Pleraei, who lived on hillforts and were economically oriented towards the sea and maritime trade (Zaninović 1970: 494; cf. Džino 2010: 64). After the conquests of Octavian in 36 BC, Romanization started in this area, with the creation of the colony of *Narona* and its *ager centuriatus*, which was taken from the previous inhabitants and divided among the colonists. The best preserved centuriation grid is located in the Ston Field. The confirmation that the Pelješac Peninsula was part of the *ager Naronitanus* comes from the inscription of a decurion and quattuorvir from *Narona* found in Janjina in the central part of the peninsula (*CIL* III 8451 = 14623) (Zaninović 1970: 498).

In the Ston Field, a Roman settlement developed under the S. Michael (Sv. Mihajlo) hill, on the isthmus that connects the Pelješac Peninsula with the mainland. Ston and the Pelješac Peninsula are first mentioned on the Tabula Peutingeriana, where the peninsula is called *Turris Stagna*. The name *Stamnes* for Ston is cited in the Anonymous of Ravenna (7th century, using sources from the 3rd-4th centuries), while in the work of Constantinus Porphyrogenitus (10th century) it is called *Stagnon*. The meaning of *Stamnum* – *Stagnum* is salt marsh, pond, standing water (see Ch. 2). On the S. Michael's hilltop (with the homonymous early medieval church), which dominates the Ston Field, a Byzantine *castrum* was built, on a place that was already frequented in prehistoric times, as suggested by pottery findings. This was only one of the series of Byzantine *castra* built to secure the Pelješac Peninsula and the eastern Adriatic seafaring route. In the field under the fort there were several Late Antique churches and chapels, built inside the spaces of centuriation, which reused more ancient ruins of *villae rusticae* (Zaninović 1970). The church of Gospa od Lužina at the western edge of the saltpans was built over older structures, which included a monastery (Taljeran 1935: 90). During the first half of the 10th century, Ston was the seat of one of the oldest dioceses in Croatia (Lupis 2011; Krešić 2016; Puljić 2018), which attests the importance that the settlement had in the Early Middle Ages, most likely in connection with its harbor and salt exploitation.

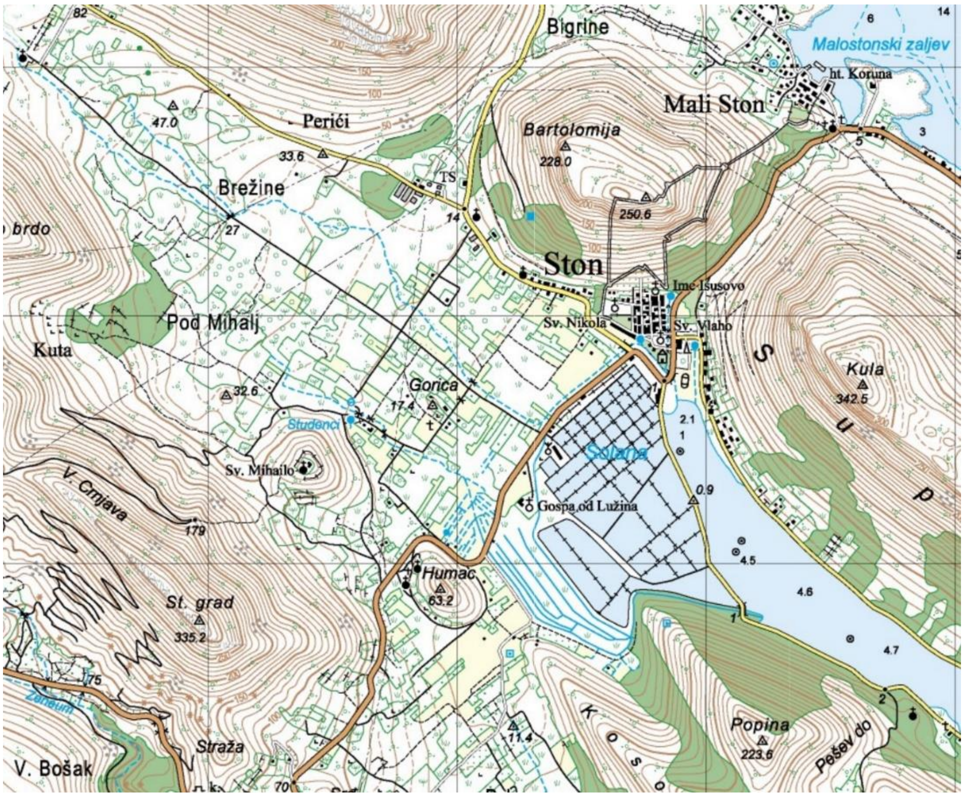


Fig. 79 Ston saltpans and the centuriation grid on the 1:25000 map of Croatia (www.arkod.hr)

The Roman centuriation in the Ston Field is still visible from the satellite pictures and reaches up to the area of the saltpans. The still-working saltpans have a regular grid, which was probably implanted at the time of the Dubrovnik Republic and slightly modified under the Habsburg Empire. Astonishingly, in this well ordered grid there is one embankment, which also serves as path and has a different, NE-SW orientation. It separates the basins of two evaporation stages. Logically, the only reason why it can have a different orientation is that it has reused or been adapted from a previously existing boundary. The nowadays freely available satellite pictures, which were not accessible to older scholars who discovered the centuriation in the Ston Field, clearly show that this path in the saltpans is parallel to the *limites* of the above *ager centuriatus*. It is 3.55 m (12 Roman *pedes*) wide, which is the usual width of the *limites quintarii*. Usually every five streets, both in the direction of the *decumani* (E-W oriented) and in the direction of the *cardini* (N-S oriented), a slightly wider road was traced, called *quintarius*, which also marked the boundary of the *ager* (Monaco 2004; Conso 2006). The embankment and at the same time passage path in the saltpans can therefore be identified with the *limitus quintarius* (in this case it is a secondary *decumanus*, fourth below the *decumanus maximus*) or boundary of the *ager centuriatus* in the Ston Field! Its orientation is adapted to the NW-SE oriented synclinal valley and it is perpendicular to the *cardo maximus*. On the 1:25000 map of Croatia, this is the only embankment on the saltpan, which is marked with a straight black line, like the other paths in the field behind that follow the ancient *limites* of centuriation (Fig. 79).

The *umbilicus* of the grid was located in the field by the church of S. Andrew (Sv. Andrija) (Zaninović 1970: 495). In such a small space, the usual grid with *centuriae* measuring 20 x 20 *actus* (side of square of 710.4 m) could not be applied. The *centuriae* in the Ston Field are smaller quadrants with an internal surface of c. 14 ha (Fig. 80), which were probably assigned to some dozens of colonists. In total, twelve *centuriae* can be counted simply with the aid of satellite pictures. The southern six *centuriae* next to the sea had an elongated rectangular shape. They included a part that was incorporated inside the walls of medieval Ston and the majority of the still-working Ston saltpans. A parallel with the situation in Ston can be drawn in the saltpans of Cervia, where the modern saltworks maintained the directions of the axes of Roman centuriation in the surrounding field. In the excavated part of the Roman saltpans of Cervia, an internal path and some drainage channels follow the same orientation of the centuriation grid (Guarnieri 2019: 20-22; Guarnieri *et al*. 2021: 48).

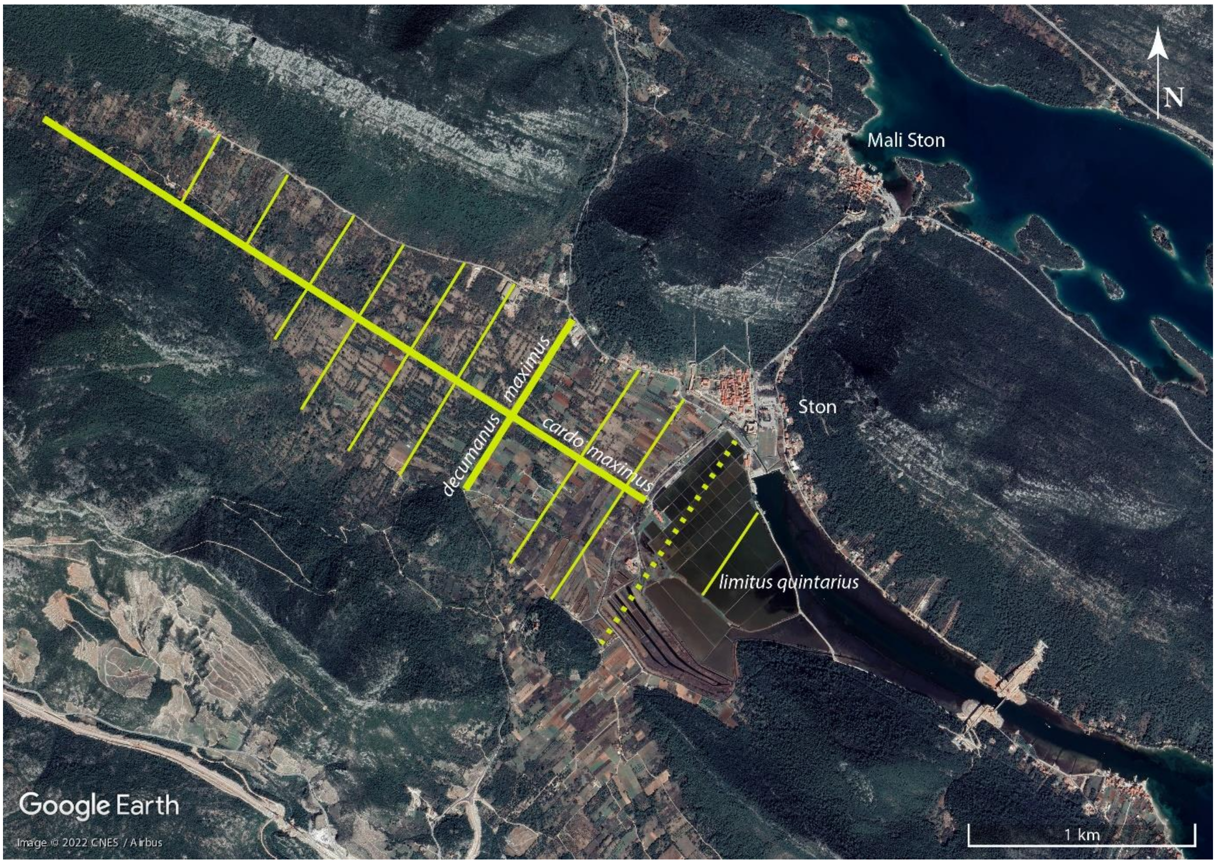


Fig. 80 Centuriation on the Ston Field and on the saltpans.

Paleoenvironmental studies have not yet been performed in the area of Ston, therefore it is not known how the area might have looked like in Classical Antiquity. We know that the marshy area around the saltpans, which was once much larger, was dried up under the Habsburg monarchy (Zaninović 1970: 492). The narrow and shallow 1-mile long channel connecting the harbor in Ston to the southern larger and deeper part of Ston Channel has been dredged in modern times and recently it has been even deepened for the construction of a marina. From the satellite pictures, the submerged ancient coastline is visible at both sides of the narrow stretch of the channel. In Roman times, the coast was most likely located further to the SE and since then the sea level has risen. In the lack of punctual sea level studies in the Ston Channel, according to general data of the sea level fluctuations on the eastern Adriatic coast, the difference between the present and the 1st century AD sea level would be roughly 1.25 m (Lambeck *et al*. 2004: 1593, fig. 12). At the same time, the sedimentation caused by the streams that flow in the sea around the saltpans probably lowered the differences in mean sea level.

Alas, the boundary of the *ager centuriatus* of the Ston Field, which is located inside the present-day saltpans of Ston, does not prove the existence of saltpans in Roman times, but the reuse of a Roman boundary in more recent saltworks. If saltpans were installed in Ston in Roman times, which is very likely, were they included inside the limits of centuriation, as it seems that it has been the case of Cervia? Saltpans are a dried up area of the sea, which might had been assigned to colonists as any other agricultural field. A second possibility is that possible ancient saltworks in Ston could had been located on the ancient coastline just outside the *ager centuriatus*, probably further to the SE, in the area of the present first evaporation basins.

Salt production in Roman villas

It is generally assumed that the majority of Roman villas on the eastern Adriatic coast had their own saltpans, or at least a salt pool, from which they were extracting salt for their own needs (Zaninović 1991: 259, 261; Krnjak 2016: 278; Grisonic 2022). Some landlords built saltpans on a bigger scale and traded salt in the neighboring markets. Because of the widespread demand for salt throughout the antique Mediterranean and its relative ease of local manufacture, salt was probably not traded over long distances, because such a practice would have been too expensive for this bulky and heavy product (Carusi 2008: 248-250; 2018; Marzano 2013: 125; García Vargas, Martínez Maganto 2017).

On the eastern Adriatic coast, most Roman coastal villas were necessarily located around fertile valleys close to natural harbors, both on the mainland and the islands (Grisonic 2022). These locations offered many economic opportunities: in *Histria*, they were associated with intensive oil and wine production, as well as with the exploitation of marine resources. One example is the enormous Roman coastal estate of Brijuni/Brioni-Fažana/Fasana, in the territory of Pula, with the majestic residential part in the Verige/Val Catena Cove on Veliki Brijun/Brioni Grande Island, and the associated pottery workshop in Fažana on the mainland (Fig. 81) (Bezeczky 1998; Begović, Schrunk 2010; Auriemma 2016; Bulić, Koncani Uhač 2020). Several other Roman villas have been discovered on Veliki Brijun Island, among which the most noteworthy are the oil production complex on Kolci Hill/Monte Collisi and the multi-stratified archaeological site in Dobrika/Val Madonna Cove, known in scholarly literature as Castrum, inhabited continuously from the 1st century BC to the 7th century AD (Bezeczky *et al*. 2015). This huge estate was owned by the family of the Laecanii Bassi, which counted three generations of consuls (Tassaux 1982). They were the biggest producers of olive oil in Istria, which was exported to northern Italy and to the Alpine-Danubian provinces (Bezeczky 1998). In AD 78, after the death of C. Laecanius Bassus, consul in AD 64, his estates on Brijuni Islands and the figlina in Fažana became imperial property.

Fig. 81 Brijuni Islands with the locations mentioned in the text (Grisonic 2022, fig. 2).

According to Schrunk and Begović (2000: 265), the complexes on Veliki Brijun Island produced oil and wine, and extracted construction stones and salt. Saltpans on the Brijuni Islands are mentioned in the AD 542 document issued by the archbishop Eufrasius from *Parentium* (Poreč), who donated one third of them to his clergy (Kandler 1848: 213; Hocquet 1978: 83; Zaninović 1991: 259). This is the oldest literary mention of the existence of saltpans in Croatian territory. These saltpans were located either (or maybe both) in Javorika/Val Laura Cove in the southern part of the island, and/or in Ribnjak Cove/Val di Torre in the northern part of the island. Both coves were once called *Val Saline* (Hocquet 1978: 83). Saltpans in Javorika Cove are documented in several Venetian documents and were active until the end of the 19th century (Hocquet 1978; Schrunk, Begović 2020: 268). During an underwater survey carried out in the 1980s in Javorika Cove, remains of a Roman productive complex with a wharf were found, with spaces interpreted for production and storage of salt (Begović, Schrunk 1999: 434-435; Koncani Uhač 2020: 40). Underwater archaeological excavations are needed to clarify the function and the chronology of these structures.

Contrary to the Istrian villas, which intensively produced oil and wine in combination with the exploitation of marine resources, the villas in *Dalmatia* were mainly linked to the latter and to maritime trade (Grisonic 2022). The peculiar morphology of the Dalmatian territory did not afford extensive agricultural exploitation, with the exception of the Ravni Kotari region, north of the colony of *Iader* (Zadar) and the lower Neretva Valley, included in the *ager* of the colony of *Narona*. Some smaller cultivable areas were located on the islands in front of *Iader*, in the territory of *Salona*, on the central Dalmatian islands and on the promontory of Pelješac (Škegro 1999: 154). However, along the coast of the province of *Dalmatia* numerous shallow bays and coves were suitable for the organization of saltworks and fish traps. Salt exploitation, as well as fishing and fish-salting industries, must have played a very important role in the productive economy of the Dalmatian coastal villas.

The best example of this statement is the Roman *villa* in Soline Bay on the small S. Klement Island, close to the bigger island and town of Hvar in central Dalmatia. The *villa* was built on the southern coast of the island, on the main eastern Adriatic seafaring route, close to a fertile field. It has different chronological phases, dating from the 2nd/1st century BC to the 6th century AD (Kirigin *et al.* 2010; Begović *et al*. 2012; Ugarković *et al*. 2016; 2019). The cove in front of the *villa* is a safe harbor, with the islet of Dobri protecting its entrance from the scirocco wind and waves. In the shallow waters of the cove there are four parallel walls under water, delimiting a flat area. They have been interpreted as partition walls of Roman saltworks and salt has been suggested as being the most important product of this *villa* (Kirigin *et al.* 2010). Salt exploitation on this site is evoked also by the toponym Soline, derived from the Latin *salinae*, as confirmed by medieval documents (Kirigin *et al.* 2010; Begović *et al.* 2012). In 2012 an underwater archaeological survey was conducted in the cove, which determined that due to the shallow depth at which the partition walls are located (20 to 50 cm), they likely belong to medieval saltworks. Nevertheless, because they are located in front of the Roman *villa* and because conspicuous Roman artifacts lay scattered across the surface, it is very likely that the remains of ancient saltpans are hidden underneath the deep sediment that formed the foundation for the medieval saltpans (Brusić *et al.* 2012). The confirmation of this hypothesis must wait for underwater archaeological excavations. It is interesting to note that during the last excavation campaign, some basins with waterproof mortar have been discovered in the *pars rustica* of the *villa*, maybe for the production of fish sauces (Ugarković *et al*. 2019).

The fish processing sites

Salt exploitation and the making of fish sauces were closely related. The fish processing establishments needed a considerable amount of salt in the process to obtain the fish sauces (*garum, muria, liquamen, allec/hallex*), which were so popular in Classical Antiquity, fostering important medium- and long-distance commerce (Grisonic 2022). Widespread was also the trade of salt-fish (Roman *salsamentum* or Greek *tarichos*) (Auriemma 2016: 489). The fish-salting factories were established in areas where the fish and salt supplies were easy to obtain, even if sometimes one of the two had to be imported from more distant zones (Carusi 2008: 249-250; 2018). In one passage of his *Naturalis Historia*, Pliny stated that *Dalmatia* was known for the production of *muria* (*Nat. Hist.*, XXXI, 94), while at the time of Cassiodorus, we know that numerous *garismatia* – factories producing *garum* – existed in Istria (*Var.,* XII, 22, 4). Despite the ancient literary sources, the remains of fish processing facilities on the eastern Adriatic have not yet been identified, probably because they were different from those known in the rest of the Roman world (Auriemma 2016: 488). Nevertheless, the site of Kumenat south of Biograd-na-Moru could be an exception to this statement (see below) and maybe also the new evidence that is emerging in the *villa* of S. Klement (Hvar).

Fish processing in Histrian villas

For the moment we do not have clear evidence of fish processing workshops in Istria, but we do have the remains of numerous *vivaria* of quite big dimensions, which were probably connected to salt production sites (Grisonic 2022). In these larger Roman fishponds, different types of fish would have been bred and sold at local and more distant markets. A considerable amount of salt would have been required for fish salting and for processing fish into different kinds of fish sauces. The economy of the Istrian Peninsula flourished in the first two centuries of the Roman Empire. All along the coast from *Tergeste* (Trieste) to *Colonia Iulia Pola* (Pula) big maritime villas were built, exploiting the fertile agricultural lands of the Istrian Peninsula and the rich marine resources of the Adriatic Sea (Tassaux 1984; Matijašić 2001; Girardi-Jurkić 2004; Auriemma 2016: 475). In several maritime villas large *vivaria* were constructed (Carre, Auriemma 2009; Auriemma 2016: 475, with previous bibliography).

A huge Roman estate existed in Jernejev zaliv/San Bartolomeo Cove close to Ankaran in Slovenia, which included at least a partially residential *villa* on Punta Sottile, big installations in the harbor, the *villa* on Debeli rtič/Punta Grossa connected to a big fish salting workshop and eventual saltpans at the bottom of the bay (Auriemma *et al*. 2008: 142; Auriemma 2016: 478). All these structures could have been included in one unitary property, as it is the case with the estate of S. Marina-Loron-Červar and the estates on Veliki Brijun Island. Unfortunately, in S. Bartolomeo Cove this cannot be verified, due to the anthropization on this part of the coast.

Fizine, located in between Portorož and Piran on the Slovenian coast, is a toponym derived from Latin *figlinae*. A Roman settlement and *vivarium* with two pools (measuring 37 x 29 and 26 x 25 m, with 2.7 to 3.5 m wide walls) are located next to the two Austrian salt warehouses built at the beginning of the 19th century. This shows the continuity of exploitation of marine resources from Classical Antiquity through the Modern era (Gaspari *et al*. 2007; Stokin *et al*. 2008; Auriemma 2016: 491). The *vivarium* was in use between the 1st century BC and the 5th century AD (Stokin *et al*. 2008: 63) and it was built about 2 km north of the location of the medieval saltpans of Lucija (Piran), attested from 1278 (Hocquet 1978: 82). About 1 km northwest of Fizine, there is another significant toponym: Fornače, deriving from Latin *furnax*, probably alluding to the existence of a pottery workshop.

The coastal complex of S. Marina-Loron-Červar (Fig. 82), known for the big pottery workshop in Loron, comprised a *villa* in Červar for oil production that possibly also had fish processing facilities (Tassaux *et al*. 2001; Carre *et al*. 2012; Džin 2011; Auriemma 2016: 476; Rousse *et al*. 2020). On the northern side of Črvar Bay/Porto Cervera, in Kupanja, there was a large *vivarium*. Possible saltpans could have been located at the entrance of the bay, evoked by the toponyms Cape/Punta Soline, Soline Cove and Velike Soline (Carre *et al*. 2012: 104-106; Auriemma 2016). Velike Soline is nowadays a coastal marsh, located in a sheltered position at the internal, eastern side of the cape, open towards Črvar Bay and connected to the sea by a narrow passage. This huge maritime *villa* was conceived according to a unitary plan, which integrated the production of oil, fish farming, salting and processing and the fabrication of amphorae for the transport of these goods (Auriemma 2016). The small-size Dressel 6B amphorae produced in the Loron kilns may have been designed exactly for trading fish sauces (Marion 2009; Maggi, Marion 2011; Marion, Tassaux 2020: 31). This huge senatorial and later imperial property was in operation from approximately AD 10 to the end of the 5th century AD. During the first half of the 1st century AD, the estate belonged to Statilius Taurus Sisenna, consul in 16 BC and son of T. Statilius Taurus, one of the closest collaborators of Emperor Augustus (Girardi-Jurkić 2011: 60). Later owners were Messalina and Calvia Crispinilla, until it became an imperial property under the reign of Domitianus (Tassaux *et al*. 2001).

Fig. 82 The coast from Črvar Bay to Busuja Cove north of Poreč, with the two Roman estates of S. Marina-Loron-Červar and Villa Mozaik-Busuja (Grisonic 2022, fig. 3).

Less than 1 km south of Velike Soline there is a smaller coastal marsh known as Male Soline (Grisonic 2022). Both locations might have produced salt until the end of the Modern era (Zaninović 2007). Male Soline is situated next to Pličina (= shoal) beach, north of the Roman *villa* known as Villa Mozaik/Mosaico, the *fundus* of which extended from approximately Male Soline to Cape Albareti at the northern side of S. Martin Bay, for a total surface of about 135 hectares (Carre *et al*. 2012). The fishpond in Busuja Cove most likely belonged to this *villa*

(Carre *et al*. 2012; Rousse *et al*. 2013). In the nearby Fratrija located at the eastern side of the cove, numerous remains of crushed and pierced marine snails *Murex trunculus* and *Murex brandaris* testify to the existence of a purple dye workshop in the vicinity (Carre *et al*. 2012; Machebœuf *et al*. 2013). Both the *vivarium* and the purple dye workshop in Busuja Cove must have required large quantities of salt, possibly harvested in Male Soline. According to F. Tassaux, additional saltpans could have been situated at the bottom of Busuja Cove, sheltered from the bora and scirocco winds (Carre *et al*. 2012).

Fish processing in Dalmatia

The Roman province of *Dalmatia* had all the natural characteristics to develop an important fish processing industry, of which, with the exception maybe of the structures in Kumenat, we lack direct archaeological evidence (Borzić 2011: 82; Parica 2017: 93-95; Lipovac Vrkljan, Konestra 2017: 54-55; Grisonic 2022). Kumenat is a big, but poorly known coastal archaeological site, located south of Biograd-na-Moru, in between Soline Cove and Crvena Luka, which preserves ruins of various Roman structures, mosaic floors, a cistern, canalization and two piers (Ilakovac 1992; Parica 2017: 93-95, fig. 6-7). According to Ilakovac, who surveyed the site in the 1970s, the most spectacular remains on the site were dozens of square shallow pools hollowed in the coastal rock, organized in an orthogonal coordinate system. Some of the pools have been submerged by the rise in relative sea levels. Ilakovac stated that these pits (Fig. 83) were filled with fertile humus for the intensive cultivation of vines and that all these remains belonged to a Roman estate, active between the 1st and 4th centuries AD (Ilakovac 1992).

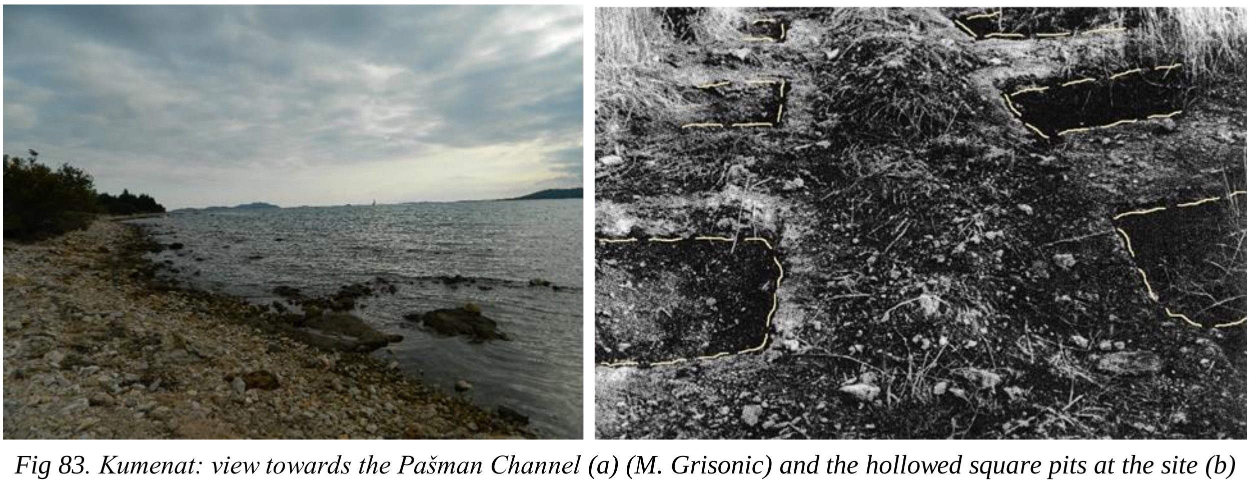


Fig 83. Kumenat: view towards the Pašman Channel (a) (M. Grisonic) and the hollowed square pits at the site (b) (Ilakovac 1992).

Matijašić (2012b) accepted the thesis of Roman planting pits for the site of Kumenat and he found hundreds of similar pits on the Kamenjak Promontory in southern Istria. Contrarily, both Borzić (2011: 82) and Parica (2017: 93-95) share a different opinion about the pits at Kumenat: they should rather constitute remains of *cetariae* or Roman fish salting vats. New archaeological researches are needed to unveil the purpose of this intriguing site, without forgetting that it is located in between *Soline* (saltpans) and *Slanica* (*slan* = salty) coves, both deriving from Latin *sal*.

According to some indirect archaeological evidence, we can assume that one of the most important fish-processing workshops in the Roman province of *Dalmatia* was located close to the large pottery manufacture at the *Ad Turres* Roman road station, in present-day Crikvenica (Grisonic 2022). This is for the moment the only confirmed ceramic manufacturing center of the province of *Dalmatia*, which is estimated to have operated a regional-scale production (Lipovac Vrkljan *et al.* 2016; Lipovac Vrkljan, Konestra 2018). From 2006 to 2015, this site was systematically excavated by the Institute of Archaeology of Zagreb and the City of Crikvenica, under the scientific direction of Goranka Lipovac Vrkljan. Remains of four ceramic kilns with many different manufacturing spaces, as well as dozens of tons of waste ceramic materials were found. The activity of the workshop dates from the mid-1st century to the early 2nd century AD, when it reached its peak of production (Lipovac Vrkljan *et al.* 2016; Lipovac Vrkljan, Konestra 2018). In the workshop, more than ninety different pottery shapes and eleven types of amphorae, as well as roof tiles, were fabricated. Based on morphological and comparative analyses, it was possible to distinguish different amphorae types, which served as containers for the transport of wine, oil and fish sauces (Lipovac Vrkljan *et al.* 2016: 145). Owing to the roof tiles' stamps, we know that the pottery manufacture was owned by Sextus Metilius Maximus.

Crikvenica is located in the deep semi-closed Kvarner Gulf in the northern part of ancient *Liburnia*, the coastal territory inhabited by the native Liburni and later absorbed into the Roman province of *Dalmatia*. These indented shores, dotted with abundant coves and inlets, constituted a rich resource for fish. In Classical Antiquity, the fishing activity in this region is attested by archaeological finds, but the existence of fish-salting workshops that also produced the renowned fish sauces is harder to document. For the moment, no remains of built fish processing industries have been found on this coast (Lipovac Vrkljan, Konestra 2017: 50-52; Grisonic 2022). Nevertheless, the pottery workshop in Crikvenica also produced a distinct type of amphora, denominated “Crikvenica fish amphora”. No entire specimens of this amphora have been found yet, but it is one of the three most attested types of amphorae recoverd from the Crikvenica pottery manufacture site. The morphological elements of the fragments belonging to this type suggest that it was small, perhaps 30-40 cm high. For the moment, the typology of this amphora seems to be connected to one type of the Adriatic fish-salting amphorae, known as Grado I (Lipovac Vrkljan, Konestra 2017: 53-54, with bibliography). As attested by several *tituli picti*, the Grado I type amphorae were used for the transport of *garum* (Auriemma 2000; Carre *et al.* 2009; Fig. 84).

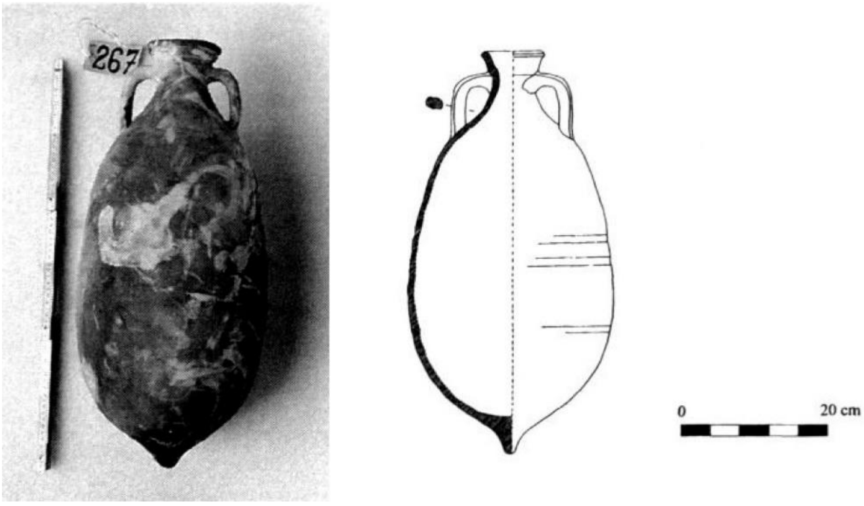


Fig. 84 Two variants of the Grado 1 garum *amphora (Auriemma 2000).*

According to the similarity in shape and dimension, we can assume that the Crikvenica fish-salting amphorae were manufactured to hold similar contents. Considering the testimony of Pliny (*Nat. Hist.*, XXXI, 93-95), who mentioned the well-known Dalmatian *muria* as well as the abundant sources of fish in the Kvarner Gulf, it is hard to believe that this region lacked fish processing facilities. Another element suggesting the presence of regional fish-salting workshops is the fact that very few amphorae types manufactured on the Italic or Iberian Peninsulas to contain fish sauces have been found in *Liburnia* and *Dalmatia* in general (Lipovac Vrkljan, Konestra 2017: 55-56; Borzić, Ožanić Roguljić 2018). The continuation of the archaeological and archaeometric analyses of these amphorae and their contents will hopefully provide us with further elements to demonstrate the existence of local fish processing industries (Lipovac Vrkljan, Konestra 2017: 55-56), one of which might have existed in the area of ancient *Cissa*, on the northern part of the island of Pag (Grisonic, Stepan 2022).

It is likely that a fish-salting factory situated somewhere in the proximity of, or at least easily reachable from the pottery manufacture in Crikvenica would have imported salt from the saltpans located at the bottom of Soline Bay on Krk Island, just on the other side of the Vinodol Channel (Grisonic 2022). This was a famous medieval salt exploitation site, producing high quality salt (Šiljeg 2017: 104-105). Like most of eastern Adriatic saltpans, once they fell under Venetian rule after 1409, they were abandoned in order not to compete with the Venetian saltpans. While currently there is no direct archaeological evidence, scholars believe that salt was extracted from Soline Bay also in Roman times (Šiljeg 2017: 104-105).

In the valley of Pag, the continuity of salt exploitation from the Liburnian or Roman period, which has been suggested by several authors (Juras 1910: 41; Suić 1953: 14; Zaninović 1991; Oštarić, Kurilić 2013), can at present only be insinuated. The presence of an ideal natural and climatic context: a large NW-oriented flysh valley, abundant in clay, the high insolation (Pag is one of the less rainy territories on the eastern Adriatic coast), the extremely frequent and strong winds and the salinity of the sea, which in the closed and shallow (up to 45 m deep) Gulf of Pag reaches higher concentrations than the average in the Adriatic Sea, made the location where the present saltpans are situated exceptional in the whole Dalmatian region in much earlier periods as well. Although the town of Pag developed in the Middle Ages and there are very few archaeological findings that show a frequentation of the zone around the present saltpans in Classical Antiquity (the Roman graveyard in Zamet next to the saltpans, with artifacts dating from the 1st to the 4th centuries AD, most likely connected to a settlement or a *villa rustica*), this whole area likely gravitated both towards *Aenona*, located south on the mainland, and the northern part of the island, which included the settlement of *Cissa*, after which the whole island of Pag was named. *Cissa* is mentioned by Pliny in the 1st century AD (*Nat. Hist*., III, 140). It developed in the area of the Novalja Valley, in between the present town of Novalja and the villages of Stara Novalja and Caska, the latter located at the northern shore of the Gulf of Pag. Before the Roman conquest, this whole northern part of the island was settled by Liburnians, whose main *oppidum* was located on the Košljun Hill bordering the Novalja Valley. Since the end of the 1st century BC, the area was Romanized: Novalja was the main port set on the eastern Adriatic seafaring route, with a 1042 m long aqueduct hollowed in the living rock (Radić Rossi, Zmaić 2009) and a ceramic workshop (Gluščević 2017). Stara Novalja was an internal port, open on the Velebit Channel, while in Caska Cove there was an imposing maritime *villa* of the Roman senatorial family of the Calpurnii Pisones, with a second, 8200 m long aqueduct that was supplying their property (see Radić Rossi, Boetto 2020).

The traditional source of sustenance of Caska was fishing, especially that of tuna, attested by the still-surviving Tunera or Turanj, the tuna fish watching tower, built in masonry on the shore. Considering that at least from the 17th century the main economic activity in Caska Cove was tuna fishing and that Caska was known for this in the Adriatic, we can assume that fishing and fish processing were already common activities in Roman times. The 1637 statute of the Pag Commune gives regulations about the trade of mackerel in Caska Cove, not mentioning tunas. Tuna trade in Caska is remarked a little later, in 1662: it was regulated by the Venetian Republic, which shipped tunas mainly to Venice (Basioli 1962: 47). In his *Viaggio in Dalmazia*, Alberto Fortis (1741-1803), the Venetian monk who travelled throughout this region, wrote that the Gulf of Pag was frequented by schools of tuna that were then unable to leave (Fortis 2004: 267, 279-280). Tuna watching towers, among which the Tunera in Caska is the oldest, were located in at least five different spots on the island and were in function until the mid-20th century (Basioli 1962: 47; Magaš 2011: 41). Record tuna catches in Caska occurred during the 18th and 19th centuries. The net used to close Caska Cove to catch the tunas, called "preteg," was the longest on the Adriatic Sea, measuring 920 m, while smaller tuna fishing nets were called "trate" (Basioli 1962: 47-48).

It is interesting to note that the beloved Roman sauce *muria*, of which Pliny says that *Dalmatia* was known (*Nat. Hist.*, XXXI, 93-95), was made of tuna or by mixing different types of fish. For the moment, we are lacking clear archaeological evidence of fish processing in Caska Cove during Classical Antiquity. The Tunera tower was built during the 19th century above the remains of a destroyed Roman wall, which belonged to the sea façade of the maritime *villa* in Caska (Radić Rossi, Boetto 2020). In two spots of the cove there are the remains of structures in *opus signinum* from Roman times: one is located in front of the Roman breakwater in the NE part of Caska Cove and another was built on the nearby Zrće Peninsula to the SW of Caska Cove, on the opposite side from where the Tunera tower stands (Fig. 85). The function of these structures remains unknown (Radić Rossi, Boetto 2020), but due to their vicinity to the sea and the lining in waterproof *opus signinum*, we can suppose that they were connected to activities that involved processing of fish and/or other marine resources.

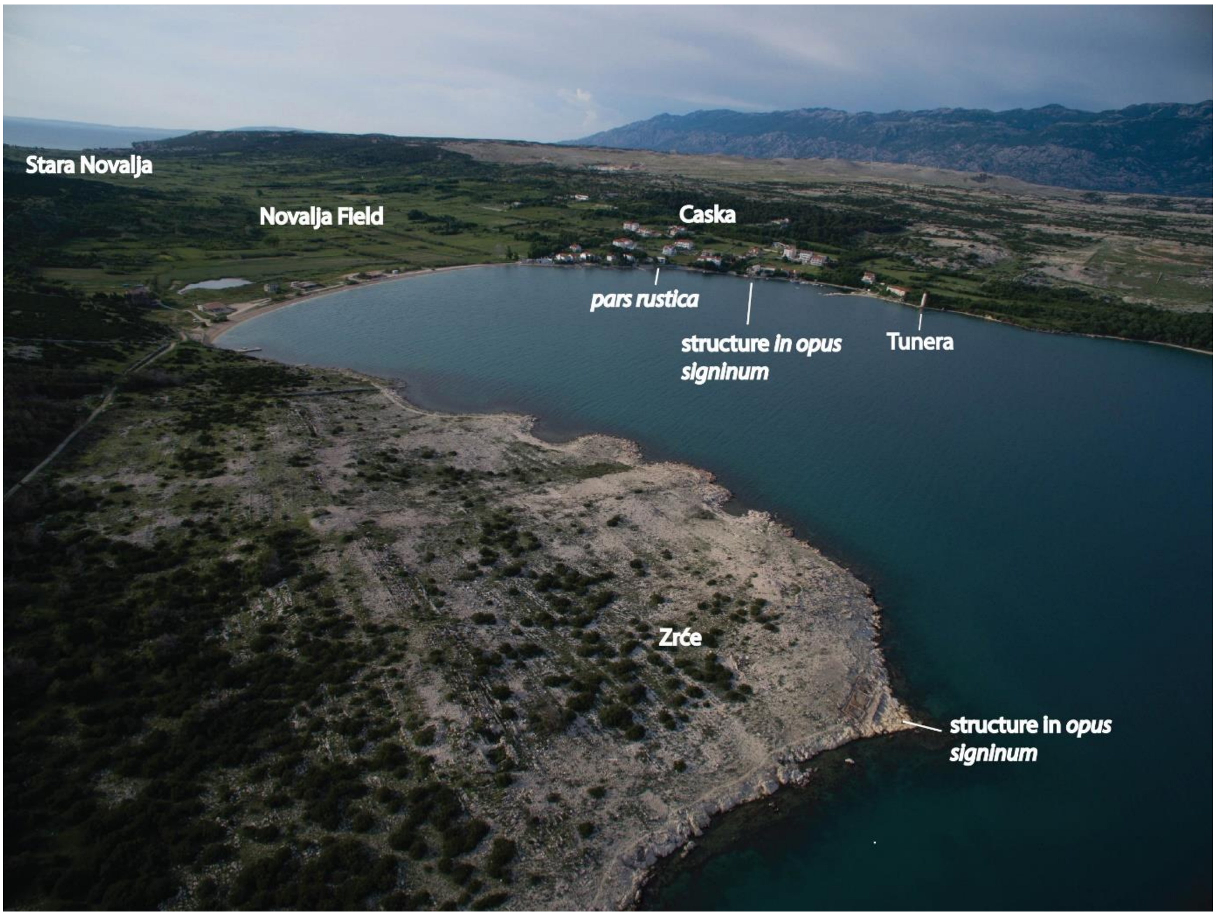


Fig. 85 Caska Cove and the Novalja Field (photo of Ervin Šilić, courtesy of I. Radić Rossi).

Fishing for migratory fish such as tuna or mackerel produced a great amount of fish all at once and the surplus had to be sold or processed immediately (Bekker-Nielsen 2010: 203; Marzano 2013: 66-79). The estimated quantity of salt needed for fish salting was half or equal to the weight of the product (see Felici 2018: 138), hence the need for locally available sources of salt. In the Middle Ages, saltpans are attested in Pag and Stara Novalja (Peričić 2001: 47), just 1 km north of Caska. According to a local legend, saltpans were installed also on Cape Katarelac, where there is the coastal lake of Lodovo and a shoal (Oštarić 2011: 310), located just in front of the structure in *opus signinum* on the Zrće Peninsula (Fig. 86). At the same time, a local production of ceramic containers designed for fish products (Caska 1 type), which for the moment appear only in Caska, has been postulated (Grisonic, Stepan 2022).

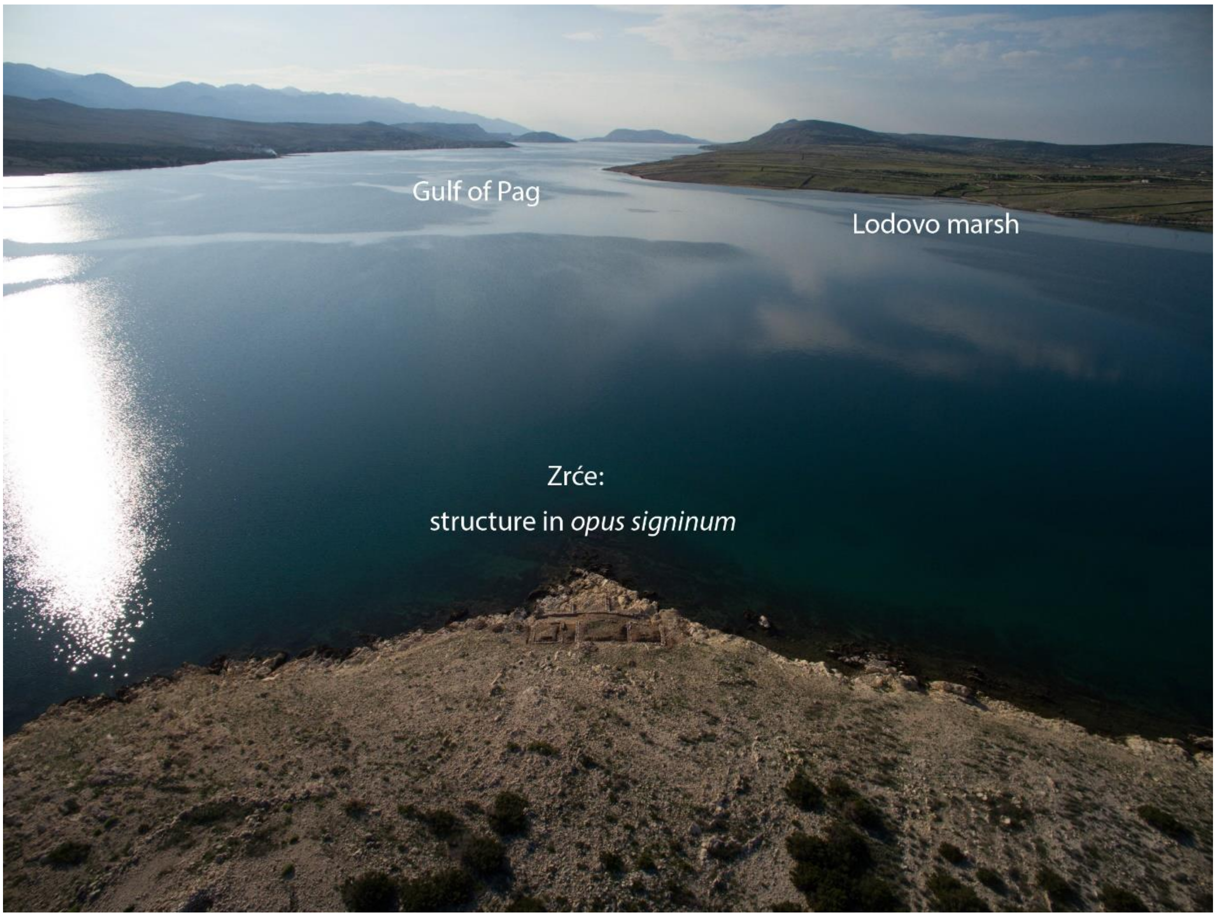


Fig. 86 View from Cape Zrće towards south (photo of Ervin Šilić, courtesy of I. Radić Rossi).

The distribution of the three mentioned locally produced types of amphorae, which possibly contained fish sauces (the small-size Dressel 6B amphorae from Loron, the Crikvenica fish amphora and the Caska 1 type amphora), must yet be determined. Salt was not only imported to the sites, where fish sauces were produced, but it most likely also followed the same trade routes and shared the same markets of the fish products.

3.7.2. Functioning and typology of saltpans

Ancient saltpans on the eastern Adriatic coast can be divided in two main types: primitive and traditional.

Primitive saltpans, both coastal and inland, are formed of a pond hollowed in a rock, where seawater is brought by waves or filled by men. They can be found on remote islands and amid rural communities (Petanidou 2005: 14). Salt forms with simple solar evaporation and it is gathered with simple tools like spoons or even bare fingers. They are frequent on the Greek islands (particularly on Kythira), Malta and the Canary Islands. Along the eastern Adriatic coast, primitive saltpans constituted of a simple pond on the shore, fenced with a drywall (Bodrožić *et al*. 2018).

Traditional saltpans (salt-pans/salt pans), saltworks (salt-works/salt works), salterns or salinas/salines (sing. salina) are intertidal facilities, in which, during high tide, seawater is channeled into a system of shallow pools (basins), usually lined in mud. The water flows by gravity between successive basins of different evaporation grades, regulated by sluice gates. In every succession of pools, thanks to the action of the sun and winds, the brine reaches a higher concentration, until the crystallization phase, when salt can be harvested (Trakadas 2015: 17-19; Bechor *et al*. 2020). The first evaporation basins are usually located on higher ground and with each succession of basins the ground is gradually lowered. The crystallization pools, where salt is harvested, are generally built on the lowest ground, but this is not always the case, as pumps can also be used to raise water from lower to higher parts of the saltpan. In Sečovlje (Piran) Salina in Slovenian Istria a manual salt water pump called "zorno" was used until the 1940s, later replaced by the more functional big movable windmill pump "machina" (Žagar 1995: 70-72; Bonifacio 2005: 65; see the drawing of the "zorno" in Lusa 2005: 60). Until the modernization of the saltpans in Pag at the beginning of the 20th century, salt workers used to move the brine among the basins with showels (Usmiani 1984; Peričić 2001)! Saltpans need constant maintenance: after the salt harvest, the basins, embankments and dikes need to be repaired every year.

The difficulty of finding remains of saltpans is related to the perishable materials used to construct the pools and the embankments of saltworks, which consisted of mud, wood and rushes, which leave little or no evidence in the archaeological record, while the stones employed in the saltpan structures could have been reused for the construction of different, more recent structures (Grisonic 2022). Since the relative sea level in this part of the Adriatic has risen over the past 2,000 years, most remains of Roman coastal structures, including saltpans, are nowadays partially submerged. The saltpans from Classical Antiquity on the northeastern Adriatic coast are located at approximately 1 to 1.5 m depth below relative sea level (Faivre *et al*. 2010).

Contemporary saltpans

From the 20th century, the mechanization and other technological improvements have changed the architecture and the productivity of the saltpans to some extension, but the main improvements have been made in the harvesting and transportation of salt, while the evaporation process fundamentally remained the same (Bergier 1984: 97-104; Hocquet *et al*. 2001: 41-86).

The surface of saltpans comprises two main parts: the evaporation and the crystallization area. On eastern Adriatic saltpans, in the evaporation area water reaches the density of 25° Bé, while in the crystallization basins the obtained density of water ranges between 25° and 30° Bé. The evaporation area is usually divided into four parts, and the size of each evaporation surface depends on the configuration of the ground, the construction conditions and on the desired water concentration to be achieved on each succeeding surface. The first evaporation generally comprises 60 % of the saltpans' surface. It is normally provided with a channel for the inflow of water from the sea; the water enters through a sluice gate during high tide and then flows with the aid of gravitation (or with the assistance of pumps) in the following basins. During stage I, water thickens to 7° Bé, during stage II to 12°-13° Bé, during stage III to 20° Bé and during stage IV to 25° Bé. In pre-crystallization basins, organic (algae) and inorganic (clay) impurities are deposited, together with heavier metals (Bonin 2009: 79).

Crystallization basins are usually impermeable to avoid the loss of brine. Like in previous basins, water flows in them with the aid of gravitation or pumps (Bonin 2009: 79). With the action of the sun and wind, water gradually evaporates and what is left on the bottom of the pools in pure white salt, ready to be gathered.

While the evaporation process did not change over time, some improvements have nevertheless been made in the frequency of salt harvest. Depending on the climate of different geographical latitudes, **continuous** or **periodical/intermittent crystallization** can be applied in the saltpans. Continuous crystallization presupposes one harvest of salt per season (or even one harvest every four/five years, like in the Margherita di Savoia saltworks), while the periodical crystallization involves several harvests per season, which can occur daily or few times during the season (Petanidou 2005: 13). The northern and central eastern Adriatic saltpans, where rains are more frequent, belong to this second group: salt is collected every day to avoid the loss that rain may cause. In Ston, which is located in southern Dalmatia, the weather is sunnier and in salt is collected less frequently, usually every three to four days.

Elimination of impurities

During the salt production cycle, other salts, like magnesium, which give to the salt a bitter taste, need to be gradually eliminated. These salts have a different solubility degree, therefore the marine water is let into a succession of pools, of which the surface and depth progressively diminish. At each step the different kinds of salts deposit at the bottom of the pools, until the sodium chloride or common salt is obtained. In the Mediterranean basin, this cyclus usually lasts 80-100 days. The crystallization of sodium chloride is faster than the crystallization of magnesium salts, therefore in the final crystallization basins the crust of salt has to be shoveled before all the brine has evaporated and the magnesium salts deposited (Forbes 1955[3]: 164; Carusi 2008: 36). The saturated brine that is left in the crystallization basins, containing almost all magnesium and some potassium salts, is called mother liquor (It. acqua madre, in Sečovlje "acqua mora", in Pag "lužina"). Because it is very bitter, it needs to be expulsed from the basins or cleansed by leaching, which eliminates most magnesium salts. The simplest way to do it is to leave heaps of salt under the rain that makes the bitter taste fade and it diminishes the hygroscopicity. Sometimes leaching is even performed at earlier stages (Forbes 1955[3]: 164). Pliny (*Nat. Hist.*, XXXI, 81) stated that in Utica salt was collected in big heaps, where it was probably let expose to the rain for the same purpose. This practice was therefore probably used in Roman times.

The elimination of impurities can also be acquired through the addition of fresh water to raw salt (Harding 2013). It is not clear yet whether this was done in Classical Antiquity. Pliny precised that fresh water was added in the salt pools to help crystallization, although not in Crete (*Nat. Hist.*, XXXI, 81). He also decribed the benefitial effects of rain on salt.

In Prehistory, fresh water was used for brine processing. The presence of a pond near the *castelliere* (fortified structure on a hilltop) of Elleri close to Muggia is judged fundamental for the workshop for boiling brine that was probably located on it (Montagnari Kokelj 2007: 162, 177).

Ethnographic examples have shown that salty earth is washed, while salt plants and seaweeds are burned and their ashes are then washed with fresh water or with lightly concentrated brine, in order to obtain concentrated brine (Gouletquer, Weller 2015: 15-16). The role of fresh water is to remove the undesired minerals.

Saltpans in the Modern period and in the Middle Ages

Salt harvesting is a seasonal activity that in the Eastern Adriatic starts at the beginning of May, when the rains become less common, and ends towards the end of September or at the beginning of October. In historical times whole families, who were mostly farmers or fishers in other periods of the year, used to work on the saltpans, sometimes (like in Sečovlje) even moving to the saltpan houses that they had close to their salt fields.

During the whole period of the Middle Ages, chapels were built next to the saltpans, because “heavenly help” was invoked for a good harvest. Around the saltpans of Pag there is the biggest concentration of churches and chapels located outside the medieval settlements (Hilje 2011: 165). At the same time, churches and monasteries were among the biggest owners of saltpans.

Medieval documents have preserved different nomenclatures of the features that constitute the saltworks, which in various Mediterranean and Atlantic saltpans had different names (see Joubert 1973; Hocquet, Hocquet 1974; Hocquet 1978; 1985; Benati 1997; Ditchfield 2007). The main embankment, which separated the saltpans from the sea was called "agger", "arzere" or "argine" (Hocquet 1978: 119). The first evaporation basin was called "moraro" and the successive ones "corboli". An embankment, the "secunda/secondal," was protecting the main productive part of the saltpans, with the smallest pools. One part of these basins were the so-called "servidori" or final evaporation pools, which were receiving brine through the channel called "lida". From the "servidori" the highly concentrated brine was poured into the annexed "cavedini" or crystallization pools, where salt could be finally gathered (see the plan and presumed functioning of the saltpans in Brbinj in Ch. 4.1.2).

Medieval documents also attest an improvement of the salt-making tecnhiques, which occurred in Pag, probably during the 14th century. The pattern of the salt pools changed, with the introduction of 21 "servidori" and 21 "cavedini". Furthermore, "petola" started to be cultivated at the bottom of the "cavedini", which greatly improved the quality of salt. Salters from Pag spread this technology in Piran (1370-1380) and Trieste (Hocquet 2013).

Saltpans in Classical Antiquity

According to most scholars, the origin of saltpans in the Mediterranean is connected with the development of big cities (notably Rome), when the demand for salt greatly increased (Giovannini 1985; Traina 1992; Alessandri, Attema 2022). The Romans are considered the ones who started to produce salt on large scale.

Ancient authors, foremost Rutilius Claudius Namatianus during the 5th century AD (*De reditu suo*, 475-490), indicate that the technological process of obtaining salt through coastal saltpans was very similar in Roman times (Grisonic 2022). This was confirmed by the finding of the Roman saltpans of O Areal, buried underneath the modern city of Vigo in Galicia, on the Spanish Atlantic coast. These saltpans, the best preserved of the Roman world, consist of successions of rectangular evaporation ponds of various dimensions, paved with impermeable clay and delimited by vertically driven stone slabs. They can be dated from the middle of the 1st century AD to the 3rd/4th centuries AD and were probably supplying the nearby fish processing facility (Castro Carrera 2006; Currás 2017; Castro Carrera *et al*. 2022). The similar functioning of Roman and present traditional saltpans has also been shown on the saltworks in Cervia, which date from the end of the 3rd (?) century BC to the middle of the 1st century AD.

When the slope of the terrain did not allow the flow of seawater to successive salt pools by gravity, as was the case with the saltpans of O Areal, different water-lifting devices, an example of which is the *tympanum* mentioned by Vitruvius (*De arch*., X, 4, 1-2), were probably used to move water among the different compartments of the saltpans. In some cases, this could also had been done manually, using shovels, as it is still attested in the 19th century saltpans of Pag (Usmiani 1984; Peričić 2001).

Dasen Vrsalović is one of the few scholars who first identified the sumberged remains of few ancient saltpans along the eastern Adriatic coast. He stated that the saltpans from Classical Antiquity were located in shallow bays with high insolation and were separated from the sea by long walls bound by mortar. According to him, examples of these were the separation walls in Lavsa and Šipnate on the Kornati archipelago (Vrsalović 1979: 467, 549, tab. 62). We have shown that the walls in Lavsa are in fact drywalls, built with several rows of irregular blocks of various dimensions, which have concreted together underwater. These walls all belong to the medieval saltpans, which are attested in several Late Medieval archival documents (see Ch. 4.1.2).

It is still too early to postulate any typological classification of the saltpans on the eastern Adriatic coast, because none of them has been excavated to an extent which would allow a sufficient understanding. The submerged embankments and pools visible on the satellite pictures on many sites along the mainland coast and the islands, are located at lower depths (generally less than 1 m) and probably can all be attributed to medieval saltpans. Possible saltpans from Classical Antiquity should in many cases be located in the proximate vicinity of the medieval ones, at slightly greater depths (generally 1 to 1.5 m below the local datum, as indicated by Lambeck *et al*. 2004 and Faivre *et al.* 2010). The Makirina case study has highlighted that the embankments and other elements of older saltpans could have been reused in more recent saltworks, in which they might have had a different function, adapted to the changing mean sea level (see Ch. 4.1.1). Bearing all this in mind, some first observations can nevertheless be made.

The eastern Adriatic saltpans from Classical Antiquity, described site by site in the following chapter, show several common characteristics:

1. Stone embankments (Makirina, Pakoštane, Kopilice) that separated the saltpans from the sea. They can be identified with the *margo, -inis* mentioned by Manilius (*Astr.*, V, 684). The separation wall in Makirina was a drywall built with carefully selected, more or less regularly cut blocks and it differs from the unsystematic assemblage of stones observed on the sites of medieval saltpans.
2. Parallel and perpendicular walls (Makirina) or rows of vertically driven poles, which created palisades (Bijeca, Pantan, Kopilice). In Makirina mortar was found on two secondary walls, which delimited a channel provided with a sluice gate.

3. Rows of vertically driven poles that support planks placed with their longer side upright (Bijeca, Pakoštane, Pantan). This is a common feature in all still-active saltpans, where so-built fences protect the edges of the embankments in between the salt pools and the channels or between the different salt basins.
4. Rectangular basins inserted in a wooden frame (Bijeca, Pakoštane).
5. Channels (Bijeca, Pakoštane, Makirina).
6. Openings for sluice gates, the *cataractae* mentioned by Rutilius Namatianus (I, 481) (Makirina). A wooden sluice gate, similar to the ones discovered in Cervia, was found in Makirina.
7. Wooden gutters/troughs (Bijeca, Pantan), which served to move water in the saltpans and maybe among their different compartments. Direct parallels can be drawn with inland saltpans, an example of which are the still-surviving saltworks of Añana.
8. Nearby piers, which were probably also used for the transport of salt by sea.
9. The area in between the saltpans' separation wall and the shore needs to be a flat plain with abundant clay sediments, suitable for the construction of salt pools, channels and dykes.
10. The remains of saltpans from Classical Antiquity are presently located at about 1 to 1.5 m depth below the local datum, on the ancient coastline (while the fishponds were necessarily located at greater depths). Punctual sea level studies need to be performed at each site to obtain reliable values of the mean sea level changes during various historical periods. In lack of them, depths that oscillate around -1 to -1.5 m can be taken as an approximate indicator of the mean sea level from 2,000 years ago.

Differences between saltpans and fishponds

Medieval and modern archival documents attest the possible transformation of saltpans into fishponds, especially in the 15th century, after Venice banned almost all eastern Adriatic saltworks, which had been previously widespread all along the mainland and the islands.

Because the saltpan sites from Classical Antiquity have been only partially investigated, we are lacking the wider picture and a clearer typology of ancient saltpans cannot be postulated for the moment. We can only differentiate between the traditional successive-pool evaporation saltpans and the primitive saltpans, which constituted of a single or some coastal shallow pools, sometimes delimited by drywalls. The latter saltpans could sometimes be confused with fish traps and fishponds. While the differences with the fish traps could be fewer, the crucial fact to remember compared with the fishponds is the difference in depth: saltpans were located directly on the ancient coastline, while fishponds were generally quite deeper structures that needed to host fish. Remains of saltpans can nowadays be found at very shallow depths, up to -1.5 m, while the fishponds can reach 4-11 m depth.

The ancient fishponds (*vivaria*) along the eastern Adriatic coast were usually large structures with several pools, built to hold different species of fish that were later salted or processed, or they held fresh fish that was consumed on local markets (Carre, Auriemma 2009; Auriemma 2016: 478). Powerful senatorial families from Rome, who acquired big properties on the Istrian Peninsula, started to build fishponds inside their estates in the Augustan age. The quite important dimensions of the *vivaria* (1200-1500 m^2 and 2200-2500 m^2) suggest that fish or fish products were designed for trade (Auriemma 2016: 481). The fishponds were never isolated facilities, but were integrated in a precise framework of exploitation of local natural resources (Auriemma *et al*. 2008: 144). Several fishponds from Classical Antiquity have been found along the eastern Adriatic coast and new evidence is rapidly emerging with the spread of drone photography.

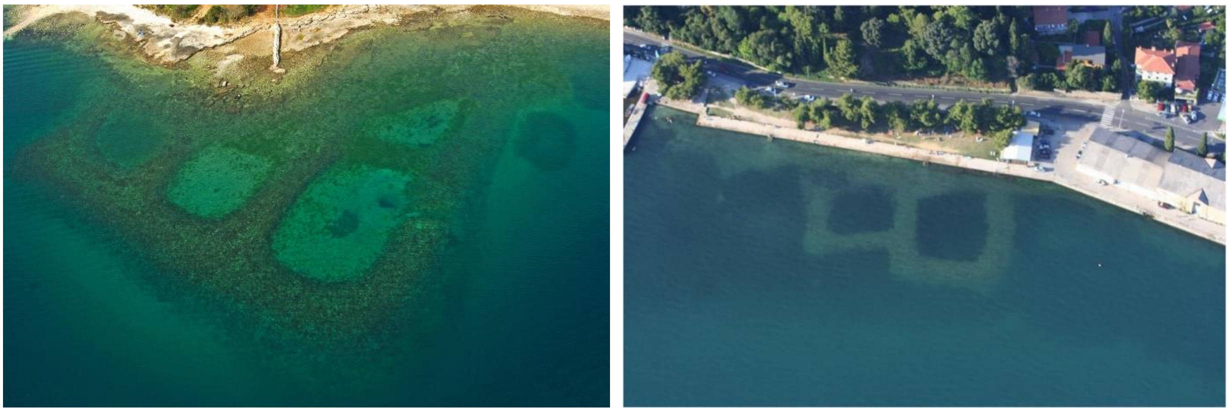


Fig. 87 Vivaria *in Kupanja (https://www.istria-culture.com/lorun-i99, accessed 22/05/2021) and in Fizine, Portorož (photo of J. Benjamin, from Stokin* et al. *2008: 58, fig. 2).*

As an example, the *vivarium* **in Kupanja** (Fig. 87a) is located next to the maritime *villa* of S. Marina-Loron-Červar at 4-11 m depth (Carre *et al*. 2012: 84). It is constructed with an accumulation of small calcareous stones stacked one on top of another, without any binders. The southern side of the *vivarium* was 100 m long, while the eastern side was 75 m wide, for a total surface of 5400 m^2 (Carre *et al*. 2012: 87). In the internal side of the structure, four oval pools were obtained: originally, they were most likely rectangular and later their corners collapsed. The building technique was simply a dry stone foundation, built of an accumulation of irregular stones, which consolidated due to their weight, while other stones were later thrown on top of them to build the elevated parts of the *vivarium*.

According to the researchers (Carre *et al*. 2012: 89), it is the same building technique (although executed with stones of smaller dimensions), described by Pliny the Younger for the arrangement of Trajan's *villa* in *Centumcellae*: huge blocks were brought by boats and placed one on top of another, like an embankment (*Epist.*, VI, 31, 16). The stones of the fishpond's foundations in Kupanja were put directly on the natural calcareous substratum. This underwater building technique is widespread in many coastal regions during all historical periods. It required a major width of the foundations (and consequently of the perimetral walls of the *vivarium*, which also served as a walking surface), while the more or less contemporary fishponds along the Tyrrhenian coast were dug in the coastal rock and/or had elevations in *opus caementicium* (Auriemma *et al*. 2008: 144). The stability of the Adriatic fishponds was assured by the large width of their bases and the weight of the local rocks with which they were built. They were porous structures resistant to big waves and did not need channels for the flow of seawater: the water change occurred during high tides. They were built in places, where they were exposed to right winds and currents (Carre *et al*. 2012: 89; Auriemma 2016: 480).

Additionally, the stones of these kind of fishponds might have been thrown inside a grid of vertically driven poles, which would have permitted to control the superposition of stones (Auriemma 2016: 479). Usually, the Adriatic fishponds have an extension of the perimetral wall, which served for docking. In some cases, the presence of big aligned blocks on top of the perimetral walls suggest the existence of piers and/or walkable surfaces. It has been underlined that near the fishponds there are small watercourses or springs, which blended the salty water, cooled it and elevated the oxygen level, creating spaces suitable for fish breeding.

Similar constructions to the one described in Kupanja have been discovered in **Katoro** near Umag (Carre, Katunarić 2012) and in the Slovenian part of Istria, in **Sveti Jernej**/San Bartolomeo close to Ankaran and in **Fizine** by Portorož (Fig. 87b) (Gaspari *et al*. 2007; Stokin *et al*. 2008).

Fig. 88 Vivarium *in Svršata Vela, Kornati archipelago (http://srbija-forum.com/viewtopic.php?f=422&t=6749&start=10, 15/08/2022).*

A different kind of *vivarium* is located on **Svršata Vela** in the Kornati archipelago in central Dalmatia (Fig. 88). It has a single pool and smaller dimensions (600 m^2). Maybe it operated as fishing trap during tidal range changes (Auriemma 2016: 481). This fishpond could be dated to the Late Roman Republic or the Early Imperial period. Similar structures have been found at other locations along the Croatian coast (Jurišić 1997; Parica 2017). It has been supposed that the *vivarium* in Svršata Vela belonged to the Roman *villa* located 3 miles to the northwest, on the sea passage of Mala Proversa, between Dugi otok and Katina Islet (Radić Rossi, Fabijanić 2013). Similarly, the saltworks in Šipnate on Kornat Island might also had belonged to the same property.

Saltpans in the Greek world[33]

To demonstrate where and when the technological process of obtaining salt through successive basin solar evaporation saltpans was invented is an impossible task. The fact that the Greeks probably never produced salt in artificial saltpans with successive basins, but simply collected naturally formed salt from coastal lagoons and pools (Adshead 1992: 28; Petanidou 2005: 11) is doubtful, but currently there are no proofs that would attest successive basin salt exploitation in the Greek world. If the site of Caunus in Anatolia has been correctly interpreted as a salt production facility, it shows that in 1st century BC Anatolia other techniques of salt production were preferred over the "classic" saltpans (see the discussion in Ch. 2.5), while in the 2nd century BC Ionian coast salt exploitation techniques seem to have been well known, as hinted

[33] For an exhaustive discussion about salt-making places in the Greek world see Carusi 2008.

by Nicander of Colophon, the only Greek author who mentioned a salter, ἀνὴρ ἁλοπηγός (*Alex.*, 518-520; Carusi 2008: 248).

At the present state of research, there are no data that can be linked with possible salt production in the Greek *poleis* and *emporia*, which developed in central Dalmatia from the 4th century BC, except for one indication. On the northwestern coast of the Gulf of Kaštela, the Hellenistic *emporion* of *Tragurion* might already have had its saltpans close to the Pantan wetlands, where it seems that they were located during the Roman period. Radiocarbon analysis of a plank from Pantan was dated to the 1st century BC, possibly before the Romanization of the area. This dating could nevertheless have another explanation: the evidence from Cervia has shown that the reuse of older planks, including elements of disused boats, was normal on the saltpans (Beltrame 2019), as well as for building piers and various harbor facilities (see Radić Rossi, Boetto 2020).

Saltpans of the Liburni?

In the Podvelebit Littoral, four Late Bronze/Early Iron Age salt production sites were identified so far, testimonied by the finds of typical three-horned and spool-like briquetage pedestals, as well as significant quantities of very fragmented thin-walled reddish pottery (Domines Peter, Parica 2021), which can be identified as broken remains of salt molds (see Ch. 1.3.1).

The prehistoric coastal hillforts on the Podvelebit Littoral were located in strategic positions close to the mountain trails that assured the passage across the steep Velebit mountain range, towards the Lika plateau. From the 9th century BC until the end of the 1st century BC, the culture that developed in the northern and central eastern Adriatic coast were the Liburnians/Liburni. They were skillful sailors (pirates) and merchants, who were trading wood, cattle, fish, probably salt and other goods with the Japodes and other farming populations living on the other side of the mountains (Zaninović 1981: 192; Čače 1985: 486). An important branch of the Liburnian economy was sheep breeding, for which they needed considerable amounts of salt: with their wool they produced cloaks, known to Greek traders as early as in the 5th century BC and defined ***cuculli Liburnici*** in an epigram by Martial (*Epigr.*, XIV, 140 [139]). Pliny (*Nat. Hist.*, VIII, 191) also talked about these cloaks, remarking their poor quality (Čače 1985: 488-489; Kurilić 2008: 21).

With the growing Romanization on the eastern Adriatic coast, the Liburnian coastal hillforts were gradually abandoned in favor of fewer centralized urban settlements that developed next to the harbors: Senj (*Senia*), Sveti Juraj (*Lopsica*), Stinica (*Ortopla*), Karlobag (*Vegium*) and Starigrad Paklenica (*Argyruntum*) (Plin., *Nat. Hist*., III, 40). *Senia* had a regional economic importance, while the other settlements had smaller-scale range (Glavaš, Glavičić 2017: 123-124). Most of these settlements acquired the municipal status in the early imperial period, which means that the Roman state gained full control over the old Liburnian spheres of influence and trading routes.

One Late Bronze/Eary Iron Age salt production site was located in Sveti Juraj (Roman *Lopsica*) and another one near Karlobag (Roman *Vegium*). Probably the trade of salt and other goods continued during the Late Iron Age, Protohistory and in the Roman period, when the techniques of salt exploitation changed.

In the period of the Roman Kings, following the increase of population, salt started to be obtained by evaporation in artificially built saltpans at the mouth of the Tiber and probably in other areas of the Mediterranean as well, supplying the growing demand for salt. The previous briquetage salt production technique, slower, less efficient, time and resource (firing wood) consuming, was abandoned (Alessandri, Attema 2022). The Liburni had important commercial connections with the Italic farming populations on the other side of the Adriatic Sea, who were importing salt and trading goods with the Romans and Etruscans on the Tyrrhenian coast. The Liburni probably had several settlements on the western Adriatic coast: in Pliny's time there was only one that survived in Italy until his days – *Castrum Truentinum/Truentum* at the mouth of the *Truentus* (Tronto, Abruzzo) along the *via Salaria* (*Nat. Hist.*, III, 4, 13, 110). Likewise, the Liburni had relations with the Greeks, who exploited natural or artificial saltpans and from the 4th century BC started to found colonies on the central Dalmatian islands. Gradually, the knowledge of salt production in artificially built saltpans, together maybe with specialized salt workers, probably spread in the Liburnian territories. According to another hypothesis that is impossible to verify, the Liburnians came to the Apennine Peninsula during the 3rd century BC and taught the local inhabitants how to produce salt from the sea, founding today's largest Italian saltworks of Margherita di Savoia (Candida 1951).

On the Podvelebit Littoral there were no grounds suitable for the organization of saltworks. It is possible that the old briquetage salt production technique continued on these coasts for a while, but, due to the rise in sea level, probably not at the same Late Bronze/Early Iron Age salt production sites, until the imports of salt produced in artificially built saltpans prevailed. The closest saltpans that maybe started to be exploited from the Liburnian period probably arose in the flat shallow bays of the neighboring islands of Krk, Rab and Pag, where the presence of saltworks is documented in medieval archival documents and some indirect archaeological evidence allows us to suppose the continuity of exploitation at least from Roman times. Currently we are lacking all material evidence that would confirm salt production along the eastern Adriatic shore during the Late Iron Age and Protohistory.

4.

CASE STUDIES

AND CATALOGUE

4.1. Case studies

Strictly connected to the study of salt exploitation and trade on the eastern Adriatic coast is the project: *"Saltpans as Anthropogenic Landscape Intervention, a New Multidisciplinary Approach for Studying Sea-level Changes",* started in 2018 by the University of Haifa – Dep. of Maritime Civilizations and Geography (Benny Bechor, Dorit Sivan) and the Croatian Geological Survey – HGI (Slobodan Miko, Ozren Hasan), in collaboration with the University of Zadar – Dep. of Archaeology (Maja Grisonic, Irena Radić Rossi), University of Haifa – Dep. of Geography and Environmental Studies (Anna Brook), University of Zagreb – Dep. of Applied Sciences (Tamara Ivelja) and the University of Padova – Dep. of Geosciences (Gilberto Artioli, Giulia Ricci).[34] The goal of the project is to determine whether the submerged remains of antique saltpans on the Adriatic Sea can represent a new indicator for relative sea level changes over the past two millenia (Bechor *et al*. 2020). The Dalmatian shore contains a large number of preserved and historically dated ancient saltpans, now flooded by the rising sea, providing great potential for past Relative Sea Level (RSL) indication. This research focuses on four sites: Brbinj on the island of Dugi Otok in Zadar County, Makirina Cove on the mainland near Tisno, and the islands Lavsa and Vrgada in Šibenik-Knin County (Fig. 89). The investigations comprised DGPS measurements along the archaeological structures for geo-referencing purposes, photogrammetric drone and LiDAR mapping, bathymetric mapping with echo sounder and side-scan sonar, underwater archaeological surveys of the submerged remains of the saltpans, underwater wood and mortar sampling for radiocarbon dating and geological coring (see Bechor *et al*. 2020). Investigations are still on-going and the study of geological cores is currently underway.

[34] The project is part of Benny Bechor's PhD dissertation, entitled *The last millennium Relative Sea Level of the Dalmatian coast, based on combined geological and archaeological indications, compared to the Greek and the Israeli data* (supervised by D. Sivan, University of Haifa, S. Miko, Croatian Geological Survey and I. Radić Rossi, University of Zadar). The project, which originally included the above-cited scholars, was subsequently significantly enriched by the work of the following scholars: Brita Lorentzen (Cornell Tree Ring Laboratory, Department of Classics, Cornell University, USA), Giorgio Spada (Dipartimento di Fisica e Astronomia "Augusto Righi", Bologna, Italy), Simona Avnaim-Katav and Barak Herut (Israel Oceanographic and Limnological Research (IOLR), Haifa), Steffen Mischke (Faculty of Earth Sciences, University of Iceland, Reykjavík, Iceland), Nimer Taha (Department of Marine Geosciences, L. Charney School of Marine Sciences University of Haifa, Israel) and Naomi Porat (Geological Survey of Israel (GSI), Jerusalem, Israel).

Fig. 89 Location of the saltpan sites under study (Bechor et al*. 2020, fig. 1).*

Methodology of underwater archaeological surveys on saltpan sites

The four sites of Makirina, Brbinj, Lavsa and Vrgada in northern Dalmatia were chosen because all four show several submerged walls, which close the coves, forming an enclosure between them and the shore. With the aid of medieval archival documents and the still-surviving toponyms, these sites can be undoubtedly identified with past saltworks. The four sites were also chosen due to their vicinity and the consequent possibility of organizing survey campaigns in relatively short time, beacuse of the lack of substantial fundings. Even though the surveying surfaces were quite large, the survey of the submerged remains in Makirina, Lučina (Brbinj) and Lavsa Coves were esentially completed, while in S. Andrija Cove on Vrgada Island only one part of the cove was surveyed.

The main difficulty of the underwater survey and photographing on saltpan sites was diving in very shallow water, in depths ranging from about 0.30 m to 1.2 m, with the risk of easily compromising the visibility, when touching the muddy seabed. In all four sites, a typical muddy sea bottom, rich in organic sediments, was observed. The layer of mud can be quite deep and when stepping on it, the feet sink and remain stuck in it. For surveying the remains located in very shallow water, floats were used for bringing the research equipment, while for surveying and cleaning the remains located at around 1 m of depth tanks were employed. The layout of the walls located in very shallow water was much clearer on the aerial pictures than on the field, and a continuous comparison between the two was necessary for the orientation on the sites and the understanding of the vestiges.

The most promising site revealed to be Makirina Cove, the only one where wood and mortar fragments were found and sampled, which permitted an absolute dating of some parts of the saltpans. Traditional wood radiocarbon dating was performed, flanked by innovative chemical analysis of mortar samples. Experimental radiocarbon dating of underwater-recovered mortar was unsuccessful. The site of Makirina shows the biggest potential for the continuation of research: it could bring the most interesting data on the typology and functioning of saltpans from Late/Classical Antiquity, of which we barely have any direct archaeological evidence. Indeed, an archaeological excavation, which would have greatly contributed to the understanding of the layout, the construction methods and maybe the functioning of the saltpans, was not yet performed.

4.1.1. Case study 1:

MAKIRINA COVE

Fig. 90 Makirina Cove (https://hiveminer.com/Tags/ivinj/Timeline, accessed 15/12/2019).

Fig. 91 Satellite picture of the cove (Google Earth).

I. INTRODUCTION

Makirina Cove is located in the SE part of Pirovac Bay in central Dalmatia, 18 km NW of Šibenik and 44 km S of Zadar. The nearest towns are Pirovac to the N and Tisno to the W, while to the S there is the small agglomeration of Ivinj (Fig. 92). It is a long (about 1250 x 300 m) and shallow cove (< 2 m), with a N-S extension. Makirina Cove is known for its peloid or healing mud. Previously, when the area was part of Yugoslavia, there was a project to construct a hotel with wellness facilities and medical treatments. What catches the eye while watching the satellite pictures of the cove is the presence of a massive wall, which crosses it approximately in its central part, connecting the eastern and the western shores (Fig. 90, 91). This wall, which is now underwater, is about 230 m long and 1.20 to 1.95 m wide. It was the separation wall of the saltpans, which were located on the internal side of the cove.

Fig. 92 Location of Makirina Cove (www.arkod.hr).

II. GEOGRAPHICAL CHARACTERISTICS OF THE COVE

The long and shallow Makirina Cove is surrounded by low Makirina and Gračina hills. To the SE there is the valley of Ivinj Draga, where mainly vines are cultivated. The road connecting the mainland with the nearby island of Murter passes along the southern coast of the cove.

The cove has varying seawater temperatures from 0 to 35˚C and fluctuating salinities (up to 41‰ during summer), caused by seasonally enhanced evaporation and few periodic and low capacity on-shore streams and submarine springs (Šparica *et al.* 2005: 23, 48). In the southern part of the cove there is a small seasonal creek draining in the sea.

The climate is typical Mediterranean, with mild, rainy and windy winters and warm and dry summers. This area is part of the Šibenik region, which is one of the sunniest parts of the Adriatic, with 2572 sunny hours/year (Šparica *et al.* 2005: 23). The main winds are the northeastern *bura,* the southern *jugo* and the northwestern *maestral.*

Fig. 93 Makirina Cove seen from the N (http://www.apartmani-meic-pirovac, accessed 16/04/2020).

The vegetation in Makirina is the typical one that grows in the salt marshes, comprising the common glasswort (*Salicornia europaea*) and the sea lavender (*Limonium bellidifolium*), while underwater the most frequent are the seagrass (*Cymodocea nodosa*) and algae (*Codium bursa*, *Padina pavonica*).

The formation of Makirina Cove occurred after the Holocene sea-level rise into the depression formed within Albian-Cenomanian dolomites, about 4500 y BP (Šparica *et al.* 2005: 23, 48).

Up to present 3.5 m of sediments have been deposited in the cove (Fig. 95). The sediment thickness gradually increases from the coast to the central part of the cove, where the sedimentation rate is 0.75 m/1000 y (Šparica *et al.* 2005: 30-31, 48).

The organic-rich sediments from Makirina are considered one of the largest accumulation of peloids in Croatia with high balneotherapeutic potential, especially for skin disease and rheumatoid arthritis (Miko *et al.* 2008). Because of their physico-chemical characteristics and the presence of submerged saltpans, this type of peloids are classified as *marine-limanic-salinic* type (Miko *et al.* 2008). The Makirina peloids are partially polluted from metals from anthropogenic sources, primarily coming from the nearby road, quite busy during the summer time (Miko *et al.* 2008). Nevertheless, these peloids are considered to be of high quality and are comparable with the ones used in various contemporary spas, even if some additional researches should still be conducted before their actual use (Komar *et al.* 2014; Komar 2016).

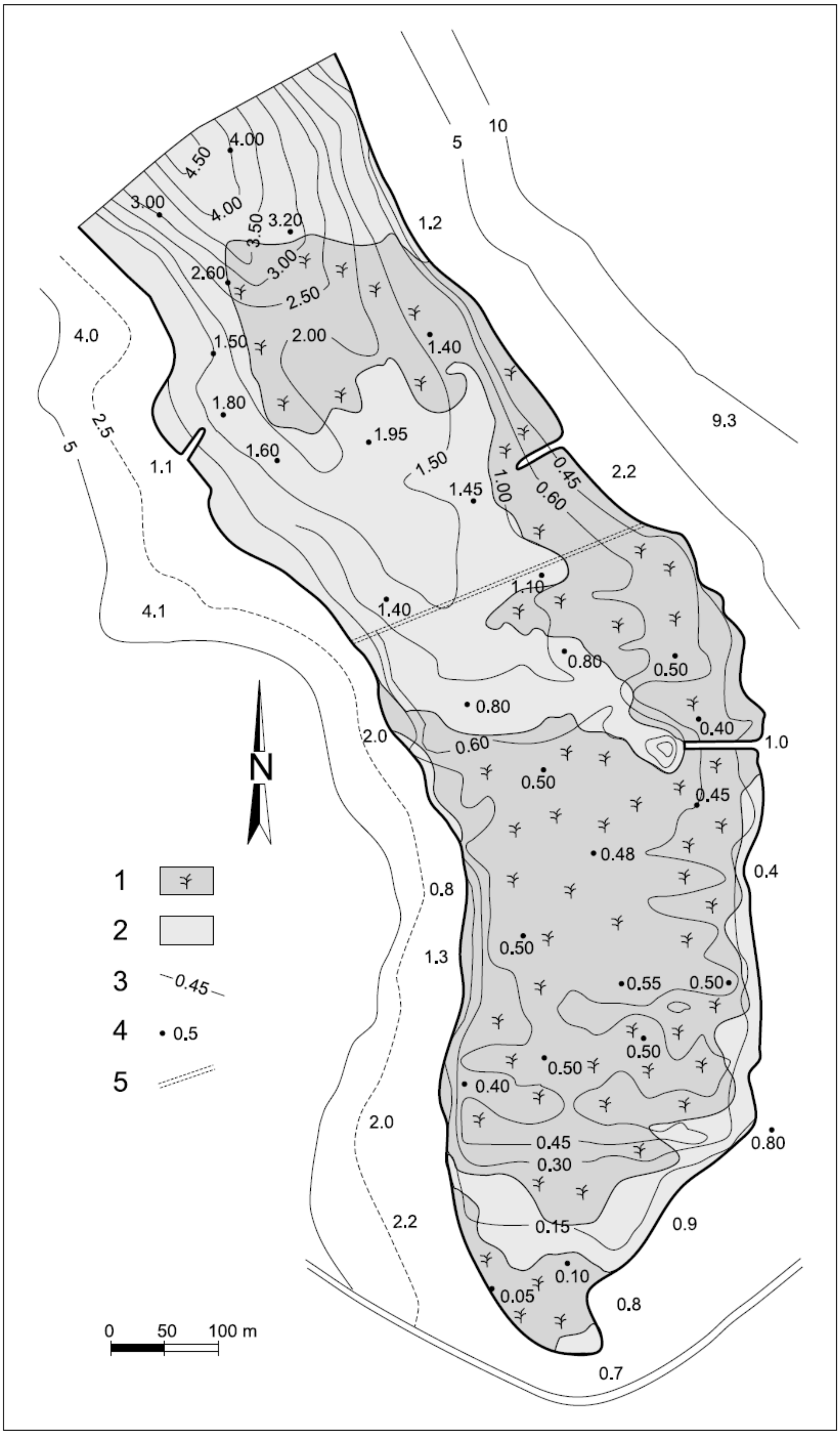


Fig. 94 Seabed map of Makirina Cove with sea depths (Šparica et al. *2005, 24, fig. 3).*

1) Sea bottom covered with vegetation.

2) Sandy-muddy bottom, gravelly with outcropping rocks along the shore.

3) Isobath.

4) Sea depth.

5) Partition wall.

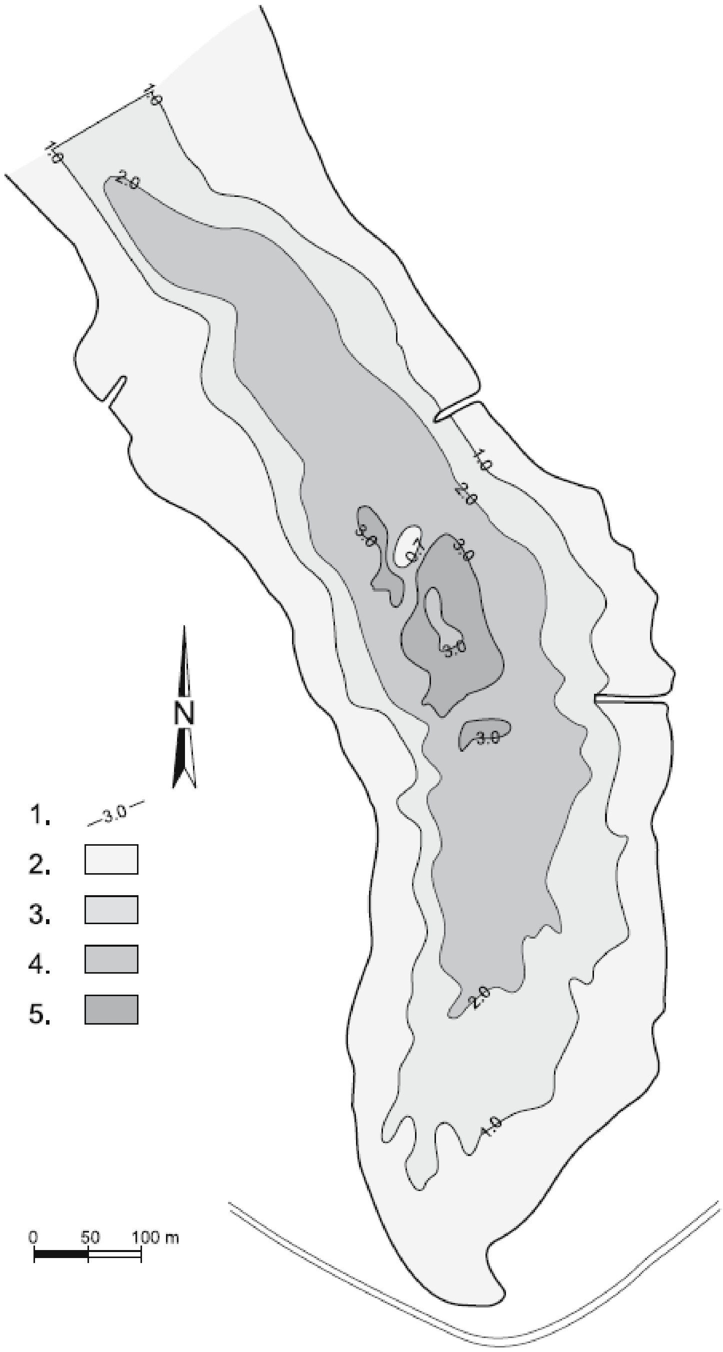


Fig. 95 Thickness of Makirina Cove sediments (Miko et al. *2008, fig. 4).*

1) Isopachs of sediment thickness:

2) 0-1 m;

3) 1-2 m;

4) 2-3 m;

5) >3 m.

III. HISTORY OF THE COVE

Toponymy

The toponym Makirina comes from the Latin *maceria* (Vuletić 2010: 338), meaning dry stone wall. We can identify without many doubts the dry stone wall with the separation wall, built to close the cove for its use for salt exploitation. This massive and very visible wall constituted a fix point in the countryside, and not just Makirina Cove, but also the nearby Makirina hill and the Makirina water spring were named after it (Juran *et al.* 2010: 189). This toponym also shows the Romanic-Slavic symbiosis of the name, which can be dated linguistically to the 7th century AD (Vuletić 2010: 337-338).

Past salt exploitation in Makirina Cove is testified also by the still-surviving toponym *Soline* (Saltpans) on the W side of the cove, while the toponym *Jaz* (= enclosed shallow seawater) is referred to the shallowest waters in the southern part of the cove (Juran *et al.* 2010: 189, 211). Another interesting toponym that most likely designated a construction located in the same spot is *Mostine* (most = bridge), probably referring to the walls of the saltpans that were rising above the sea.

Previous archaeological researches

The shallow Makirina Cove was probably suitable for salt production already in the Iron Age (Brusić 2005: 93). Because of the salt production potential and the abundance of fresh water sources, **at the beginning of the 1st century AD a relatively large *villa*** (c. 2500 m^2) was built on its southeastern side (Brusić 2005: 93; Uglešić 2006: 24). This archaeological site is known as "Archaeological site of Ivinj with Saint Martin's church" (Fig. 96, 97). Archaeological researches (1994-2004) were led by Magda Zorić from the Conservation Department in Šibenik. Unfortunately, just a small part of these excavations was published (Zorić 1994; 1999; 2006 a; 2006 b).

The *villa* was probably located along the Roman road, which was leading to the Roman town of *Colentum* on the nearby Murter Island (Zorić 1999).

Fig. 96 The Archaeological site of Ivinj with Saint Martin church facing the long Makirina Cove and the town of Pirovac in the background (https://hiveminer.com/Tags/ivinj/Timeline, accessed 15/12/2019).

The ***villa*** **has different chronological phases, ranging from the beginning of the 1st until at least the 5th century AD (**Zorić 2006 b). It had a central court, surrounded by three rooms. Two cisterns were discovered, where water, probably flowing from the roofs, was accumulating. The bottom of one cistern was covered with waterproof mortar, while the bottom of the other was paved with tiles laid in a herringbone pattern (*opus spicatum*). In the southwestern sector of the *villa* a bath complex was located: the *praefurnium* (furnace), which was heating the *tepidarium* and the *caldarium*. The *frigidarium* was also discovered. The *tepidarium* was paved with a black and white mosaic with geometrical decorations (Zorić 2006 b: 138).

The productive part of the *villa* (*pars rustica*) was located in the eastern sector. One of the five excavated rooms with four *dolia in situ* was probably a storage room. Just their lower parts were still preserved, while their upper parts were broken, when they started to use the site as a graveyard (Zorić 2006 a: 330). The eastern perimetric wall was 36.20 m long and 45 cm wide. Its maximum preserved height was 80 cm. All the walls were documented and photographed, before they were restored. The broken parts of the walls were rebuilt with stones recovered on the site. Both sides of the walls were rectified with mortar.

In the southwestern sector of the *villa* (which was later transformed into the narthex of the early-Christian basilica) a drainage channel was found: it was 6.30 m long and oriented E-W. Its bottom was paved with *tegulae* set on an abundant layer of mortar with pebble inclusions, while the sides of the channel were built with regularly cut blocks. The internal channel was 14-22 cm wide, its depth was 28 cm. The closing slates were not found. At the same level of the base of the channel, a commemorative *assus* of Augustus was found, dating between AD 34 and AD 37. On the top of the channel, in between two stones, an *assus* of Vespasianus (AD 73) was discovered.

Numerous archaeological artifacts were recovered during the excavations: ceramic vessels, glass fragments, metallic objects, like *fibulae*, keys, and a belt buckle having the form of an amphora, dating to the 4th century AD (Zorić 2006 b: 138-139). Fragments of painted wall frescoes and marble were also found. Few dark blue, light green and yellow mosaic *tesserae* – which probably belonged to a wall decoration – were recovered. The roof tiles found on the site bear the widespread stamp *Pansiana*, a pottery workshop from northern Italy active in the Augustan age (27 BC-AD 14). The stamp *Ti Pansiana* from the same workshop dates to the Tiberian age (AD 14-37), while *Neronis Claudi Pansiana* to the Neronian age (AD 54-68).

Fig. 97 The Archaeological site of Ivinj with Saint Martin's church (https://hiveminer.com/Tags/ivinj/Timeline, accessed 15/12/2019).

In the first half of the 5th century AD, or maybe even at the end of 4th, the first early-Christian building was built: the oratory or *domus ecclesiae*, which had a big central altar or *mensa* (Uglešić 2006: 24-26). The oratory was built in the western sector of the *villa*, partially reusing the already existing walls. In this period, Christian religion was quickly spreading from the cities to their territories, and many religious buildings were being constructed (Kurilić 2010: 46).

Sometime in the middle or in the second half of the 5th century AD the Christian community grew and the oratory was transformed into a complex **early-Christian three-nave church**, with the apse and narthex (see Uglešić 2006: 24-26; Kurilić 2010: 48). The baptistery with a round baptismal font was built next to the church. The dimensions of the church without the baptistery were 26.3 x 10.6 m. It probably belonged to the diocese of *Scardona* (Uglešić 2006: 11-12). Other modifications and additions to the church plan were applied in the Justinian era (first half of the 6th century) and maybe it was kept in use during the Early Middle Ages (Hilje 2005: 37).

In the 12th/13th century the Romanesque church of Saint Martin and the graveyard were built on the remains of the *villa*, about 20 m from the early-Christian church (Zorić 2006 b: 138; Uglešić 2006: 26).

Eleven late Roman and 486 medieval tombs were excavated on the site (Zorić 2006 b: 138). Most early-Christian tombs were found in the narthex of the church, among them a child burial inside an amphora. The **oldest early-Christian burial** (a man buried with a ceramic lamp with a christogram) was found about 150 m NW of the church and could be dated to the **4th century AD** (Kurilić 2010: 49). This shows that in this period some areas of the *villa* started to be used as cemetery of Christians and therefore we can suppose that they already used to celebrate religious ceremonies inside the spaces of the *villa*, before they constructed a new building dedicated to the Christian cult.

The archaeological site of Ivinj is known also because of the presence of typical monumental medieval tombstones, diffused in Bosnia, Croatia, Serbia and Montenegro from the 12th to the 16th centuries, called *stećci* (sing. *stećak*). The *stećci* in Ivinj are dated from the 13th to the 15th centuries and because of the variety of their relief decorations, this is considered as one of the richest cemeteries of this type in Croatia (Sokol 1975).

Thanks to the finding of a Venetian bronze coin, the last burial around Saint Martin's church can be dated between the end of the 17th and the end of the 18th century (Zorić 2006 b: 138).

Historical sources

The priest Krsto Stošić (1884-1944), one of the first scholars who studied the history of Šibenik and its countryside (Stošić 1941), provides us with some historical information regarding Makirina Cove in the Middle Ages. The scholar Vladimir Sokol later published an article about the funerary monuments located around Saint Martin's church (Sokol 1975), partially using Stošić's data. Unfortunately, Stošić not always mentioned the archival sources from where he obtained his data, therefore we should use them carefully.

According to Sokol, Saint Martin's church (12^{th} -13^{th} centuries) was built as a votive offering by the Šubić noble family, who had a castle in Bribir and Ostrovica, 15 km from Makirina Cove (Sokol 1975: 47). **The Šubić noble family owned a saltpan by Saint Martin's church** (Sokol 1975: 47).

In 1298, the pope Bonifacius VIII issued a bull, with which the Šibenik diocese was founded (Barbarić, Kolanović 1986; Brakus 2019: 30). The lands of Ivinj and the saltpans in the cove in front of Saint Martin's church (which can be identified with those located in Makirina Cove), previously owned by the Šubić noble family, became property of the Šibenik diocese (Stošić 1941: 145, 213). The church of Saint Martin in Makirina was the parish church of the two towns of Ivinj and Oštrica (Sokol 1975: 47). Ivinj was a village, which existed in the small fertile field to the south of Makirina Cove, while Oštrica was located further to the NW.

In 1402, another document mentions the saltpans of Oštrica and Ivinj, belonging to the Šibenik diocese (Barbarić, Kolanović 1986: 40 - *salinas positas in confinibus Ostrize et Ivign*).

From 1409, Dalmatia passed under Venetian rule and Venice, because of its salt monopoly, closed or destroyed all the Dalmatian saltpans, except for those in Pag. A document from 1446 attests the existence of *peschiere de le saline de Iuign* (fish farms of the saltpans of Ivinj) among the possessions of the Šibenik diocese (Barbarić, Kolanović 1986). We can thus assume that after 1409, when salt production became illegal, the saltpans in Makirina Cove turned into fish farms and that the existent saltworks' remains were reused for fish traps. After 1409, this transformation seems to have occurred also on other Dalmatian saltpans.

In the second half of the 15^{th} century, the inhabitants of the two villages of Ivinj and Oštrica started to move to the nearby island of Murter to escape from the Turks, forming the new town of Tisno. The resettlement culminated in the first half of the 16^{th} century, at the time of the

Ottoman-Venetian war. In 1571 the Turks conquered the territories on the mainland, south of the village of Ivinj, and started to gradually leave these regions in 1684, at the beginning of the Morean war (Juran 2010 b: 85-87).

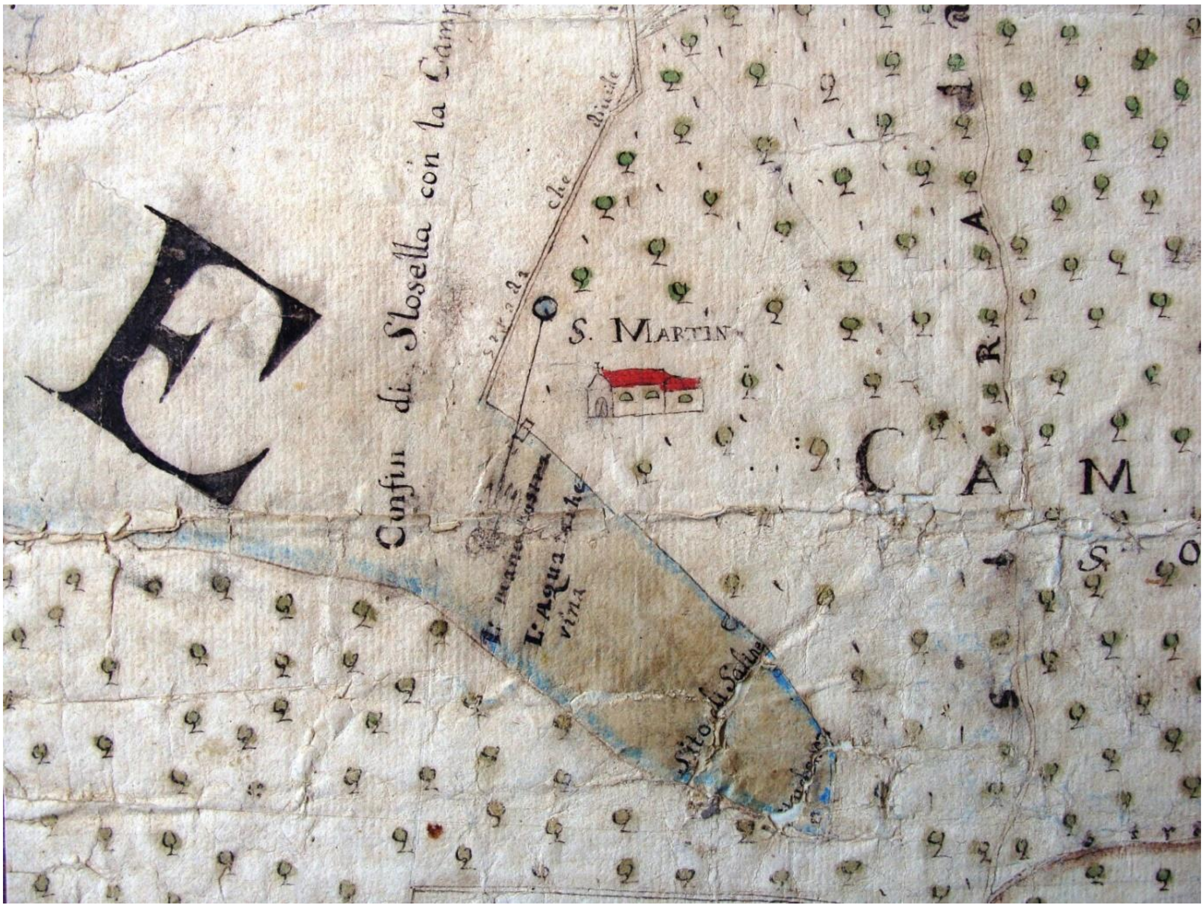


Fig. 98 Depiction of Makirina Cove from 1711 (detail of the map). State Archives in Zadar (DAZD), fond 402: Geografske i topografske karte Dalmacije i susjednih oblasti, br. 286, courtesy of K. Juran (University of Zadar).

On the map of Ivinj and Oštrica, produced by the public consultant Bartolomeo Agostini for the bishop of Šibenik in 1711, is written "*Sito di Saline*" (Saltpans site) in the lower part of Makirina Cove (Fig. 98). The cartographer probably depicted the situation in the region how it was before the arrival of the Turks (Juran 2010 b: 89). In 1711, the two villages of Ivinj and Oštrica, indicated on the map, were probably destroyed, as well as the saltpans in Makirina Cove (although maybe their remains were still visible).

On Makirina hill (112 m a.s.l.) there was a forest, mentioned in many 18th century archival documents. The local people from Pirovac (Zloselo until 1931/Slosella), Tisno and Murter island supplied themselves with wood for heating (Perinčić 2013: 21, 30), until the depletion of the trees (Stošić 1941: 146).

Nowadays Saint Martin's church was built in the 17th century, as a single-nave chapel, with a semicircular apse and a bell cote (a type of bell tower incorporated in the sacral building) on the front (Heritage register of the Croatian Ministry of Culture). The church is oriented E-W, and its dimensions are 12.2 x 6.5 m (Zorić 1994). Every year on Saint Martin's day (November 11th) the mess is celebrated. From 2012, the Archaeological site of Ivinj with Saint Martin's church is considered a protected cultural site.

IV. SCIENTIFIC RESEARCHES IN MAKIRINA COVE

Previous researches

At the time of Yugoslavia, there was a project to construct a hotel with wellness facilities and medical treatments in Makirina (Šparica *et al.* 1989). The marine sediments from the cove have since been the focus of many geochemical studies to determine their organoleptic properties, to define if they could be characterized as peloid or healing mud (Lojen *et al.* 2004; Vreča, Dolenec 2005; Šparica *et al.* 2005; Miko *et al.* 2007; 2008; Komar *et al.* 2014; 2015; Komar 2016).

Lojen *et al.* (2004) sampled in the central southern part of the cove and showed that the increasing sulfate concentration below 20 cm of depth could be attributed to an upward diffusion of sulfates deriving from past salt production.

Because of the known papal bull from 1298 (the year 1295 in Šparica *et al.* 2005 is a mistake), which mentions the saltpans in Makirina Cove, the above mentioned authors wrote that the saltpans' separation wall in Makirina dates to medieval times. According to Šparica *et al.* (2005): "The top of the partition-wall of the Cove is at present some 30 cm below the sea level, and it was certainly a functional part of a medieval salt-work. Within the space of the salt-work of that period, the sea level is at present 0.10 m (near shore) to 0.30 m (partition-wall) higher, and the thickness of the sediments is 0.75 m. According to these data, in the last 700 years the sea level has risen approximately 1 m, and during that period some 0.75 m of sediments have been deposited."

Magda Zorić from the Conservation Department in Šibenik directed the excavations of the Archaeological site of Ivinj with Saint Martin's church (1994-2004). Unfortunately, just a small part of these excavations was published (Zorić 1994; 1999; 2006 a; 2006 b).

Activities conducted on the site during the May 2018 campaign

The project *Saltpans as Anthropogenic Landscape Intervention, a new multidisciplinary Approach for Studying Sea-level changes* started in 2018 with the goal of determining whether the submerged remains of antique saltpans on the Adriatic Sea can provide a new indicator for relative sea level changes over the past two millenia.

The first survey campaign in Marikina Cove took place in May 2018, with the collaboration of Croatian and Israeli researchers. The team was composed of seven members: prof. Dorit Sivan and Benny Bechor (University of Haifa, Dep. of Maritime Civilizations and Geography), prof. Slobodan Miko and dr. Ozren Hasan (Croatian Geological Survey - HGI), prof. Anna Brook (Remote sensing Laboratory, Dep. of Geography and Environmental studies, University of Haifa), Tamara Ivelja (University of Zagreb, Dep. of Applied Sciences) and Maja Grisonic (University of Zadar, Dep. of Archaeology). The following activities were conducted on the site:

- **DGPS measurements** of the separation wall and other points for geo-referencing purpose, in order to align the DTM coordinates in the Croatian Terrestrial Reference System - HTRS 96, based on the Geodesic Reference System - GRS 80 (B. Bechor, D. Sivan);

- **photogrammetric drone mapping** of the separation wall, with a vertical accuracy of 4 cm and a horizontal accuracy of 2 cm and LiDAR from two points in the east side of the cove (A. Brook, T. Ivelja);

- **side-scan sonar bathymetric mapping** of the separation wall and the portion of the cove comprised between the wall and the shore, from 2 m until 0.30 m of depth (S. Miko, O. Hasan). Side-scan sonar data were collected using Humminbird 999ci HD SI combo echosounder, in combination with Humminbird AS+GPS HS precision GPS with heading sensor. The equipment was mounted on a 4.5 m zodiac boat with outboard engine and trolling motor for use in shallow environment;

- **underwater archaeological survey** of the submerged remains of the wall and its surroundings (M. Grisonic).

Activities conducted on the site during the October 2018 campaign

The goals of the second survey campaign were to take geological cores of the sediments in Makirina Cove, the archaeological survey and documentation of the underwater remains and the collection of wood and mortar samples for dendrochronological and radiocarbon dating.

The team was composed of five members: prof. D. Sivan and B. Bechor, prof. S. Miko and dr. O. Hasan and M. Grisonic.

Five geological cores were taken from the cove and the chosen timbers T1 and T2 were lifted out of the water and sampled on the shore. They were sent to Cornell University, Ithaca, USA, for dendrochronological and radiocarbon analyses, while the remaining pieces were returned to the site and covered with geotextile.

Activities conducted on the site during the May 2019 campaign

The goal of the third research campaign was to take mortar/binder samples from the separation wall and the probable remains of a wall perpendicular to it (W6) in the central part of the cove, for radiocarbon dating. Gilberto Artioli and Giulia Ricci (University of Padova, Department of Geosciences), experts in mortar dating, joined us for this purpose.

The team was composed of seven members: prof. G. Artioli and dr. G. Ricci, prof. D. Sivan and B. Bechor, prof. S. Miko and dr. O. Hasan and M. Grisonic.

Six mortar/binder samples were taken from the separation wall and the probable remains of a wall perpendicular to it (W6). A sample of Timber 4 from the central part of the cove was taken for radiocarbon dating.

August 2019 survey

The drone pictures showed the presence of a lateral channel of the saltpans in Makirina Cove, similar to those spotted on the sites of Brbinj on Dugi otok and Lavsa in the Kornati archipelago (see below). The lateral channel of the saltpans in Makirina is located NW of the separation wall. It was surveyed in August 2019, with the help of the archaeologist Vincenzo Pellegrino (Labex Archimede, Montpellier).

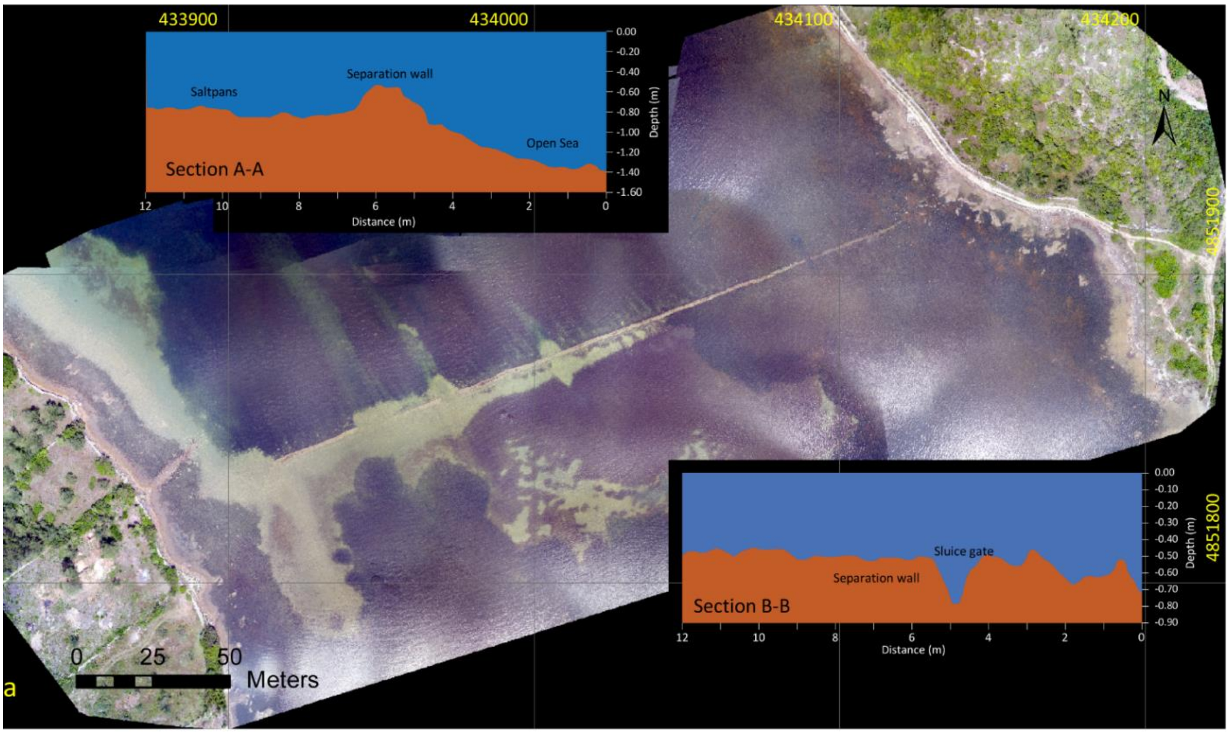


Fig. 99 The separation wall in Makirina Cove (Bechor et al. *2020, fig. 3a).*

Fig. 100 The separation wall W1 seen from above (a) and from the internal side of the wall (b) (M. Grisonic).

Fig. 101 The separation wall W1 in the central part of Makirina Cove (a) and the external part of the wall close to the opening, sustained by a large rock (b) (M. Grisonic).

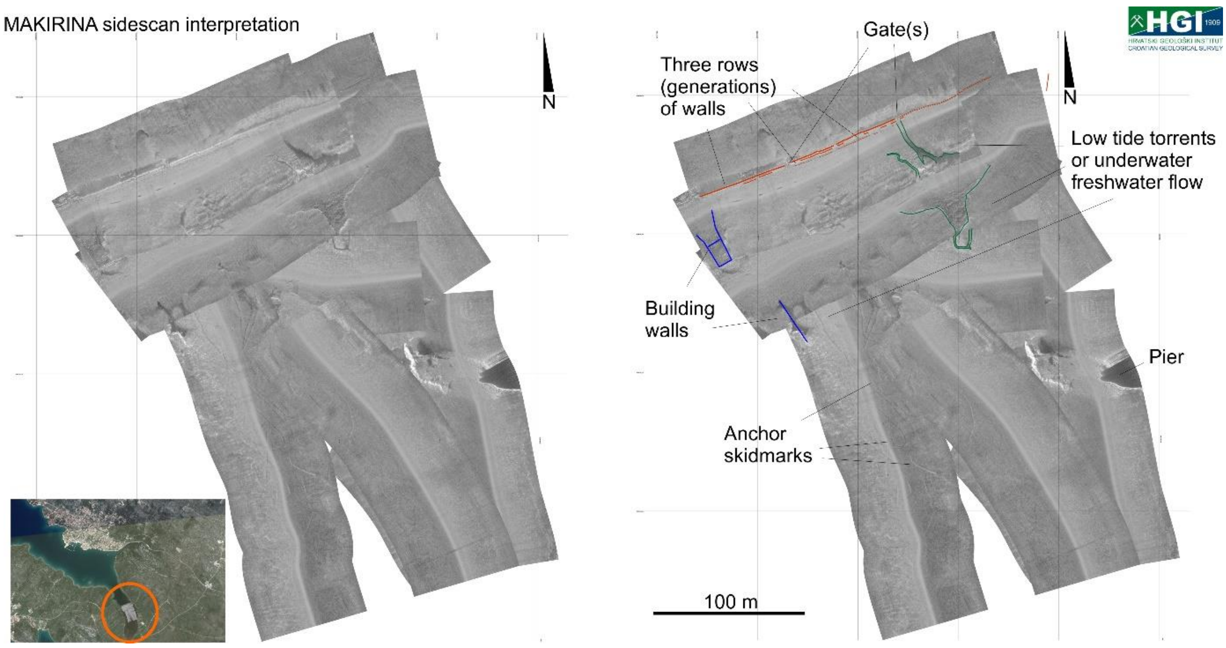


Fig. 102 Side-scan mosaic of Makirina Cove with detected structures highlighted (O. Hasan, S. Miko).

The last survey in Makirina Cove, meant for taking better-quality underwater pictures, was performed in October 2021.

V. DESCRIPTION OF THE SITE

W part of the cove: the area by the beginning of Wall 1 and around Timber 1 (Zone A)

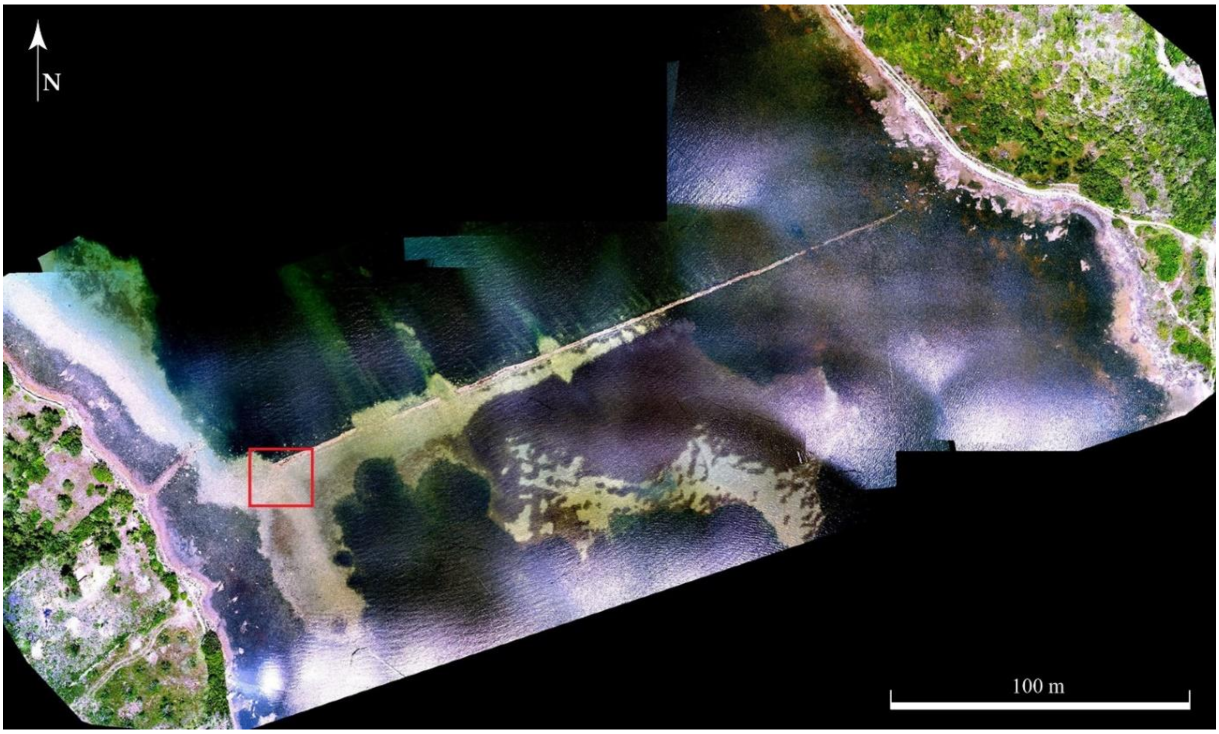


Fig. 103 Makirina Cove: Zone A highlighted by the red square.

The **separation wall of the saltpans** (**W1**) is oriented E-W and runs across the whole Makirina Cove. It is about 230 m long and 1.20 to 1.95 m wide. The wall preserved its original height. The top of the wall lays at -56 cm below the datum, while the visible bottom of the wall lays from -86 cm (by the bottom of the sluice gate) to -125 cm (in the central part of the cove) below the datum. The visible height of the wall underwater is 50 to 70 cm.

Only few cm west of the beginning of the separation wall of the saltpans (W1) and perpendicular to it, there is a small **timber** (**T1**), 135 x 11 cm, oriented N-S, laying at 1 m depth. Another **smaller wall (W2),** 40-70 cm wide, and parallel to W1, begins running immediately few cm south of Timber 1.

Fig. 104 Two parallel walls Wall 1 and Wall 2 (a) and detail of Wall 1 (b) (M. Grisonic).

W2 is oriented E-W and from what it appears from the surface, it is made of two to three rows of stones, which probably had no binder. It runs across the whole cove, parallel to the separation wall W1. The distance between W1 and W2 is 70 cm to more than 1 m. We first thought that W1 and W2 belonged to different wall generations, but it is more likely that they were contemporary and that they were delimiting a channel for the passage of water.

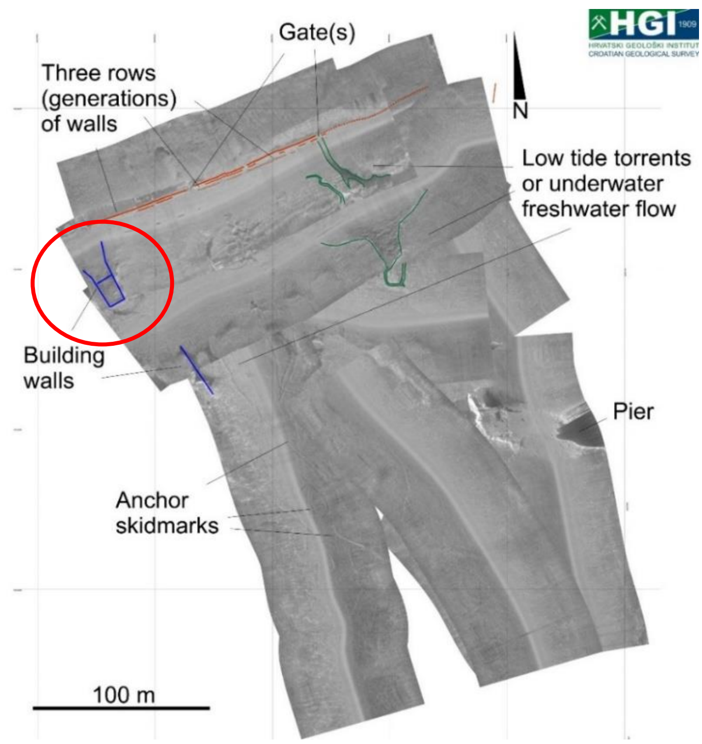


Fig. 105 Side-scan mosaic of Makirina Cove, with detected structures highlighted: the northern "Building walls" circled in red should include Timber 1 and Wall 5, discovered during the underwater survey (O. Hasan, S. Miko).

Fig. 106 Timber 1 in context, seen from north (a) (M. Grisonic) and its recovery (b) (S. Miko).

On the W side of Timber 1, about in the middle of the timber's length, there is a **wooden pole** (**P5**), having an irregular rectangular shape (11.5 x 8 cm).

Parallel to Timber 1, precisely 65 cm west of it, there is a 65 cm wide **wall** (**W5**). It is made of a succession of rocks put in a row. It is not clear whether there was some kind of binder between them. The upper (northern) and lower (southern) limits of the wall are not visible, at least not from the surface. Timber 1 and Wall 5 should be part of the "building walls", a possible structure detected by the side-scan sonar in the western part of the cove.

Fig.107 Timber 1 (O. Hasan).

It looks like W5, T1, W1 and the beginning of W2 had some functional connection. T1 lays in the space in between the two parallel walls W1 and W2, perpendicularly to them. The distance between W1 and W2 in this point is about 1.50 m, while the distance between T1 (and the beginning of W2) and W5 is 65 cm. At this point of research, further interpretations of these remains are hazardous.

Several meters east of the beginning of Wall 1 and Wall 2 there is a **sluice gate** open in Wall 1. The sluice gate is about 37 cm wide. The depth at its bottom is -0.86 m. The width of the wall W1 on both sides of the sluice gate is 1.60 m.

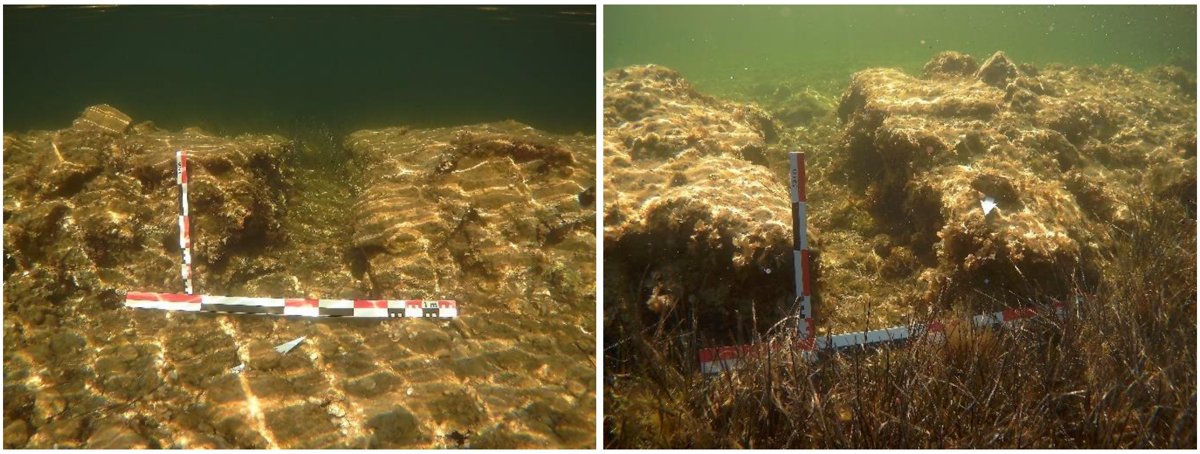


Fig. 108 Sluice gate in the separation wall seen from the internal (a) and from the external (b) part of the wall (M. Grisonic).

The central part of the cove, where the separation wall W1 is destroyed (Zone B)

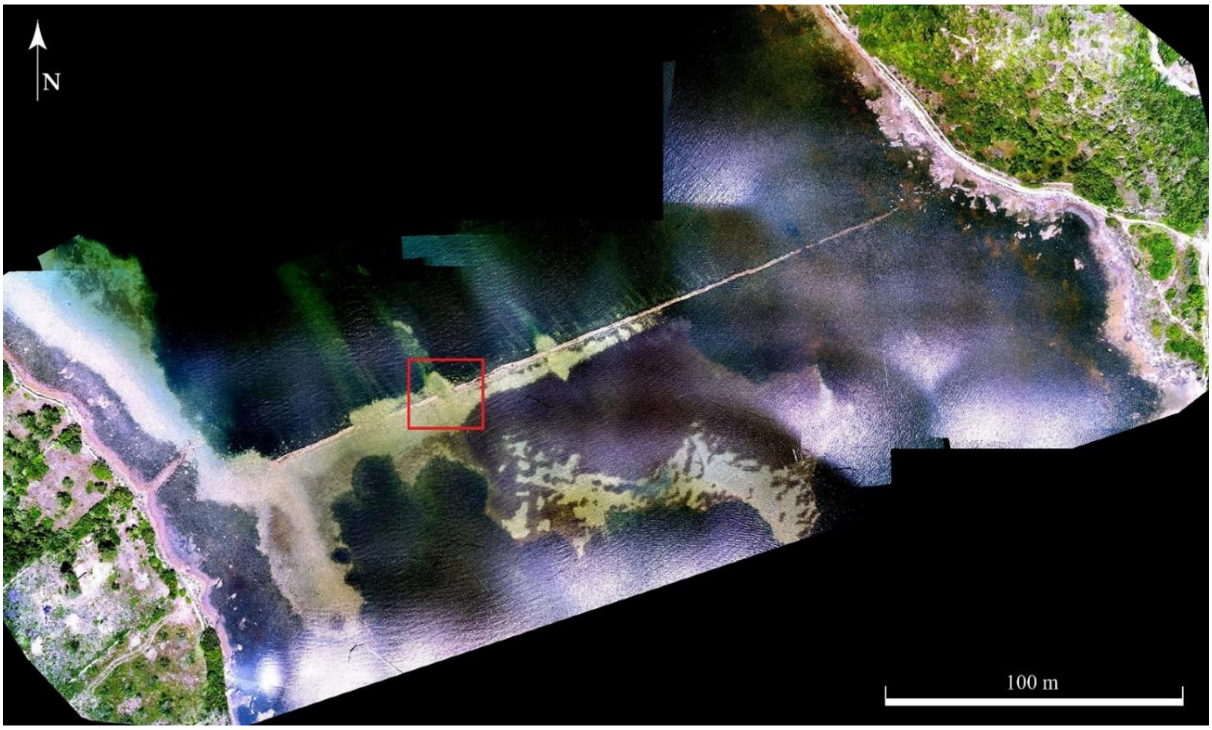


Fig. 109 Makirina Cove: Zone B highlighted by the red square.

Fig. 110 Opening in the separation wall in the central part of the cove (B. Bechor, A. Brook, T. Ivelja).

In the central part of the cove, the separation wall W1 was destroyed for the passage of boats, probably in more recent times. The passage is marked by two modern metal sticks stuck in a base of concrete, one on each side of the passage. This is the deepest part of the cove, with the depth reaching 1.2 m. The passage was probably obtained by enlarging an already existing opening that was located at this spot (maybe the central channel of the saltpans, perpendicular to the separation wall W1?).

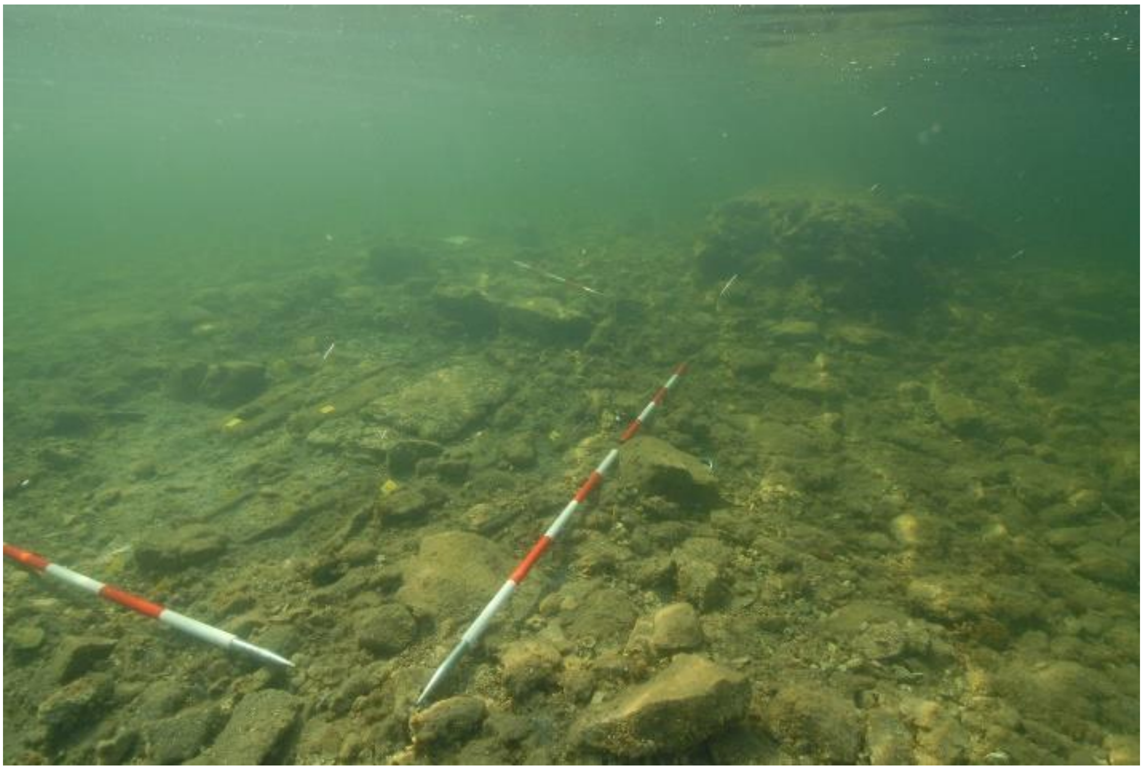


Fig. 111 Remains in the central part of the cove seen from E, with W1 in the background (M. Grisonic).

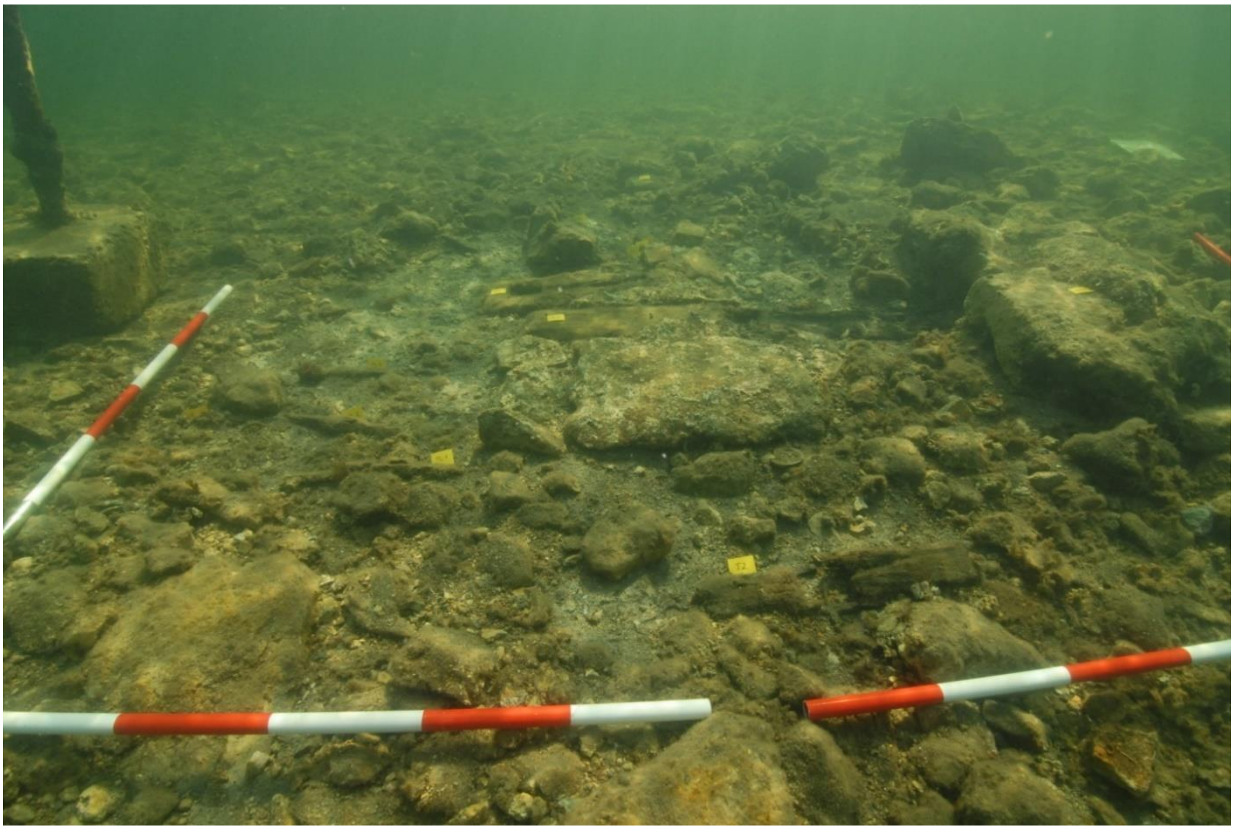


Fig. 112 Remains in the central part of the cove seen from N towards S (M. Grisonic).

Fig. 113 Probable Wall 6 foundations and a sluice gate in between W6 and W4 (M. Grisonic).

In the central part of Makirina Cove about 10 m of the separation wall W1 are destroyed. Some blocks still lay *in situ*, following the direction of the wall, while most stones, which originally belonged to the wall, lay scattered on the sea floor. About a meter east of the last well-preserved portion of Wall 1, there is a fragment of a wooden timber with mortise, **Timber 2**. It lays at 1.2 m depth and it is oriented E-W, following the alignment of Wall 1. The dimensions of the preserved part of the timber are 75 x 10 cm, and those of the mortise are 9 x 7 cm.

Fig. 114 Timber 2 (T2) (M. Grisonic).

Few centimeters south of Timber 2 and southeast of the last well-preserved portion of Wall 1, there is a 280 cm long and 70 cm wide wall (**W4**), oriented N-S, thus running perpendicular to Wall 1 and Timber 2. It is made of rows of stones bound together by white mortar containing big ceramic fragments. It lays at 1.2 m depth.

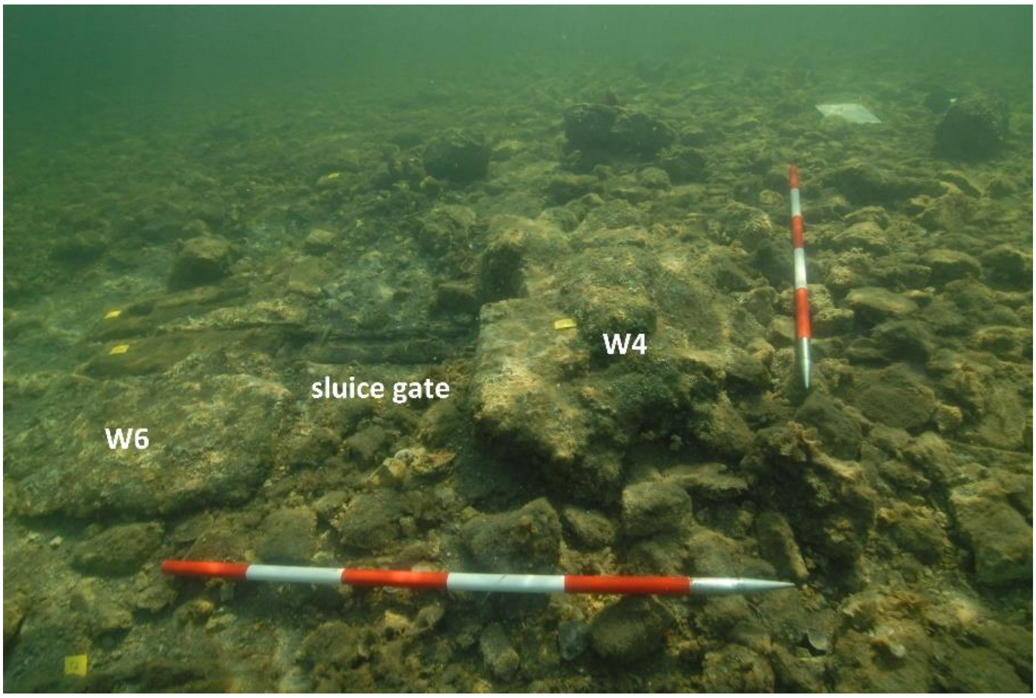


Fig. 115 Probable Wall 6 foundations, sluice gate in between W6 and W4 and Wall 4 (M. Grisonic).

45 cm east of Wall 4, there is another 70 cm wide wall (**Wall 6**), that can be followed for about 130 cm, running in N-S direction. This wall, which lays at 1.2 m depth, is parallel to Wall 4 and perpendicular to the separation wall W1 and to Timber 2. On the northern part of Wall 6, where it was probably intersecting Wall 1, just its foundations are preserved: they are made of wooden timbers and poles, stone slabs, brick fragments and abundant mortar. Probably all these materials were recycled to give as much stability as possible to this wall, built on non-solid ground. Wall 6 is better preserved toward south, where the width of the wall that can be seen from the surface is 35 cm, and the rest is probably buried under the sediment (it should be 70 cm wide, like at its northern part). It is made of rows of stones bound together by the same white mortar with big ceramic fragments present in its foundations and on the nearby Wall 4.

The **foundations of Wall 6**, which can be seen at its northern part, are made of different elements bound together by waterproof mortar. They consist of (from N to S):

- a big flat, 60 cm wide stone slab, and smaller flat rocks put at its eastern side, in order to form a flat surface measuring 70 cm of width;

- **Timber 3** (**T3**) : it is oriented E-W, like Wall 1. It is therefore perpendicular to Wall 6. His dimensions are 135 x 20 cm. Its western edge inserts in a rectangular cavity located at the eastern side of Wall 4. It is not clear whether the timber ends in this cavity or if it continues on the other (W) side of Wall 4. Timber 3 has two rectangular mortices, both having dimensions of 10 x 10 cm. The eastern one is placed on the western border of the Wall 6 foundations, while the other one is situated on the part of the timber right before it inserts into the Wall 4 cavity.

Fig. 116 Timber 3 (below) and Tiber 4 (above) bound together by waterproof mortar (M. Grisonic).

Fig. 117 Timber 3: E mortise with the remains of a sluice plank? (M. Grisonic).

Fig. 118 Groove on Timber 3 (M. Grisonic).

In between the two mortices there is a 45 cm long groove, which can be seen on the surface of Timber 3. This groove (45 x 5 cm) was possibly tailored to fit a sluice plank (see the comparison with the saltpans in Cervia, in Guarnieri 2019: 118, fig. 20). The wooden pieces that can be seen inside the mortices of Timber 3 might be those of the sluice plank, which was regulating the flow in the **channel in between W4 and W6**. The channel was 45 cm wide.

Fig. 119 Timber 3 going into the cavity in Wall 4. The mortise can be seen in the foreground (M. Grisonic).

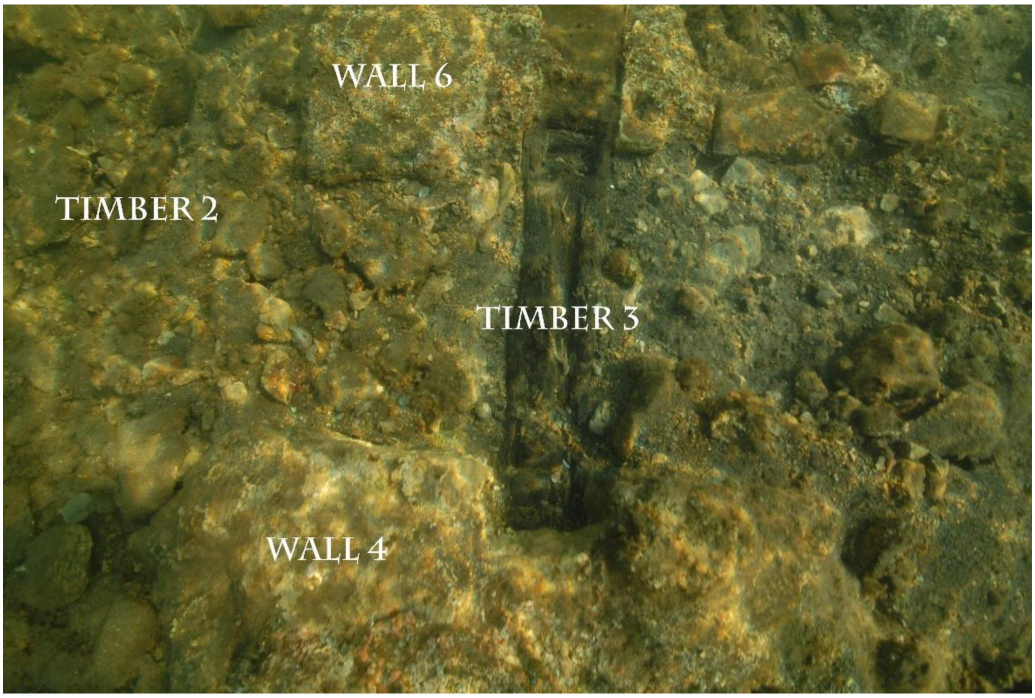


Fig. 120 Channel in between Wall 4 and Wall 6 (M. Grisonic).

- **Timber 4** (**T4**) lays parallel to Timber 3. The two timbers are separated by a layer of waterproof mortar. The visible dimensions of T4 are 70 x 20 cm, but it might continue toward west, under the mortar layer. Timber 4 has a rectangular mortise on its eastern side, having dimensions of 11 x 8 cm. The mortise is empty. T4 has also a groove (45 x 5 cm) on its upper face, but in this case it is less probable that it was made to fit a sluice plank. At this point of research, it is not clear whether there was something wrong with this timber and it was thus reused to build the foundations of Wall 6, or Wall 6 was not just a wall, but also a more complex structure.

- one **brick**, two big pieces of ***imbrices*** (curved roof tiles) and a flat green **slate** fragment lay inside the **layer of mortar**, which is abundant by the western edge of Wall 6: it is white, with big and numerous pottery fragments. Several samples of mortar were taken from this spot to be analyzed.

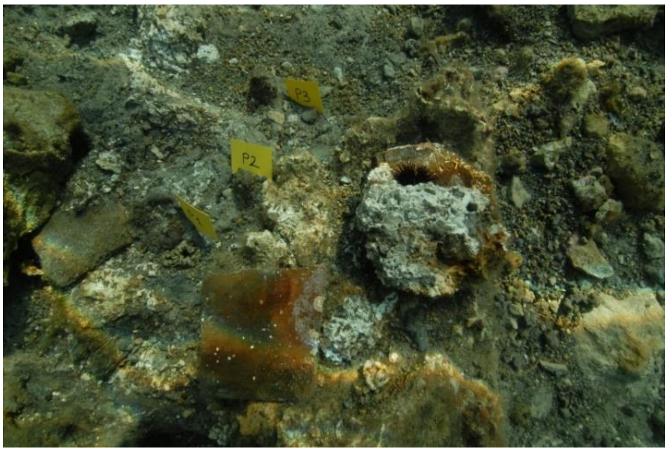


Fig. 121 Wooden poles, bricks and white mortar in Wall 6 foundations (M. Grisonic).

- three **poles** with a round section (**P1-P3,** and another pole with the square section (**P4**) lay immediately southeast of the bricks, inside the layer of mortar.

The dimensions of the poles are:

○ P1: diam. = 5 cm
○ P2: diam. = 3 cm
○ P3: diam. = 4.5 cm
□ P4: 10 x 10 cm

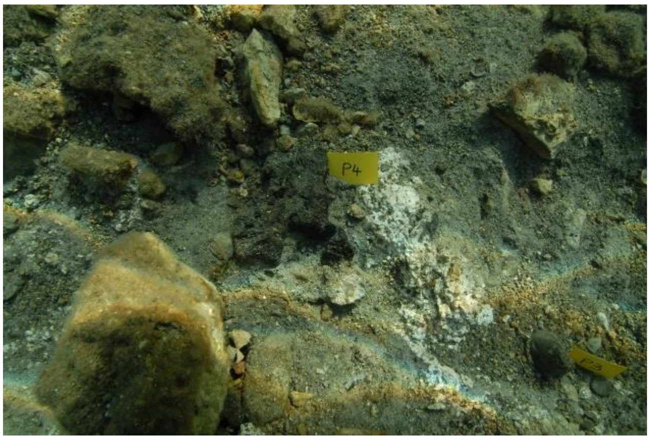


Fig. 122 Pole 4 with a square section (M. Grisonic).

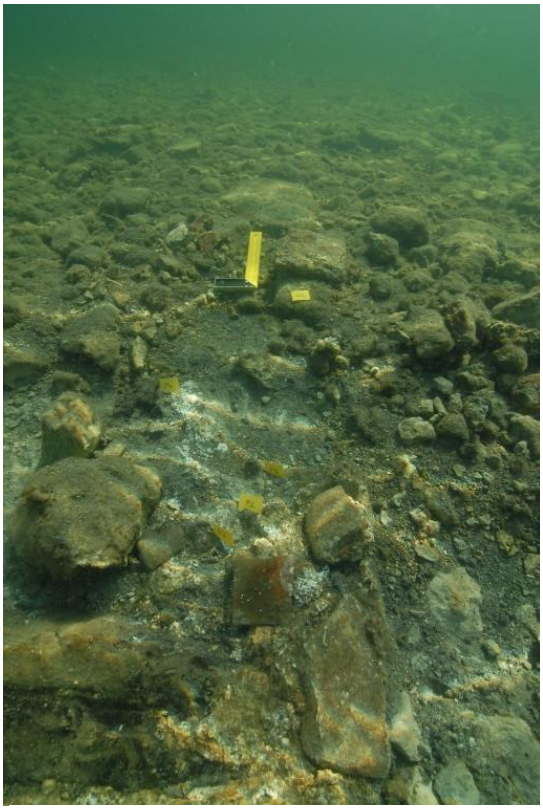


Fig. 123 Wall 6: in the foreground it is preserved at the level of foundations, while in the background a row of blocks still stands (M.Grisonic).

East of the Wall 6 foundations, there are five fragments of **planks** (**PL 1-PL 5**). They stand with their longer side upright.

Fig. 124 Planks located east of Wall 6 (MG).

The dimensions of the planks are:

PL 1: 35 x 4 cm
PL 2: 35 x 7 cm
PL 3: 35 x 4 cm
PL 4: 15 cm long (badly preserved)
PL 5: 15 cm long (badly preserved).

Traces of the white mortar lay scattered on the seabed in several places east of Wall 6 and among the planks.

East side of the separation wall W1 (Zone C)

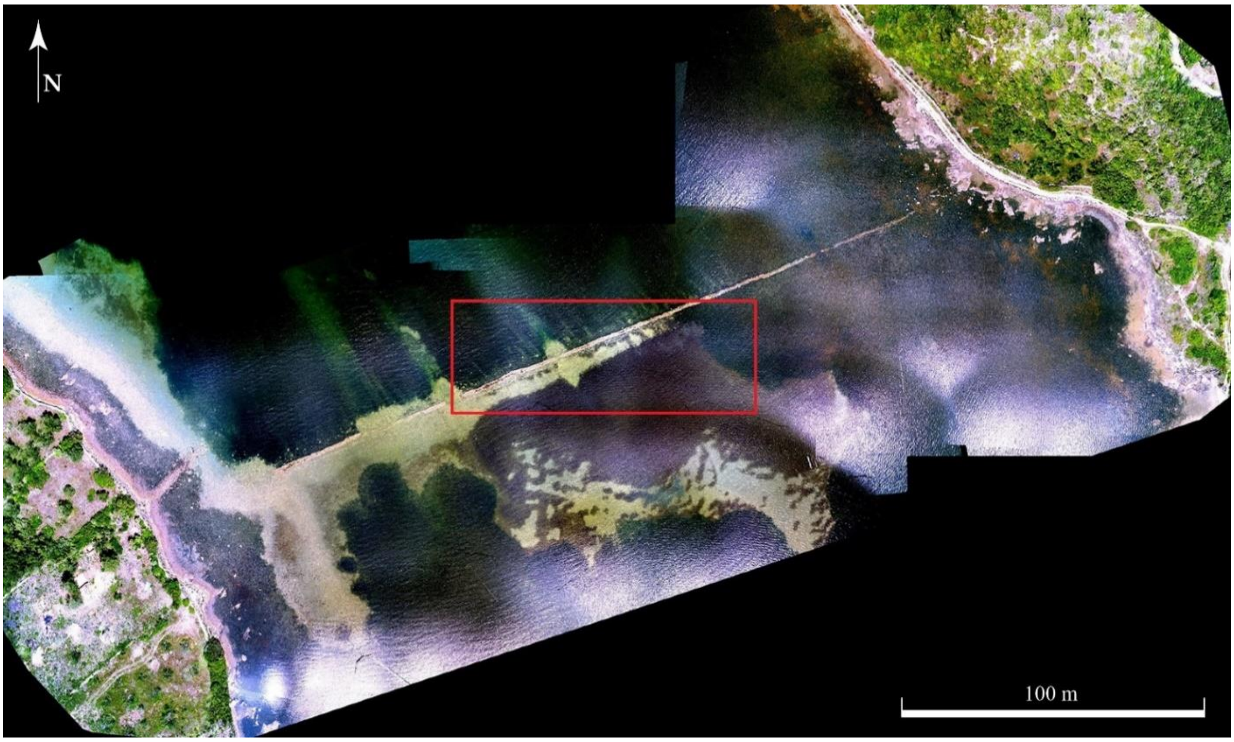


Fig. 125 Makirina Cove: Zone C highlighted by the red square.

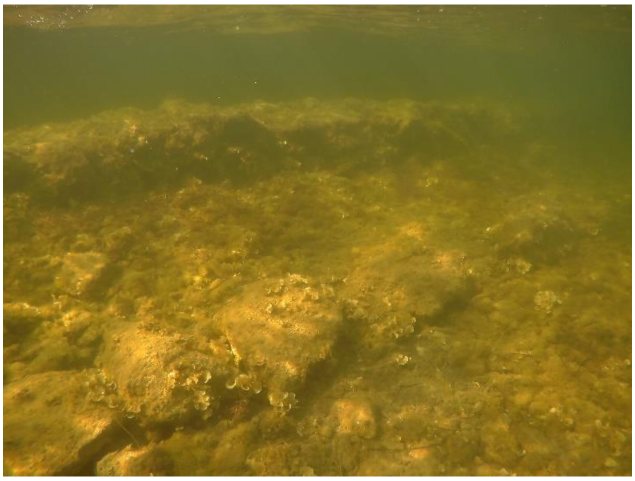


Fig. 126 Wall 1 in the background and Wall 2 in the foreground (M. Grisonic).

In the eastern part of the cove, the separation wall W1 is well preserved. Towards east, it gradually starts to be covered with sea grass, until it completely disappears underneath it. About a meter south of it, the Wall 2 (**W2**) appears again, running parallel to Wall 1. In one spot two rows of stones of W2 are preserved.

1 m south of W2 there is a third wall (**W3)** running parallel to W2 and W1. It is 30-40 cm wide. From the surface, just a row of irregular middle-sized stones (of about 30 x 20 cm) can be observed. Originally, they were probably bound together by clay. This wall maybe constituted the boundary between a channel? and the first row of the saltpans' pools.

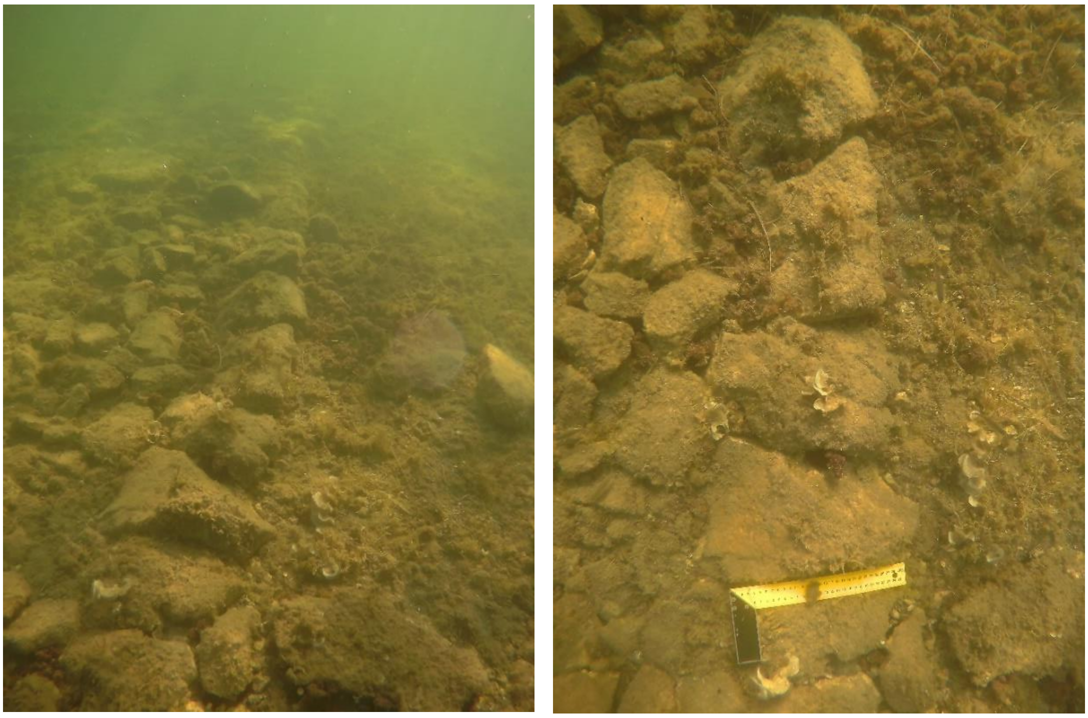


Fig. 127 Wall 3 (M. Grisonic).

Area on the NW side of the cove: a probable medieval channel (Zone D)

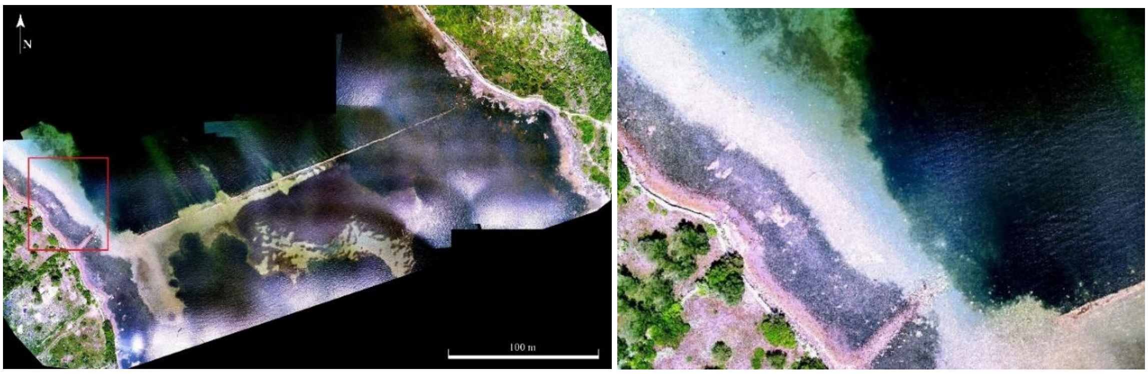


Fig. 128 Makirina Cove: Zone D highlighted by the red square (a) and zoomed (b).

From the drone pictures a wall can be noticed in the shallow waters in the NW part of Makirina Cove, north of the pier and of the beginning of the separation wall W1. Compared to the latter, this wall (**W8**) – which constitutes the external, deeper bank of a water channel, is badly preserved, but thanks to its location and building technique, it can be compared to the lateral channels that were observed in the medieval saltpans of Brbinj and Lavsa (see below).

The underwater archaeological survey confirmed that there was a similar lateral channel in Makirina Cove too, although much less preserved and with unclear limits, therefore non-suitable for sea-level studies. The lateral channel in Makirina is oriented N-S, it is 0.6-0.7 m wide and located at 0.95 m depth. The two parallel retaining walls of the channel (**W8** and **W9**) can be spotted immediately north of the jetty. They are built by rows of stones of different dimensions, with no noticeable binder between them. The outer wall (W8) can be followed for about 69 m, while the internal one (W9) for about 20 m and it later disappears.

Fig. 129 Lateral channel in Makirina Cove with its two retaining walls W9 and W8 (M. Grisonic).

Like in Brbinj, also in Makirina the connection between this channel (which is probably medieval) and the Roman separation wall is destroyed, while in Lavsa the lateral channel connects almost perpendicularly to the separation wall of the saltpans. We can assume a similar situation in Brbinj and Makirina too. It is possible that the medieval saltpans reused the Roman separation wall in some way. Most likely the lateral channel continued south of the separation wall (Wall 7 in Zone E, see below), maybe even destroying the westernmost edge of W1.

Area at the W side of the cove: walls detected by the side-scan sonar (Zone E)

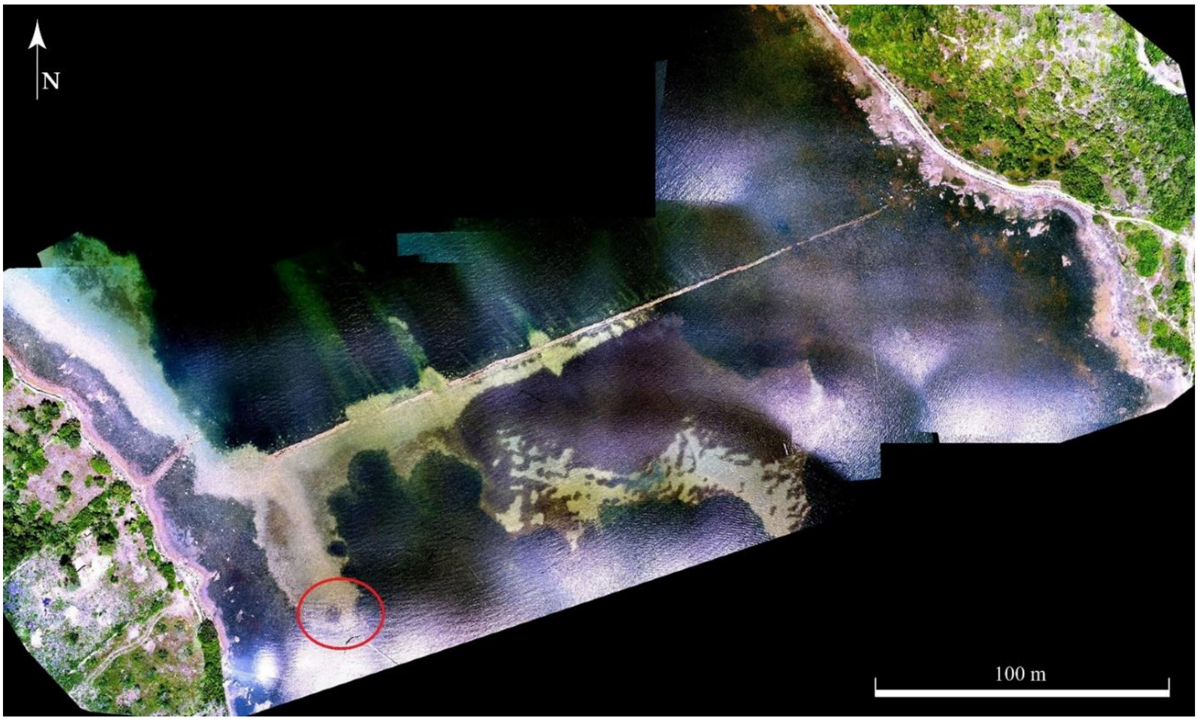


Fig. 130 Makirina Cove: Zone E highlighted by the red circle.

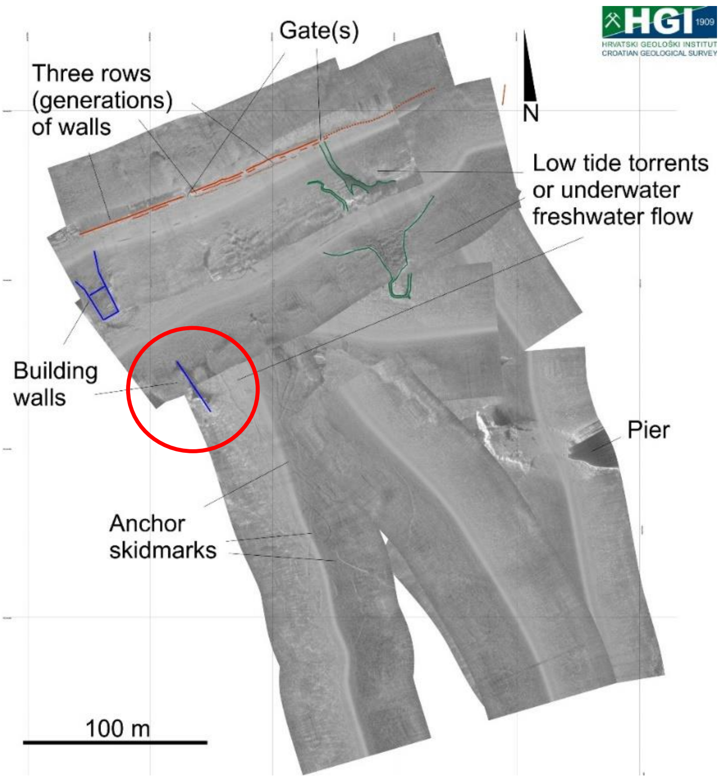


Fig. 131 Side-scan mosaic of Makirina Cove with detected structures highlighted: the southern "Building walls" circled in red represent probably Wall 7, discovered during the underwater survey (S. Miko, O. Hasan).

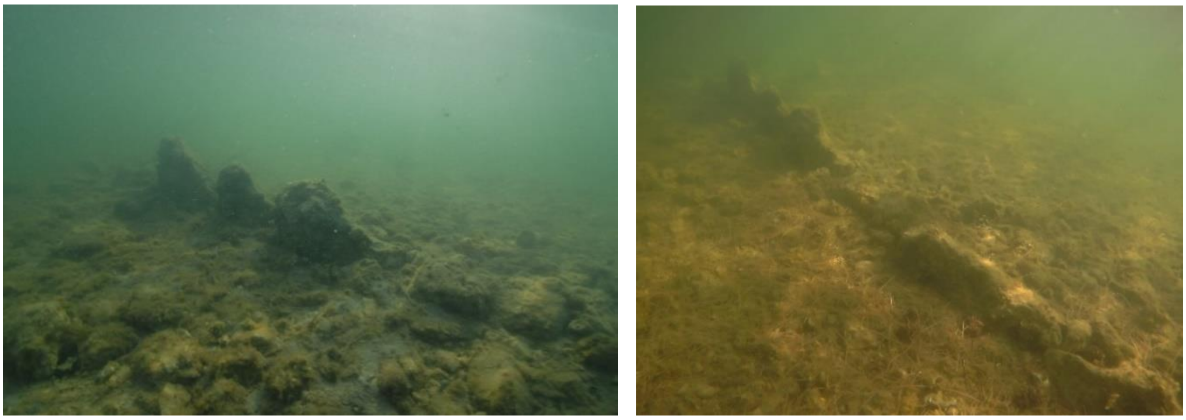


Fig. 132 Wall 7: continuation of W8? (M. Grisonic).

At the western side of the cove, about 80 m south of the separation wall W1, the side-scan mosaic showed the presence of a linear structure. During the underwater survey the remains of a wall (**W7**) were observed at this spot. The wall is preserved for about 3 m in length. It is built with big stones, having dimensions of approx. 60 x 40 cm. The stones are stuck into the sediment, leaving their longer part upright.

They might be the edging stone slabs of saltworks' pools or channels, like in the Roman saltworks of O Areal in Vigo in Galicia (Castro Carrera 2006; 2008; Currás 2017). In Makirina this wall (W7) looks exactly like W8, the external wall on the lateral branch of the saltpans: it has its same orientation (N-S) and it is located at the same depth of 0.95 m. About 1 m W of W7, the upper part of some stones put in a row can be observed, suggesting the presence of a wall parallel to W7. It is probable that there was a channel in between them. For these reasons it is probable that W7 was the southern continuation of W8 and therefore of the lateral (probably medieval) branch of the saltpans in Makirina Cove, although already existing walls might have been reused for this purpose.

Fig. 133 Salt pools in O Areal, Vigo (Castro Carrera 2006).

The bottom of Makirina Cove: the SE side

Fig. 134 SE shore of Makirina Cove with its archaeological remains (www.arkod.hr).

Fig. 135 Orthophoto of the big dry wall structure (a) (www.arkod.hr) and its possible ground plan (b).

The bottom of Makirina Cove is a Mediterranean marsh, where fresh and salty water mix. In the very shallow southern part of the cove, the contour of a wall buried under dozens of centimeters of mud was detected with the help of a stick, at the spot where there were probably the medieval saltpans, as shown on the 1711 map of Makirina Cove.

Fig. 136 Big dry wall structure on the coast – a salt warehouse?: the N side (a) and its NE corner (b) (M. Grisonic).

On the nearby shore in the SE part of Makirina Cove, not very far from Saint Martin's church, a quite big dry wall structure was spotted, having dimensions of about 40 x 13 m. It was partially surveyed, not being an easy task because of the high vegetation. The walls of the structure, of which maximum six rows are preserved, are built with calcareous blocks. Some of them are covered with mortar: they were probably taken from the nearby archaeological area around the church and reused to build this structure, which should be medieval or even later. Nowadays, after the sea level has risen, its northern and western walls are partly underwater. The walls are 55 cm wide, while the wall foundations, which can be seen on the northern and eastern walls, measure 70 cm.

Because of its location near the medieval saltpans, it can be hypothesized that this could have been a salt warehouse or a building somehow connected to salt exploitation.

South of the structure, there are at least two fresh water wells.

Fig. 137 Big dry wall structure on the coast – a salt warehouse?: the wall building technique (a) and the E wall (b) (M. Grisonic).

Fig. 138 Big dry wall structure on the coast – a salt warehouse?: the N wall (a) and the E wall (b) (M. Grisonic).

VI. LABORATORY RESULTS OF SAMPLE ANALYSES

Wood analysis

The **xylological analysis** of the wooden samples was conducted at the University of Haifa by Benny Bechor. All samples belong to **common oak** (*Quercus robur*).

The two timber samples (T1 and T2) were first sent to the Tree-Ring Laboratory at Cornell University in Ithaca, USA. **Dendrochronological analyses** were **unsuccessful**, tree-ring sequences could not be securely crossmatched with one another, nor could secure dendrochronological crossmatches be found with any available absolutely dated oak reference chronologies.

Because it was not possible to date the two timbers dendrochronologically, sections of the outermost rings were dissected from each timber sample and sent to the University of Georgia Center of Applied Isotope Studies for **radiocarbon** (^{14}C) **dating**. The calibrated dates (at 95.4% probability) are the following: **Timber 1** from the western part of the cove was cut in **AD 420-600** and **Timber 2** from the central part of the cove during **AD 400-540**. They might be contemporary to the early-Christian buildings on the coast.

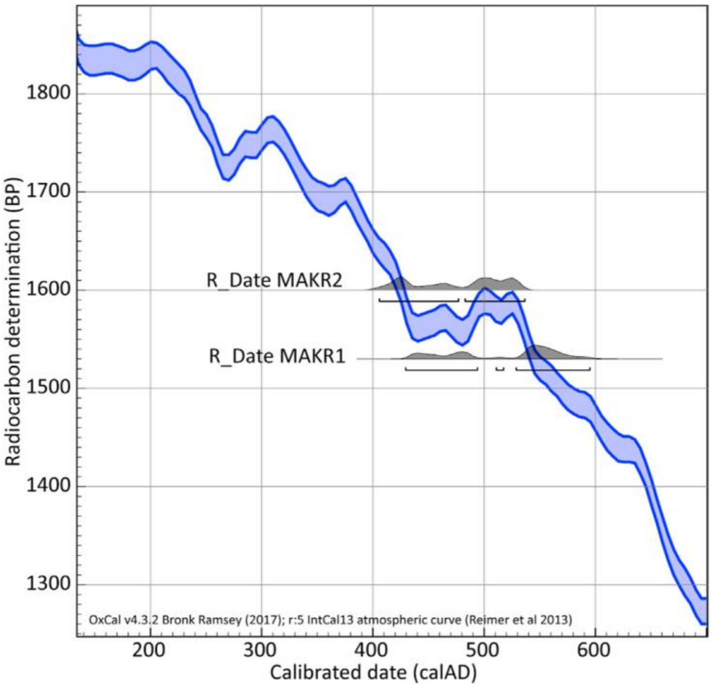


Fig. 139 Calibrated ^{14}C dates for Timber 1 and Timber 2 (Bechor et al*. 2020, fig. 5).*

Mortar/binder analysis

The mortar/binder samples were analyzed in the Inter-Departmental Research Center for the Study of Cement Materials and Hydraulic Binders (CIRCe) at the Department of Geosciences of the University of Padova by prof. Gilberto Artioli and dr. Giulia Ricci.

The sampling spots were the following:

Sample C1: from the southern side of Wall 1, east of the destroyed part of the wall in the central part of the cove;

Sample C2: from the Wall 6 foundations, taken underneath a stone englobed in the mortar layer;

Samples C3 and C4: they belonged to Wall 1, they were collected on the sea bottom in front of Wall 4, where Wall 1 is destroyed.

Sample C5: from the northern side of Wall 1, west of the destroyed part of the wall in the central part of the cove;

Sample C6: includes a wood fragment of Timber 3 and a piece of mortar partially covering the Timber. This sample is interesting to compare wood and mortar radiocarbon dating.

Sample C7: a wooden fragment of Timber 4.

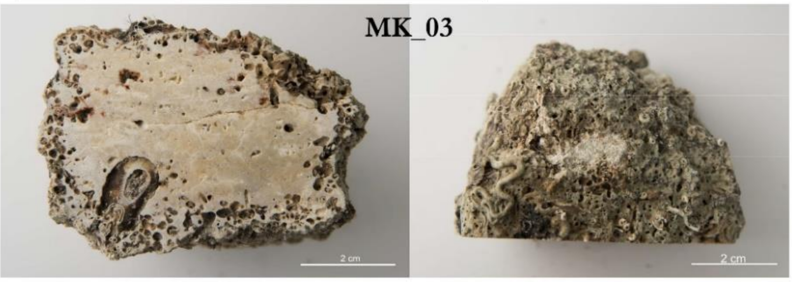
Only samples C2 and C6, which were **taken from Wall 6** (the wall perpendicular to Wall 1), **resulted to be mortar**. Mortar samples are mainly characterized by lime binder with *cocciopesto* and dolomitic sand. Analysis suggests that the mortar hardening process occurred most probably under water, even if the original lime binder was aerial (Bechor *et al*. 2020). The two mortar samples were very polluted by biological and geological carbonates and therefore impossible to date.

All samples taken from Wall 1 were determined to be concretions, or better biogenic carbonates/sediments. Chemical analysis confirmed that Wall 1 did not have mortar and that it was a dry stone wall.

Samples

C1	**MK_01**
C2	**MK_02**
C3	**MK_03**
C4	**MK_04**
C5	**MK_05**
C6	**MK_06**

C1	MK_01	Biogenic carbonate/sediment
C2	MK_02	Biogenic carbonate + mortar
C3	MK_03	Biogenic carbonate/sediment
C4	MK_04	Biogenic carbonate/sediment
C5	MK_05	Biogenic carbonate/sediment
C6	MK_06	Mortar + wood



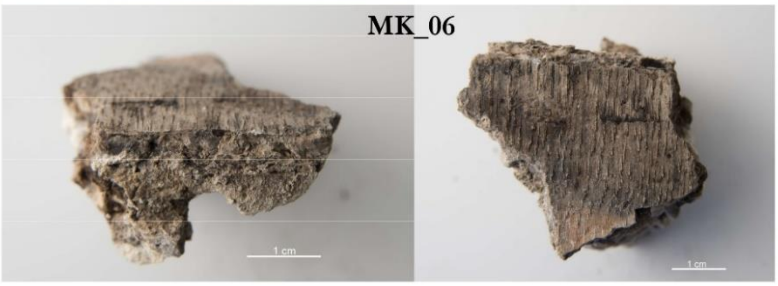


Fig. 140 Makirina mortar samples: original samples (above) and lab-treated samples (below) (courtesy of Giulia Ricci).

During the last research campaign, Giulia Ricci collected additional two samples of wood from Timber 3 (sample C6) and Timber 4 (sample C7). The wood of sample C6 was impossible to date because of the difficulty encountered to remove the mortar that was covering it.

In 2020, AMS radiocarbon dating was conducted on the second sample (C7 or MK_07), taken from **Timber 4** from the central part of the cove. The dating was conducted in the laboratories of the CIRCE INNOVA center of the Campania University Luigi Vanvitelli in Caserta, Italy, under the supervision of prof. Filippo Terrasi, prof. Fabio Marzaioli and dr. Isabella Passariello.

Calibrated radiocarbon dating was obtained following the methodology developed by Stuiver and Polach and calibrated to absolute dates using the OxCal 4.2 software, with the INTCAL20 calibration curve. The obtained calibrated date with 95.4% probability is **AD 80-214**. This dating is very tempting, but for the moment it **should be taken with a reserve**. Contrarily to the sampling method of timbers 1 and 2, where the two timbers were extracted out of the water and their whole sections were sent to the pertinent laboratories for dating, Tiber 4 was sampled underwater, without cutting the whole section of the timber, and therefore maybe missing the outermost ring. Further researches are needed to confirm the dating of this timber to the 2nd century AD.

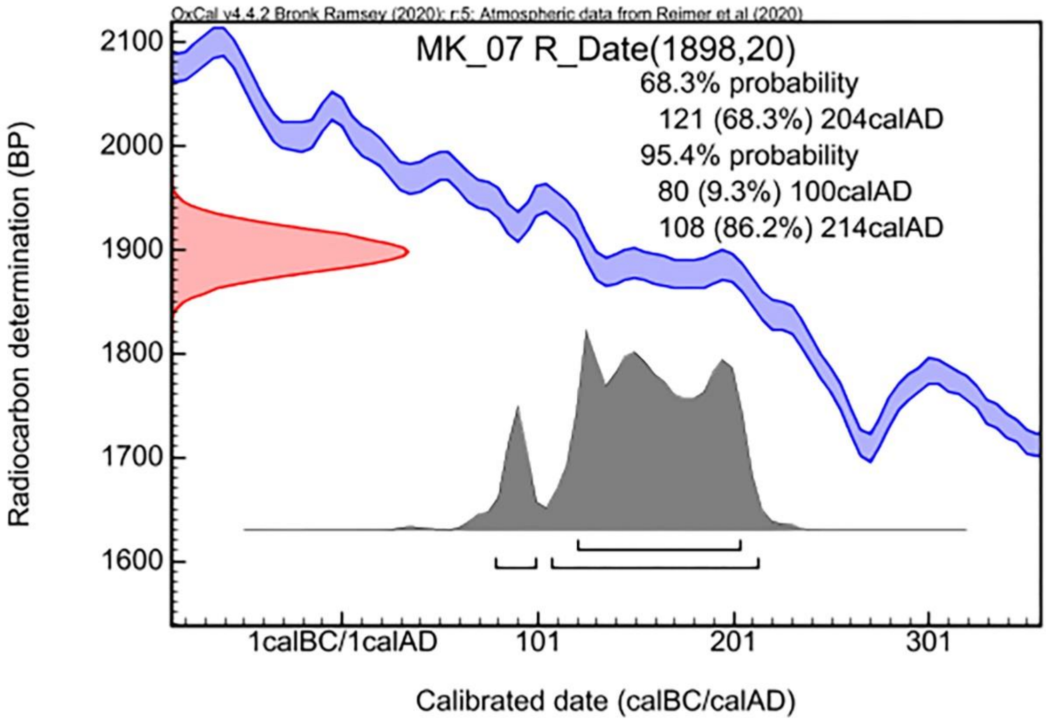


Fig. 141 Calibrated date of Timber 4 sample (courtesy of Giulia Ricci).

VII. CONCLUSIONS

The archival documentation, the archaeological and geochemical (Lojen *et al*. 2004) evidence, as well as the surviving toponyms confirm that Makirina Cove was a past salt-making site.

Wall 1 is a massive separation wall, built to close the cove for the saltpans that were constructed at its internal side. As most saltpans, also those in Makirina were built facing north, with a big separation wall protecting them from the *jugo* (sirocco), a strong wind which brings high waves and that could easily destroy them. **The wall is just the upper part of a massive embankment, 6-7 m wide**, built with a big mound of stones. The wall was built on the upper part of the embankment, in the middle. We do not know yet how deep the wall is, we do not know anything about its foundations (which might had contained mortar, like the foundations of Wall 6 in the central part of the cove). The separation wall W1 was surely built on hard ground, otherwise it would had moved. Probably it was also used as a walking surface, a bridge between the two shores of the cove, to avoid the long walk around it.

There was no sense to build such a massive and thus expensive structure (embankment with the wall) to create fish traps. **The surface created between the separation wall and the shore is a completely flat plain**, suitable for salt exploitation. Additionally, the presence of at least two other parallel walls on the internal side of Wall 1 can be put in relation with the construction methods of modern saltpans, where they are used to delimit water channels or saltpans' pools (Koludrović, Franić 1954). The seabed on the internal part of Makirina Cove is muddy and it looks very similar to what was observed on other saltpan sites that were surveyed. The sediment on the internal side of the wall is 1 to 3 m deep.

The site of Makirina can be compared to the underwater walls discovered in Elaia Bay, the harbor of Pergamum in western Anatolia (Seeliger *et al*. 2014). In an area of relatively flat bathymetry, approximately 1 km south of the ancient closed harbor basin of Elaia, in front of a salt marsh, there are six parallel submerged walls, located at 1 m depth, covering an area of c. 1150 x 265 m^2. The lengths of each wall range between 80 and 265 m and they have a width of 1 m, rising few decimeters above the silty-sandy seabed. The building technique of the walls consists of two parallel rows of ashlars and quarry stones, with the *nucleus* of the wall filled with smaller stones and debris. The ashlars have dowel holes, witnessing that they are reused *spolia*. These walls were constructed without solid foundations and most of them date between the 4th and 6th centuries AD, with possible later reuses. They were convincingly interpreted as walls of ancient saltpans, built, as observed by the authors, in a fast and economic way, without foundations, reusing available blocks from demolished city buildings (Seeliger *et al*. 2014: 151-152). Unlike in Makirina, most of the submerged walls in Elaia were demolished because of anthropic or natural causes, not allowing the reconstruction of their functional height and therefore they were not useful as sea level markers (Seeliger *et al*. 2014).

Fig. 142 Underwater walls in Elaia Bay (Seeliger et al*. 2014, fig. 3).*

The exploitation of salt in Makirina had **at least two different chronological phases: a Late Antique (5th-6th century) and a medieval phase**. For the moment, the 2nd century AD dating of the timber T4 englobed in the foundations of Wall 6 in the central part of the cove, must be taken with a reserve.

The radiocarbon dating of the other two timbers (T1 from the western side of the cove and T2, which laid just 2 m north of Timber 4), showed that they were cut in the 5th-6th centuries. Their employment in the saltpans' structure could be contemporary to the construction of the early-Christian buildings on the coast, the earlier *domus ecclesiae* from the first half of the 5th century AD, or the later three-nave-church from the second half of the same century, or during the Justinian time (AD 527-565), when some interventions in the early-Christian church were applied.

Although it is hazardous to compare the two sites of Makirina and Elaia, because they are very distant one from another, there is an important clue that differentiates the two sites, which, according to the so-far obtained data, should be more or less contemporary: the building technique of the saltpans' walls. The walls in Elaia are typical, rapidly built Late Antique walls, having an outer core of reused ashlars and larger sized blocks, with the inner core filled with smaller stones. Moreover, these walls do not have foundations and apparently mortar was not used to link the different components of the walls. Differently, the saltpans' separation wall in Makirina is a very solid dry wall, built with several rows of stones fitted one on top of another. This building technique required mastery, time and economic availability. Although the foundations of the wall have not yet been explored, it is hard to believe that it was built on non-solid ground, because it would have moved over the centuries. The studies of Bechor *et al*. (2020) demonstrate that the wall stayed in place and that it is preserving its original height. Furthermore, the exposed foundations of Wall 6 in the central part of the cove show the abundant use of mortar and other materials, such as stone slabs, ceramic building materials, wooden poles and timbers to consolidate the base of the wall. It is very likely that similar or probably even more compact materials were used in the foundations of the separation wall. All this points toward an earlier construction phase for the saltpans in Makirina and the fact that the two reliably dated timbers (T1 and T2) were part of a Late-Antique reconstruction of the saltpans.

If the dating of Timber 4 (from the Wall 6 foundations) to the 2nd century AD is right, the use or reuse of timbers and planks of different chronological timespans in the same salt-making site would not be a characteristic only of the site of Makirina, but it is already attested in Pantan, 3 km southeast of Trogir in central Dalmatia. Radiocarbon dating of samples of saltpans' wooden structures located close to the Rika river mouth, showed that the planks were from the 1st century BC, while the timbers were from the 8th century AD, attesting the continuity of salt production (Radić Rossi 2008: 494-496). Similarly, also in Makirina the different dating of the timbers sampled on the site could suggest the more or less continuous use of the cove for salt exploitation from the Roman Imperial period to Late Antiquity. The function and chronology of the various underwater structures needs to be better defined with an underwater archaeological excavation, which would comprise sampling of the timbers left *in situ* for dendrochronological dating.

Even if the so-far oldest timber found on the saltpans dates to the 2nd century AD, and even this dating must be taken with a reserve, we cannot exclude the possibility that the original saltpans might have been constructed even earlier, in the 1st century AD, contemporary to the building of the *villa* on the coast. In fact, it is likely that the *dominus* of the *villa* chose this spot to build his estate, exactly because he understood the great potential of Makirina Cove for salt production, not just for his own needs, but also primarily for trading salt on local markets. At present, any dating materials in or under the separation wall W1 were found.

Relative sea level (RSL) at the time of the wall's construction and operation was between -72±16 cm >RSL> -111±16 cm (Bechor *et al*. 2020). The dating of the wall in Roman times is confirmed by the toponym *Makirina*, deriving from Latin *maceries* and meaning dry stone wall. The name *Makirina* was the result of the Romanic-Slavic linguistic symbiosis, which occurred during the 7th century AD (Vuletić 2010: 337-338). In addition to this, the dry wall building technique of Wall 1, because of the careful selection of more or less regularly cut blocks, assembled with a certain mastery, is more suitable to fit into the Roman timespan. Wall 1 is very different from the unsystematic assemblage of stones, which is characteristic of the other walls that were observed on the saltpans in Brbinj, Lavsa and Vrgada, which can all be dated to the Middle Ages (see below). The same disorganized assembly of rocks was detected for Walls 8 and 9 in Makirina Cove, which should belong to a lateral water channel, functional of the medieval saltpans.

The Roman saltpans in Makirina were probably located deeper, closer to the separation wall. In the whole area close to the wall, few scattered fragments of Roman roof tiles can be spotted. Although for the moment there is no archaeological evidence to confirm it, the original saltpans could have been constructed by the owner of the Roman *villa* located in the SE part of Makirina Cove. It is possible that during a subsequent Roman period the saltpans passed under the administration of a larger settlement, for example *Colentum* by the present town of Betina on the nearby island of Murter.

The harbor of the Modern era village of Ivinj was 1 km south, in Komanjica, and not in the shallow and hardly reachable Makirina Cove (Juran 2010 b: 89). Before the 19th century the strait of Tisno was much larger than it is today, when it is just 15 m wide (Kurilić 2010: 34, n. 10), and the sea route between Komanjica on the mainland and the northern Murter Channel (towards Betina and ancient *Colentum*) was probably more frequented than today. It is possible that also in Roman times salt produced in Makirina was brought via ground to Komanjica and shipped towards *Colentum* and other markets.

Archival documents testify the use of the cove for salt exploitation at the end of the 13th century. In the Middle Ages, we would think that the sea level in Makirina Cove rose and that the saltworks were moved to the southern part of the cove, as suggested by the 1711 map, where the “*Sito di Saline*” comprises just the southernmost part of the cove. The map was probably indicating the back then still visible remains of the late medieval saltpans.

In fact, relative sea level studies conducted on the site by Bechor *et al.* (2020) revealed a fluctuating trend of the medieval sea level. They showed that in central Dalmatia, RLS during post Roman time was -92±25 cm, rising to -62±21 cm in the 9th century and then descending to -104±20 cm in the 14th century. Therefore, we can assume that during the Middle Ages, the local peasants, who seasonally worked also on the Makirina saltpans, had to apply many modifications to adapt the saltworks’ structure to the changing sea level. It is possible that when the relative sea level was lower they reused the separation wall W1 and made it functional for the saltpans of their time. Later, when the sea level rose and the separation wall was flooded by the sea, they had to build the nowadays badly preserved lateral channel to bring the seawater to the salt basins located at lower depths, in the southern part of the cove.

In 1409, Dalmatia passed under Venetian rule and Venice, because of its salt monopoly, closed or destroyed the majority of Dalmatian saltpans. During the Late Middle Ages, an archival document attests that at least one part of Makirina Cove was reemployed for fishing traps, while the saltpans were probably greatly reduced and gradually completely abandoned.

Fig. 143 Map of the larger area surrounding Makirina Cove (Google Earth).

4.1.2. Case study 2:

BRBINJ ON DUGI OTOK

Fig. 144 The saltpans in Brbinj (www.adriatic.hr/en/accommodation/dalmatia/dugi-otok, accessed 02.02.2021).

I. INTRODUCTION

Brbinj is a small village located on the NE side of Dugi otok (= Long island) in Zadar County, northern Dalmatia. The village stretches over two coves: Jaz to the south, a safe port protected from all winds and Lučina to the north. The NE deeper side of Lučina Cove is the place where the ferries coming from Zadar dock. To the NW, there is the Utran/Utra Islet, called by the locals Školj (Kaleb 2014: 62), which closes and protects Lučina Cove from northern winds. The saltpans, located in the shallow southern part of the cove, are well preserved. The memory of it was still alive in the 1940s (Strgačić 1949: 98).

Fig. 145 Location of Lučina Cove (www.arkod.hr).

Fig. 146 View of Brbinj towards N: Jaz and Lučina Coves (www.dugiotok.hr/img/content/mjesta/brbinj.jpg, accessed 02.02.2021).

II. HISTORY OF THE COVE

Archaeological researches

The remains of the medieval saltpans in the southern part of Lučina Cove were never researched before.

On the SW shore of Utran Islet, there are the ruins of an early-Christian church (Uglešić 1993: 157; 2002: 103). These remains were first researched by Ivo Petricioli (1961). The apse of the church (3.9 x 3.2 m) leans on a rectangular (7.8 x 6.1 m) nave. In front of the church, there were other two buildings annexed to it. This complex was abandoned when the Benedictines built the new church of Saints Cosmas and Damian in the village of Brbinj (Vežić 2005: 126), mentioned in the 1195 document (see below). Both Uglešić and Vežić think that the name of the old church was transferred to the new one. The church on Utran Islet should be dated to the

5th or 6th centuries, when most early-Christian churches were built in Dalmatia (Uglešić 1993: 158).

According to Strgačić (1928: 98) and to Skok (1950: 123), the locals interpreted the remains on Utran Islet as a salt warehouse. It is clear that this could have been an ideal position to keep the salt safe and under control. On the other hand, Uglešić thinks that in Late Antiquity salt was stored and produced on the nearby Utra Peninsula (Uglešić 1993: 158), located to the W, in front of the Utran Islet. The toponym Utra probably comes from lat. *ultra* (= it. *oltre,* cro. *preko*), meaning on the other side (Skok 1950: 123). On the Utra Peninsula, there are ruins of various buildings and according to Uglešić also saltpans and fish traps that would date to Late Antiquity, based on his discovery of Byzantine pottery and Late Roman amphorae fragments on the shore (Uglešić 1993: 158). This part was not surveyed by our team. Archaeological excavations are needed to shed light on the function of all buildings, both on the Utra promontory and the islet. A short archaeological campaign on the Utran Islet was carried out in 2019, organized by Jona Petešić from the Municipality of Sali and directed by Dario Vujević from the University of Zadar.

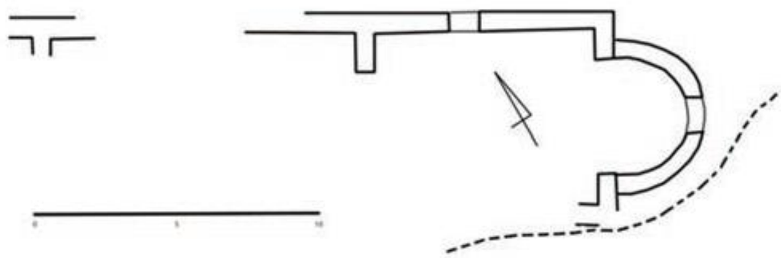


Fig. 147 Plan of the early-Christian church on Utran/Školj Island (Petricioli 1961).

Fig. 148 Remains of the early-Christian apse on Utran/Školj Islet (courtesy of J. Petešić).

Historical sources

The oldest document mentioning the existence of the village of Brbinj is the bull of pope Celestin III from the 5th of May 1195 (CD II, 273-275). In this document, the pope puts under his protection all the properties owned by the Benedictine monastery of S. Chrysogonus (Sveti Krševan/San Crisogono) from Zadar, including the church of S. Damian in Brbinj, with its possessions. The monastery of S. Chrysogonus was one of the richest in the region and had most properties on the islands of the Zadar archipelago, which were usually grouped around churches (Grgin 1996: 44).

Thanks to a subsequent document dated to the 1st of March **1196**, we find out that Vincencius (Vinko), the abbot of the **S. Chrysogonus monastery**, rented one third of the valley of *Birbinio* to the master Martino and his partner Matteo, to **build saltpans** (CD II, 277; Čolak 1963: 482; Hocquet 1978: 84). With this document, the monastery commits to finance the construction of the saltpans and therefore has the right to be the first to gather salt. Of the remaining quantity of salt, the abbey would take two parts, while the third part would be split between the two salt workers Martino and Matteo. The two of them and their families were obliged to offer their salt first to the monastery, to which they would sell it for seven *perperi* less (CD II, 277). *Perperi* were probably Venetian coins (Čolak 1963: 482, n. 15). The tenants could also leave the produced salt to the monastery as an offering for their soul. The document specifies that the saltpans of Brbinj can be leased only to Martino, Matteo and their families. This is the oldest known document attesting the exploitation of saltpans in the Zadar area (Raukar 1977: 212).

Almost 200 years later, the abbot Johannes brought three salt-workers from Trieste to rebuild and exploit 51 saltpans, which the monastery possessed in Brbinj (CD XIV, 297-298; Hocquet 1978: 83). In the document from November 3rd **1370**, it is stated that for each day of work the salt workers would receive five *soldi* and the expenses for their board and lodging will be covered. Each year they would keep one third of the salt produced, while the other two thirds would go to the S. Chrysogonus abbey. The salt workers signed the contract with the monastery for three years, during which the abbot promised to defend the saltpans. After three years, the workers would have to leave (CD XIV, 297-298).

Following the recognition of Venetian rule in 1409 and the monopolization of salt production and trade, most of the eastern Adriatic saltpans were abandoned or destroyed (Raukar 1977: 212-214), which probably happened also in Brbinj.

III. SCIENTIFIC RESEARCHES IN BRBINJ

Activities conducted on the site during the May 2018 campaign

The project *Saltpans as Anthropogenic Landscape Intervention, a new multidisciplinary Approach for Studying Sea-level changes* started in 2018 with the goal of determining whether the submerged remains of antique saltpans on the Adriatic Sea can represent a new indicator for relative sea level changes over the past two millenia (Bechor *et al*. 2020).

The first survey campaign in Brbinj/Lučina Cove took place on May 27th 2018, with the collaboration of Croatian and Israeli researchers. The team was composed of seven members: B. Bechor, D. Sivan, S. Miko, O. Hasan, M. Grisonic, A. Brook, T. Ivelja. Jona Petešić from the Municipality of Sali, who is also an archaeologist and PhD student at the University of Zadar, joined us for the underwater survey. The following activities were conducted on the site:

- **DGPS measurements** of the separation wall and other points for geo-referencing purpose, in order to align the DTM coordinates in the Croatian Terrestrial Reference System - HTRS 96, based on the Geodesic Reference System - GRS 80 (B. Bechor, D. Sivan);

- **photogrammetric drone mapping** of the separation wall, with a vertical accuracy of 4 cm and a horizontal accuracy of 2 cm and **LiDAR** from two points in the west side of the cove (A. Brook, T. Ivelja);

- **bathymetric mapping** with the **side-scan sonar** of the separation wall and the portion of the cove comprised between the wall and the shore, from 2 m until 0.30 m of depth (S. Miko, O. Hasan). Side-scan sonar data were collected using Humminbird 999ci HD SI combo echosounder, in combination with Humminbird AS+GPS HS precision GPS with heading sensor. The equipment was mounted on a 4.5 m zodiac boat with outboard engine and trolling motor for use in shallow environment;

- **underwater archaeological survey** of the submerged remains of the saltpans (M. Grisonic and J. Petešić).

During the first underwater survey, the eastern and central parts of the cove were surveyed. The survey and the photographing of archaeological remains were really challenging because of the very shallow water depths (70 cm - 30 cm).

Short survey in July 2018

In July 2018, another underwater survey of the saltpans' remains was performed with the help of Katarina Batur, research assistant from the University of Zadar. In this occasion, better underwater pictures were taken.

Activities conducted on the site during the October 2018 campaign

The goals of this survey campaign were to take geological cores of the sediments in Lučina Cove, the continuation of the archaeological survey, with the documentation of the underwater remains and the collection of wood and mortar samples to be sent to dendrochronological and radiocarbon dating.

The team was composed of five members: D. Sivan, B. Bechor, S. Miko, O. Hasan and M. Grisonic. J. Petešić joined us once again for the underwater survey.

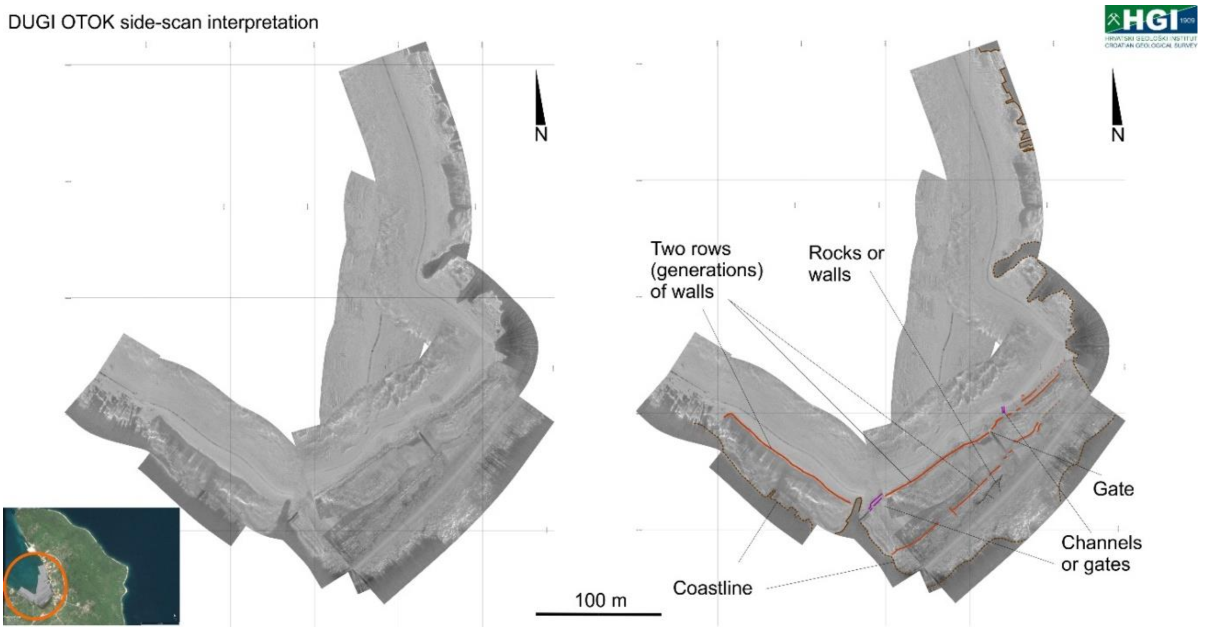


Fig. 149 Side-scan mosaic of the saltpans in Brbinj with detected structures highlighted (O. Hasan, S. Miko).

IV. DESCRIPTION OF THE SITE

General plan

Among the surveyed saltpans, those in Brbinj are the best preserved. From the satellite pictures, a planimetric similarity can be seen comparing the saltpans in Brbinj, Lavsa in the Kornati archipelago, Sutomišćica on Ugljan Island, and Ždrelac and Lučina Coves on Pašman Island.[35] All saltpans make a U-shape facing north, with two lateral (W and E) branches running parallel to the coast, one on each side of the cove. The lateral branches connected to the main southern saltpans at an almost 90° angle. On the inner side of the branches, there was an about 1-2 m wide internal channel, in between the separation (external) wall built with bigger calcareous

[35] A planimetric similarity between the saltpans in Brbinj and those of Sutomišćica on Ugljan island was already observed by Uglešić and Parica (2013: 151).

rocks, and a smaller internal wall, assembled with smaller rocks. On the flat surface obtained in between the channel and the coast, it is possible that salt pools were arranged. These pools could constitute (one part) of the evaporation basins, while the crystallization pools were probably located in the southern, main part of the saltpans. All the above-mentioned saltpans having a U-shaped plan can be dated to the Middle Ages by historical sources. The dating in medieval period is strengthened by the building technique of the saltpans' walls (dry walls constructed with a disordered assemblage of calcareous rocks of various dimensions), but also by the depth at which the saltpans' remains lie today, ranging from 30 to 60 cm below the datum. Also in Makirina there is a similar lateral branch of the saltpans, but not very well preserved (probably a medieval addition to the original Roman saltpans).

Fig. 150 Aerial picture of the saltpans in Brbinj (B. Bechor, A. Brook, T. Ivelja).

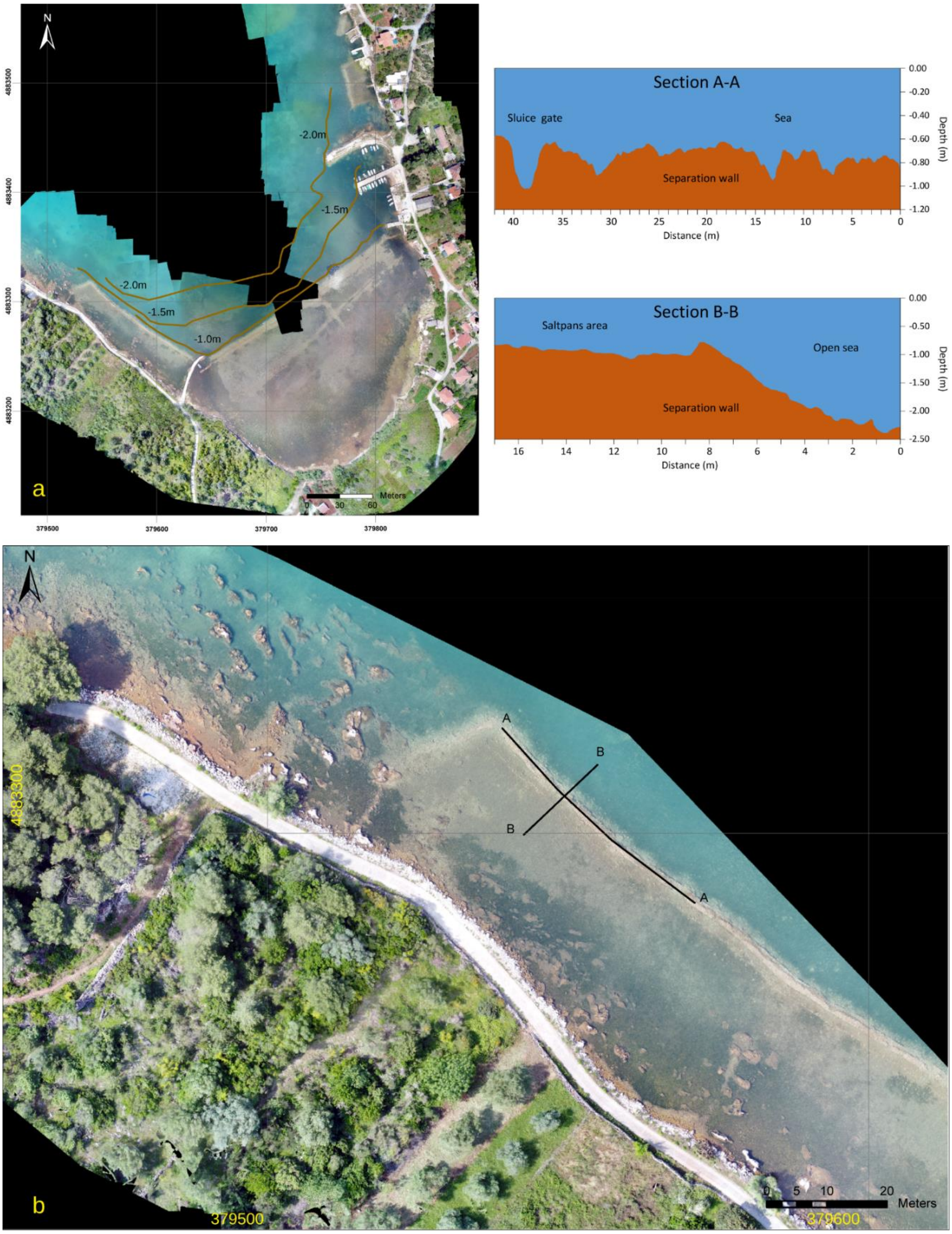


Fig. 151 Digital surface model of the saltpans in Brbinj (a) and cross-sections in the western separation wall (b) (Bechor et al*. 2020, fig. 6).*

The digital surface model of the saltpans in Brbinj shows the presence of two main walls in the central part of the cove: the massive, about 190 m long separation wall oriented E-W (**W1**) and a thick, about 65 m long central wall (**W2**), perpendicular to the separation wall W1. Three rows of salt pools located on both sides of W2 can be observed.

At the western side of the cove, there is a lateral branch of the saltpans of about 125 x 20 m, which connected at an almost 90-degree angle to the main E-W saltpans' separation wall W1. At the eastern side of the cove, there was another branch of about 185 x 20 m, symmetric to the western one, also connecting to W1. Just a small NE portion of this branch is preserved, above the three modern jetties.

The whole exploitable surface of the saltpans was about 2,2 hectares (22.000 m^2), divided as following:

- exploitable surface on the western branch of the saltpans: ca 2.800 m^2;
- estimated exploitable surface on the eastern branch of the saltpans: ca 2.900 m^2;
- southern (central) part of the saltpans: ca 17.000 m^2.

The saltpans in Brbinj were therefore twice bigger than the saltpans in Lavsa (the estimated dimension of which was about 1 hectare).

Fig. 152 The saltpans in Brbinj (Google Earth).

Fig. 153 The saltpans in Lavsa (Google Earth).

Fig. 154 The saltpans in Sutomišćica on the island of Ugljan (Google Earth).

Fig. 155 The saltpans in Lučina Cove close to the town of Pašman, island of Pašman (Google Earth).

Fig. 156 Mali Ždrelac passage between the islands of Ugljan and Pašman, with saltpans' remains on both coasts (Google Earth).

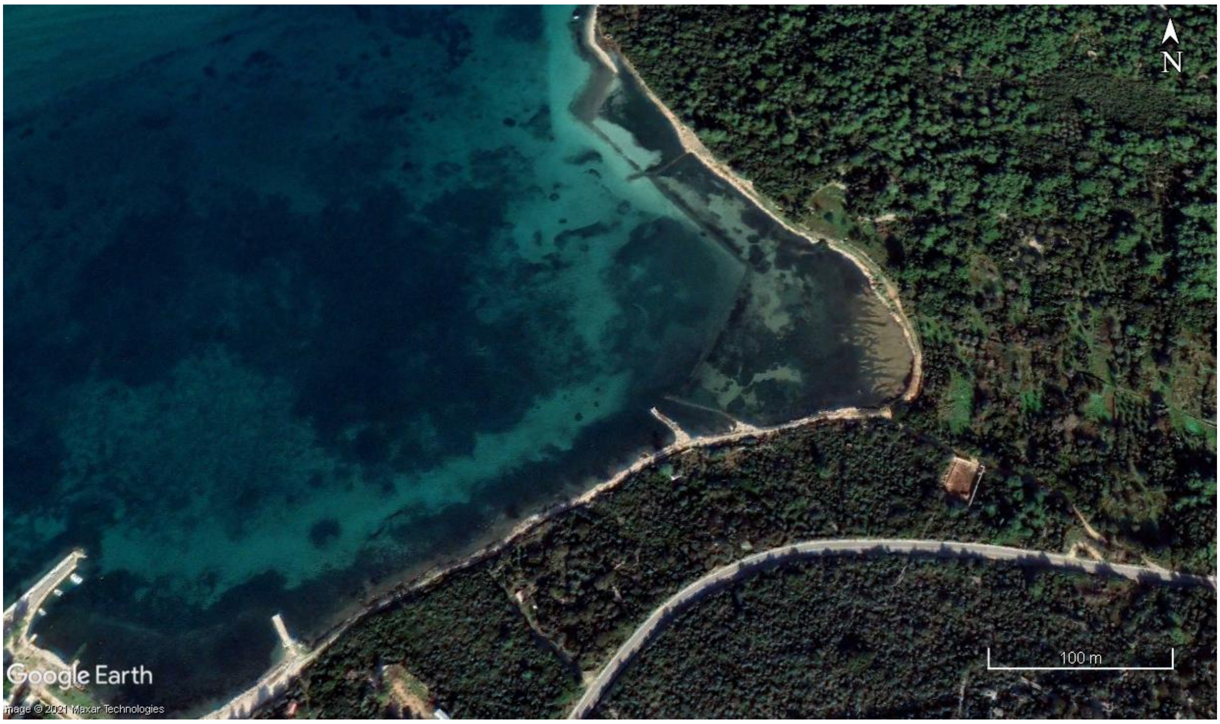


Fig. 157 Saltpans in Ždrelac (Soline) Cove on the island of Pašman (Google Earth).

The central part of the saltpans in Brbinj

The big separation wall **W1**, oriented E-W, is about 190 m long, with an average width of 7-8 m; its top sits at an average depth of -75 cm below datum. It crosses the cove, in between two modern jetties at the E and W side of the cove . In fact, W1 is a big embankment made of an accumulation of all kinds of rocks, pebbles, and ceramic fragments – mostly medieval or modern, but also Roman (amphorae fragments). On top of W1, there was a 1.5-2 m wide channel, delimited with two small walls. It is visible from the orthomosaic (Fig. 158) and from the side-scan mosaic as well. It is probably the continuation of the channel (CH1) on the western lateral branch of the saltpans. Unlike in Makirina, in the Brbinj saltpans no clearly defined sluice gates in the big separation wall were found.

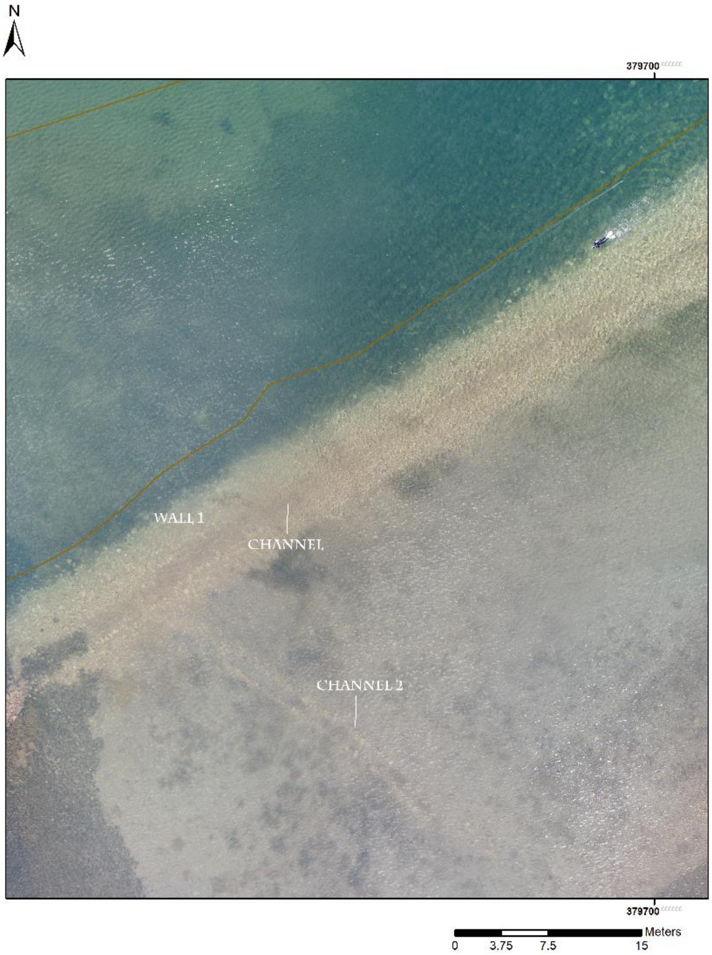


Fig. 158 Wall 1, the channel on top of it and Channel 2 (B. Bechor, A. Brook, T. Ivelja).

Behind W1, a supra-elevated flat surface was created to build the salt pools, which are nowadays located at about 50 cm depth. The depth at the external side of W1 goes from 1 to 1.5 m.

In the central part of W1, there is today a pile of stones holding the Croatian flag. Behind it, there is a large central wall (**W2**), about 65 m long, oriented N-S, perpendicular to the big separation wall W1. Like W1, W2 is built of an accumulation of rocks and smaller stones.

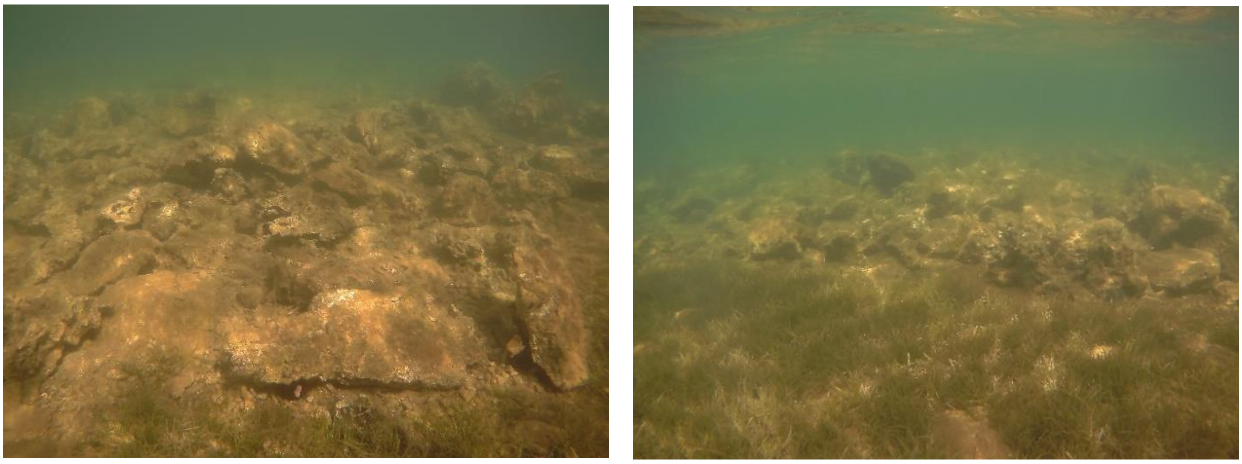


Fig. 159 Top of Wall 1 (a) and the border between salt pools and Wall 1 seen from south (b) (M. Grisonic).

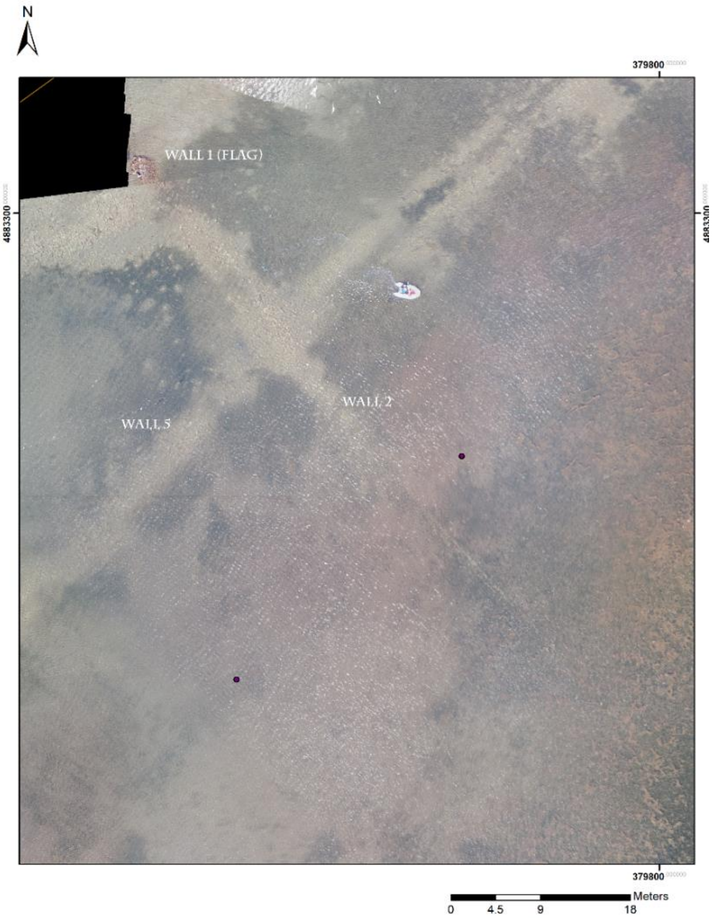


Fig. 160 Orthomosaic of the central part of the saltpans: Wall 2
(B. Bechor, A. Brook, T. Ivelja).

Combining the results of the underwater archaeological survey with the aerial photos of the saltpans, it is clear that on the flat surface created between the separation wall W1 and the coast, there were at **least two bigger enclosed surfaces**, which can be interpreted as **evaporation basins**, followed by **three rows of salt pools with similar dimensions**. These three rows can be seen on both sides of W2. Each row was separated by smaller embankments, originally constructed with stones and mud, maybe enforced by wooden planks, running parallel to W1. Two of them are clearly visible from the aerial pictures: **W5** and **W6**, and the SW corner of the saltpans is visible too. During the underwater survey, it was sufficiently easy to identify the remains of the embankments: today what is left on the seabed are numerous successions of stones positioned in straight lines, which are enclosing different rows of salt pools and dividing the salt basins of the same row. The bottom of the ancient salt pools is muddy, and while stepping in the mud, the feet remain stuck in it. As noticed in Makirina Cove, sea grass grows out of the sediment, which accumulated on the bottom of ancient salt pools (it is probably the residual of the clay that paved the salt pools), while usually it does not grow on the rocks/embankments, which were delimiting different rows of salt pools and the single salt basins. At least one part of these pools divided in three rows constituted the **crystallization basins**.

Two salt pools of the first row, located west of wall W2, in between W5 and W6, were measured. The dimensions of the second (better preserved) basin in the first row are: 1.5 m on the N side, 2.8 m on the W side, 1.4 m on the S side and 3.4 m on the E side. Another basin of the same row further to the W has the following dimensions: 1.5 m on the N side, 2.9 m on the W side, 1.4 m on the S side and 2.9 m on the E side. The small embankment separating this pool from the adjacent one to the W measures 35 cm. In the NE corner of the measured basin, a metallic nail (**A2**) was collected.

It was impossible to distinguish on the field the quadrilateral pattern of the salt pools of the second row, which can be seen on the aerial pictures. However, the remains of the walls/embankments parallel to W1, between the first and second row of salt pools (W5 and W6) were spotted. The distance between the two embankments was 1.4 m, which should correspond to the length of the salt pools of the second row.

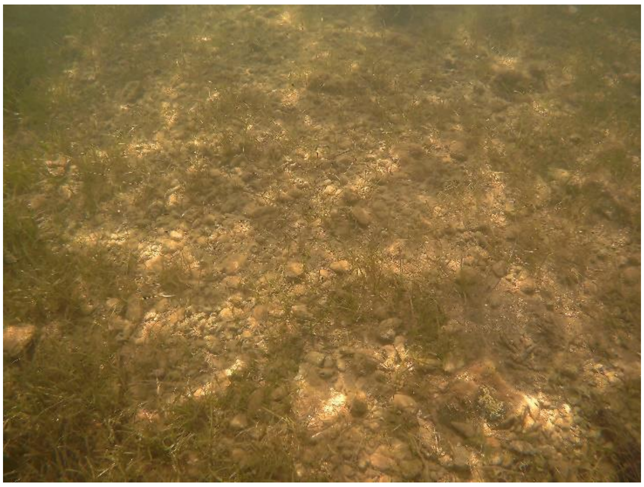


Fig. 161 The sea bottom in the presumed ancient salt basins (M. Grisonic).

The channel in the SW part of the saltpans

In the SW part of the saltpans there is a 0.7-1 m wide channel (**CH2**), oriented NW-SE, perpendicular to the central separation wall W1. The connection between W1 and CH2 is not visible underwater, but it is visible from the drone pictures. The channel can be followed for about 40 m towards S, and then it gradually disappears. It is delimited on each side by a succession of rocks, about 35 cm wide. Along them, six openings were identified, possibly for sluice gates. Four of them were 30-35 cm wide, two were 60-65 cm wide, and there was a bigger opening of about 150 cm.

Fig. 162 Channel 2 (M. Grisonic).

Fig. 163 The SW part of the saltpans, where the western branch meets the central part of the saltpans (B. Bechor, A. Brook, T. Ivelja).

The western branch of the saltpans

On the SW side of the cove, there is an opening in W1, between the two modern jetties. Their construction destroyed the connection that existed between the big separation wall W1 to the S and the western lateral branch of the saltpans to the N. Anyway, from the aerial pictures it is clear that the W separation wall of the saltpans (**W3**) connected at an almost 90° angle to the main saltpans' separation wall W1 and that the channel built along the western separation wall (CH1) continued to run along the southern separation wall. One part of the water was let into the Channel 2.

Fig. 164 View from the SW part of the cove towards the Utran Islet and the ferry port (J. Petešić).

Fig. 165 Western branch of the saltpans (B. Bechor, A. Brook, T. Ivelja).

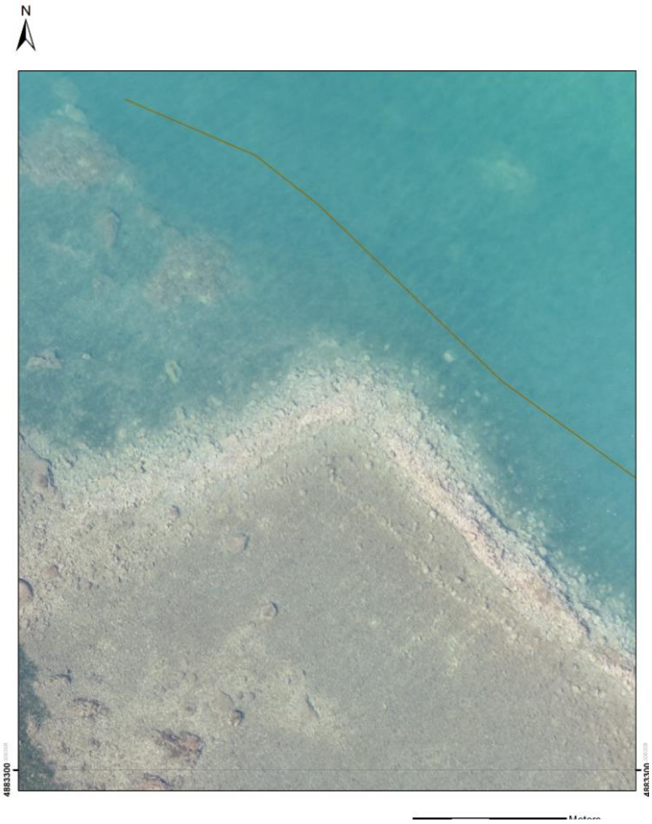


Fig. 166 Detail of the saltpans' W branch: Wall 3 and Channel 1 (B. Bechor, A. Brook, T. Ivelja).

Fig. 167 Western separation wall (Wall 3) (M. Grisonic).

The western lateral branch has an excellently preserved separation/external wall (**W3**), which is visible from the satellite pictures and from the coast. It is located on top of a large embankment, 2-3 m wide, built with a mound of rocks and stones of all dimensions. The wall is about 120 m long, with an average width of 1 m and its top is located at an average depth of -75 cm. It is a dry wall, built with four to five rows of calcareous blocks of medium dimensions, which concreted together over time. On the internal side of W3, there was an about 2 m wide channel (**CH1**), paved with smaller rocks and pebbles, running between W3 and an internal smaller embankment/wall (**W4**), also visible from the aerial pictures. Behind the channel, a supra-elevated plateau was created, probably to build other salt pools, as suggested by the typical muddy sea bottom with sea grass growing out of the sediment, observed in the central part of the saltpans. The bathymetric depth of the presumed pools on the western branch of the saltpans was about -90 cm.

Fig. 168 External side of the western embankment (M. Grisonic).

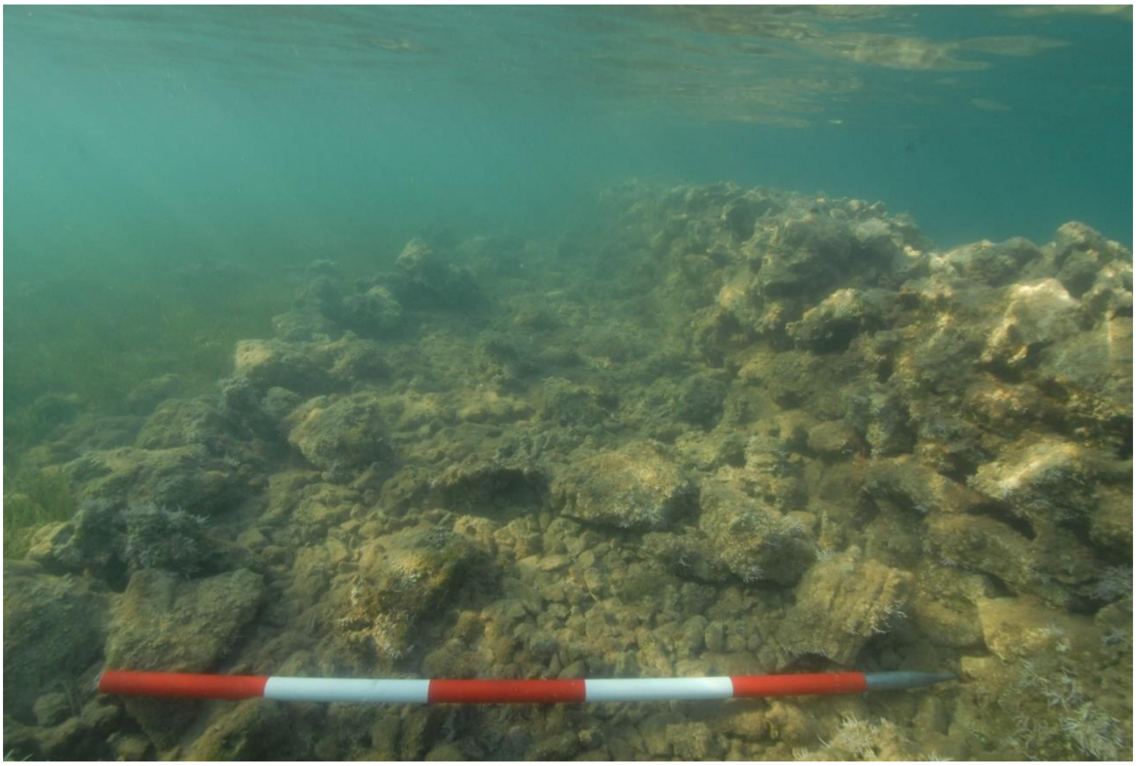


Fig. 169 Channel 1 in between W4 (left) and the separation wall W3 (right) (M. Grisonic).

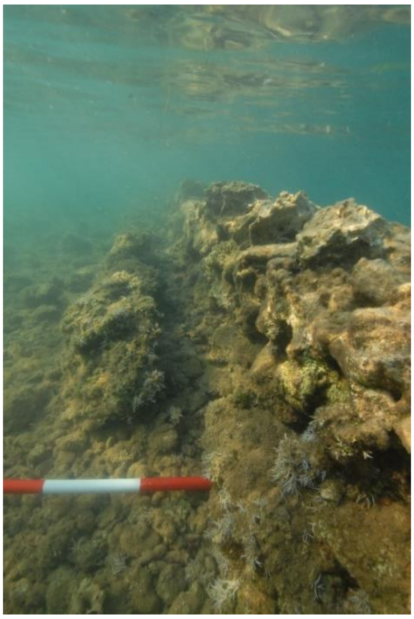


Fig. 170 Small channel getting into Channel 1?

The channel on the western lateral branch of the saltpans was most likely the main water channel, bringing water to the saltpans located in the central part of the cove. Sluice gates, like those observed in Makirina Cove, could not be identified in the separation walls W1 and W3. Several openings at the northern end of W3 may have functioned as sluice gates while it is more likely that the narrow, 20 cm wide water channel in the central part of the same wall was added to release the pressure of the water flowing in the channel CH1. The bottom of the openings and the channel floor are located at an average depth of -99 cm.

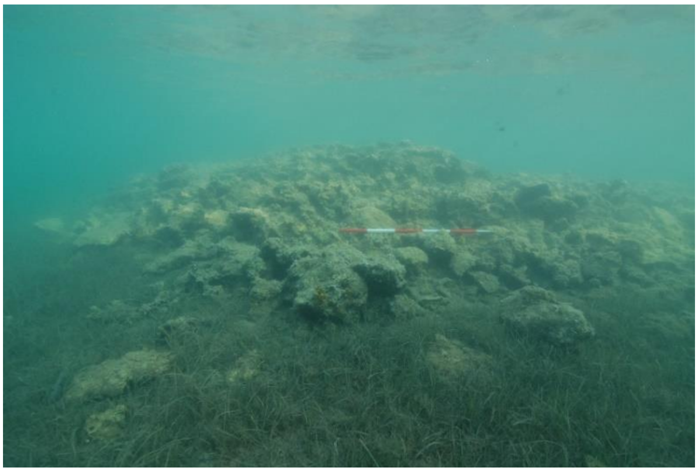


Fig. 171 NE part of the western embankment, where it turns towards S (M.Grisonic).

Fig. 172 Openings in the N part of the W branch of the saltpans (M. Grisonic).

In the shallow waters on the western coast of the cove, in the ancient intertidal zone, there is a channel built to drain fresh water from the field and bring it to the open sea further north, behind the lateral branch of the saltpans. In this way, fresh water did not enter the saltpans.

Fig. 173 Drainage channel in the W part of the cove (J. Petešić).

The eastern branch of the saltpans

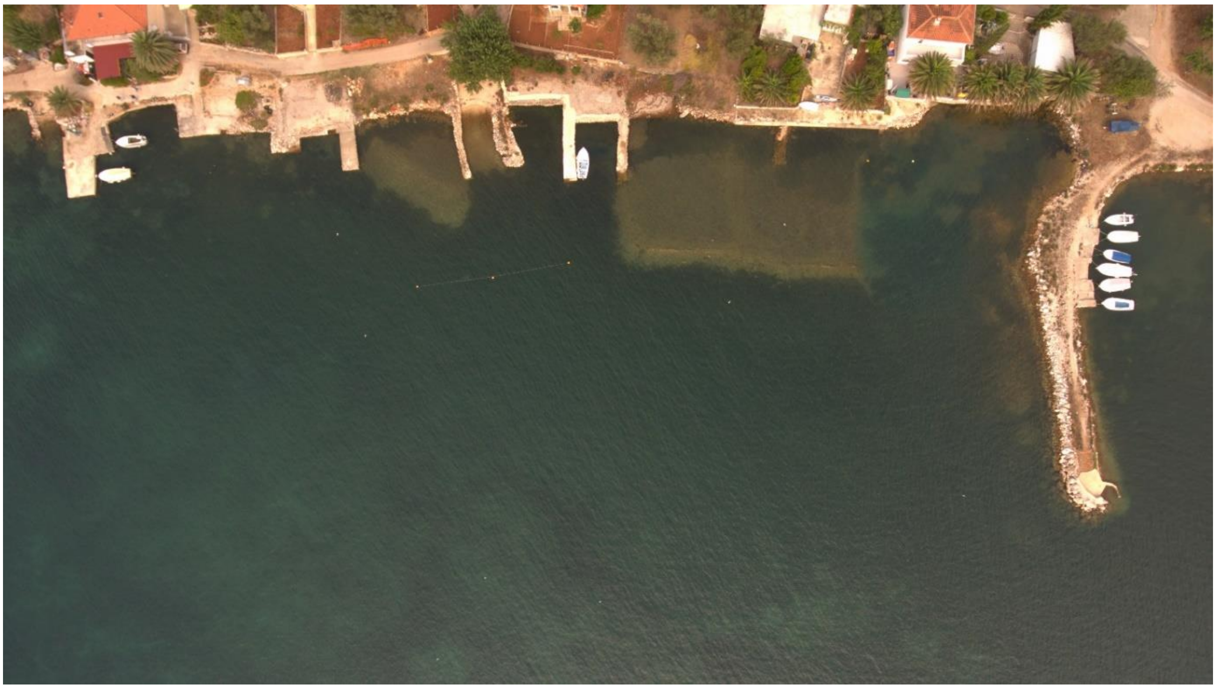


Fig. 174 Drone picture of the E lateral branch of the saltpans (courtesy of J. Petešić).

Of the eastern branch of the saltpans in Brbinj, just a small portion is preserved on the NE side. This part was not surveyed, but from the drone pictures, it looks like there was an opening at the beginning of the branch. The separation wall of the branch formed an about 165˚ angle to continue running parallel to the coast toward SE. On the internal side of the wall, it looks like there were two pools having approximately the same dimensions.

Fig. 175 Photomosaic of the eastern branch of the saltpans (B. Bechor, A. Brook, T. Ivelja).

The unknown church on the SW coast of Lučina Cove

Fig. 176 Outline of an apsidal building? (courtesy of J. Petešić).

Thanks to the drone pictures, it was possible to identify the outline of a building with an apse, located right above the beach in the SW corner of the cove. The structure is not visible from the satellite pictures. According to prof. Tomislav Fabijanić from the University of Zadar, this outline could belong to an early-Christian church, unknown to this day.

V. ARTIFACTS

On the eastern part of the saltpans' separation wall W1, a badly preserved amphora rim fragment was collected. Continuing toward W, almost at the border between W1 and the first salt pools (presumed evaporation basins), a fragment of a pole (**P1**) was spotted. A sample for xylological analysis was collected. It is uncertain whether this pole was *in situ* and originally part of the saltpans, therefore it was not a good sample for radiocarbon dating. Unfortunately, no other wooden finds were found. Further to the W, inside an enclosing that could have represented an evaporation basin, a fragment of a medieval or modern carinated cooking bowl was collected. The metallic nail recovered in the NE corner of a salt pool of the first row was impossible to date because of its form that changes very little through centuries. The nail collected in Brbinj can be medieval or modern.

Laboratory results of the wood analysis

The **xylological analysis** of the wooden pole (P1) recovered in Brbinj was conducted at the University of Haifa by Benny Bechor. The fragment was identified with **common oak** (*Quercus robur*). It is not clear whether the pole laid *in situ* or it was stuck in the sediment of the saltpans later in time. Therefore, it does not constitute a representative sample for radiocarbon dating.

Unfortunately, no other wood nor mortar samples were spotted on the site.

VI. CONCLUSIONS

The saltpans in Brbinj have a U-shaped plan, with two narrow lateral branches connecting to the central separation wall at an almost 90° angle. The total surface of the saltpans was about 2.2 hectares. The saltpans in Brbinj can be dated to the Late Middle Ages, when the separation wall of the saltpans on the Adriatic Sea was called "agger", "arzere" or "argine" (Hocquet, Hocquet 1974; Hocquet 1978: 119).

As no clearly identified sluice gates have been found in the separation wall, it is probable that the seawater was let into the channel located on the western lateral branch (ch1), and then distributed to the salt pools through the same channel that followed the central separation wall and the channel in the SW part of the saltpans (ch2).

The big basin on the western lateral branch (possibly the first evaporation basin or "moraro") and the (successive?) bigger salt basins observed in the central part of the saltpans (possibly "corboli"), most likely constituted the evaporation basins. An embankment, called the "secunda"/"secondal", was protecting the main productive part (central part) of the saltpans (Hocquet, Hocquet 1974; Hocquet 1978: 118). Here, three rows of salt basins, with approximate dimensions of 1.5 x 3 m, were identified through satellite pictures and underwater survey. One part of these basins were the so-called "servidori" or final evaporation pools, which were receiving brine through the channel called "lida". From the "servidori" the highly concentrated brine was poured into the annexed "cavedini" or crystallization pools, where salt could be finally gathered.

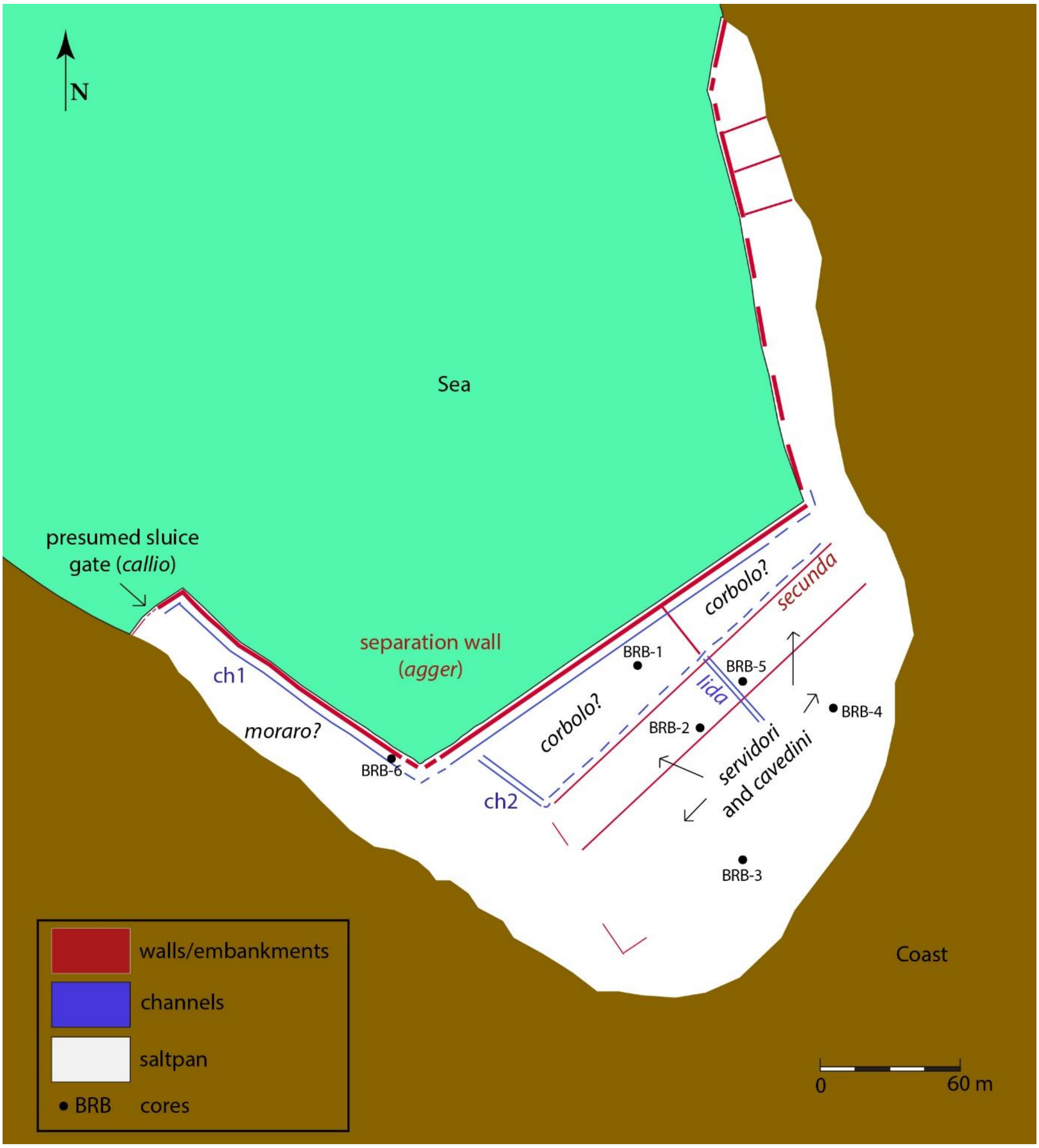


Fig. 177 Hypothetical reconstruction of the functioning of the saltpans in Brbinj based on the surviving remains and compared to the ideal plan of a 14th/15th century saltpan in Chioggia (Hocquet, Hocquet 1974: 549, fig. 7; Hocquet 1978: 119, fig. 1).

The eastern lateral branch of the saltpans is not preserved enough to allow further interpretations. Was it another "moraro"? Or was it used for the evacuation of rainwater far from the main productive part of the saltpans? Or else was it later modified to host additional "servidori" and "cavedini"? All these questions for the moment remain unsolved. What is clear is that the building technique of the saltpans in Brbinj can be attributed to the Late Middle Ages (second half of the 14th - beginning of the 15th century). Similar U-shaped saltpans' structures can be find on at least five additional now submerged ancient saltpans, located on the islands and the mainland of northern Dalmatia (Zadar and Šibenik Counties). All these saltpans were gradually abandoned during the 15th century, with the spread of Venetian rule and salt monopoly in Dalmatia.

Relative sea level (RSL) at the time of construction and operation of the saltpans in Brbinj was between -91 ± 9 cm> RSL > -124 ± 9 cm (Bechor *et al*. 2020). No wood or mortar fragments were found in Brbinj, which would have helped establishing a better chronology of the saltpans' remains.

It is possible that the preserved medieval saltpans in Brbinj were built on the same spot where older, late antique or maybe even older saltpans stood. From the aerial pictures, it looks like there is an unknown early-Christian church on the SW coast of the cove, right in front of the medieval saltpans. Another early-Christian church is located on the Utran Islet on the N side of the cove and it is currently being researched. Nothing else is known of the late antique or older Roman settlement in Brbinj, which it is very likely that existed around the fertile field south of the saltpans. Nevertheless, the central separation wall of the medieval saltpans includes several fragments of Roman amphorae, which were probably collected from nearby places and piled up with rocks to build the big separation wall W1.

Cores were performed at different spots of the medieval saltpans. They are currently being studied at the University of Haifa. With some luck, they could solve the problem whether there is a succession of different chronological phases of the saltpans.

4.1.3. Case study 3:

LAVSA COVE

Fig. 178 Drone pictures of the saltpans in Lavsa (© Aleš Kobav).

I. INTRODUCTION

Lavsa Cove is located on the homonimous island of the Kornati archipelago and it is part of the Kornati National Park, in the central part of the Croatian Adriatic, south of Zadar and west of Šibenik. Today it is comprised in the Šibenik-Knin County, while geographically and historically the Kornati Islands were considered part of the Zadar Islands (Radić Rossi, Fabijanić 2017: 7). The Kornati archipelago is the densest in the Mediterranean, comprising 149 islands and rocks (Magaš 2013: 21). They are all oriented NW-SE, following the dinaric relief direction, thus running in rows paralell to the continental shoreline. During their whole history, Kornati constituted very important fishing spots. There are no permanent settlements on the islands, which have very little vegetation, but they were seasonally inhabited by fishermen, breeders and their families from the nearby islands of Dugi otok and Murter. Nowadays most part of these seasonal houses has been transformed into charming vacation homes.

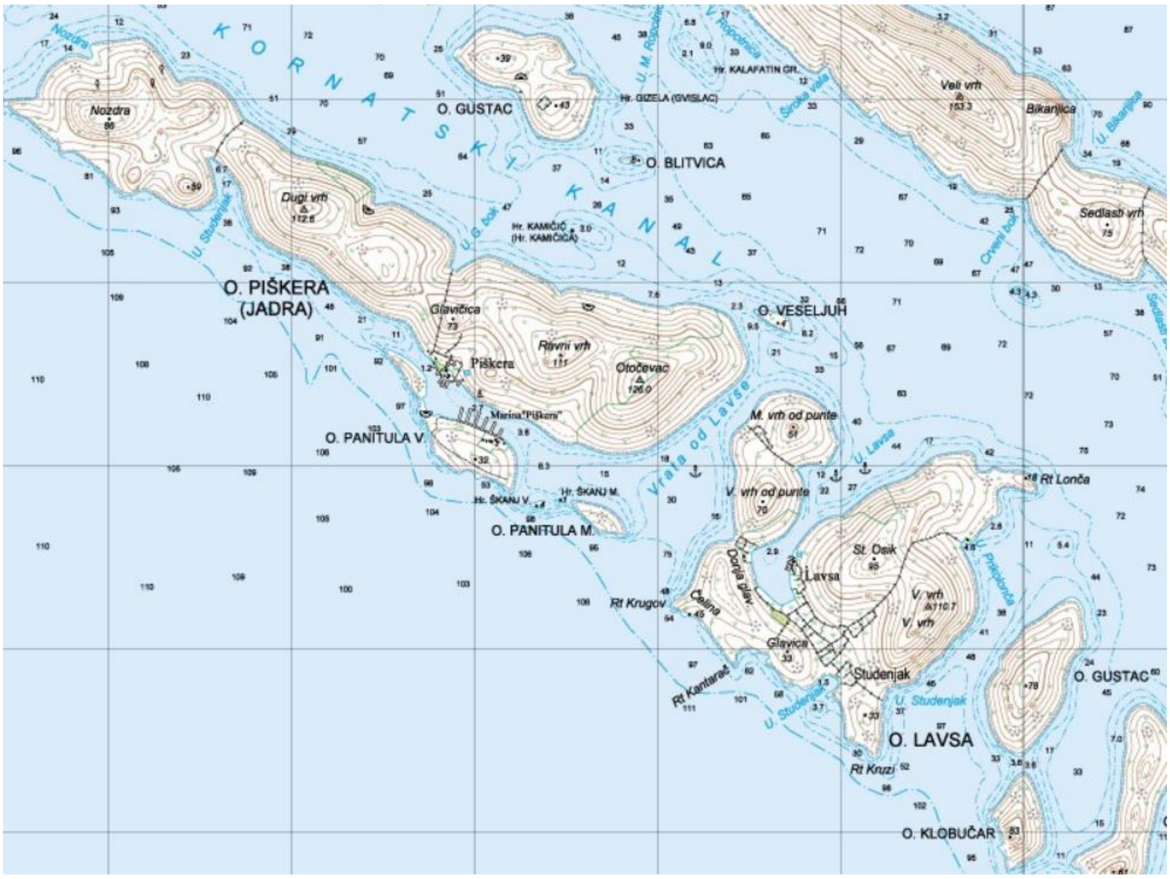


Fig. 179 Islands of Piškera and Lavsa in the Kornati archipelago (www.arkod.hr).

Lavsa Island is very indented and has a surface of 1.8 km^2 (Magaš 2013: 23). It is characterized by the presence of a fertile karstic field, called *Poje* (Magaš 2013: 31), which is the only karstic field on the small Kornati Islands.

In the Modern period, in the waters of Lavsa there were some of the most important spots for fishing small blue fish, which was salted on the neighboring island of Piškera (from ital. *peschiera*), where there was the main fishermen's village and just in front of it, on the island of Velika Panitula, there was the Venetian fortress used by the collector of the fishing tax (Filipi 1968).

Lavsa Cove is a long narrow cove facing N, located deep in between the two branches of Lavsa Island. It is protected from all winds except from the NE *bura*. In the southern shallow part of the cove there are the remains of medieval saltpans.

II. HISTORY OF THE COVE

One of the first to write about the remains of submerged walls in Lavsa Cove was A. R. Filipi (1968: 975). According to him, in Roman times salt was produced in the cove. He wrote that on the NE part of the cove, on land, there were the remains of a large Roman building, which probably served as salt warehouse and shelter for salt workers, while the salt produced was then employed for fish salting on the neighboring Piškera Island (Filipi 1968: 975). For the moment this hypothesis cannot be verified: the mentioned Roman building was probably a medieval salt warehouse (Hilje 1996; see below) and the only Roman artifacts found on Lavsa are movable archaeological finds, while on Piškera no Roman remains have yet been found.

Because of the presence of numerous fragments of Roman ceramic vessels and bricks on the shore (and partially in the shallow waters) of Lavsa Cove, the existence of a Roman *villa* was presumed on the island (Gunjaća 1971; Filipi 2003: 119; Radić Rossi, Fabijanić 2017: 24).

Archaeological researches

The first underwater survey of Lavsa Cove was carried out in 1971 by a team of archaeologists from the Archaeological Museum of Šibenik, directed by Zdenko Brusić and Zlatko Gunjača. In their unpublished report, they stated that on the bottom of Lavsa Cove remains of walls built with 2-3 rows of square blocks bound by mortar, at 0.4 m depth, were discovered. According to their interpretation, these remains belonged to a salpan from Roman times, a dating that they obtained thanks to 1st-2nd century AD ceramic artifacts recovered on the site.

Their plan of the site was published in the 1979 PhD dissertation of D. Vrsalović (2011: 110).

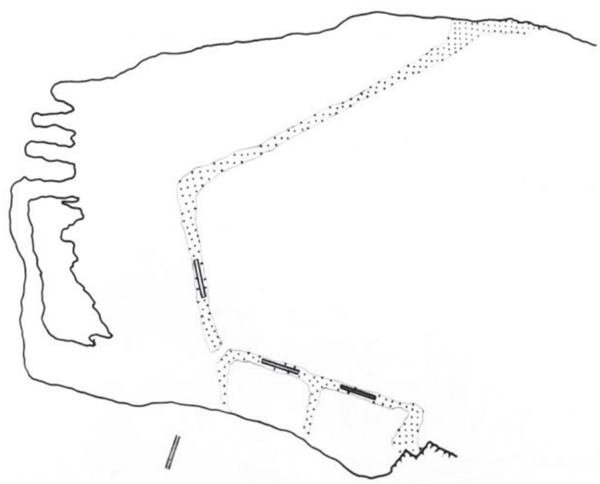


Fig. 180 First sketch of the underwater remains in Lavsa Cove drawn by Z. Brusić (Gunjaća 1971; Vrsalović 2011).

According to the 1971 report, in the eastern part of the cove, remains of ancient walls at about 40 cm depth were found: a wall parallel to the shore and three walls perpendicular to it, forming two enclosed basins (Gunjaća 1971: 4-7). On the western part of the cove there was a similar, a little longer wall parallel to the shore, with only one wall perpendicular to it, connecting it to the shore on the N side. In between the two walls parallel to the coast on both sides of the cove, there was another wall, almost perpendicular to them, which crossed the whole cove. In the SE part of the cove, there was an about 2 m wide opening in this wall (Gunjaća 1971: 4-7). All the walls were badly preserved, except for the eastern separation wall, which was better preserved at two spots, as well as one part of southern separation wall, the upper part of which could stay out of the water during low tide. At these three spots the walls were preserved with 2-3 rows of square stones, bound by mortar (Gunjaća 1971). Two small ceramic fragments from the 1st-2nd century (one of them was an amphora handle) were recovered. The sea bottom was very muddy and covered with algae, therefore it was very difficult to spot other artifacts.

On the eastern side of the cove, on land, they found the remains of a wall, preserved for 8 m in length and more than 2 m in height. Following Filipi's interpretation, they thought it was Roman. A fisherman who had a house on the island told them that his neighbours found some old walls while they were building the foundations of their house. According to the fisherman, close to these walls a grave was found – an inhumation inside an amphora (Gunjaća 1971: 4-7).

The archaeologists from the Šibenik Museum were not sure how to interpret the remains in Lavsa Cove, they were not sure whether the structures were built underwater or were submerged later. They agreed that the best interpretation for the site would have been a saltpan, rather than a fishpond. Based on the artifacts that they recovered, the wall on land and the story of the burial inside the amphora, they supposed that the saltpans were Roman, built next to a Roman *villa* (Gunjaća 1971: 4-7).

The shallow depths at which the walls in Lavsa Cove are located aroused doubts of their Roman origin (Radić Rossi, Fabijanić 2013: 79), also because there are several late medieval documents attesting the existence of saltpans in Lavsa (see below). According to Hilje (1996), the wall on land could be interpreted as part of a medieval salt warehouse.

Later, Irena Radić Rossi surveyed the cove and realized that the saltpan remains were the result of at least two different chronological phases. Also, as already stated by Vrsalović, the plan of the underwater walls in Lavsa Cove was more complex than the one sketched in 1971 (Radić Rossi, Fabijanić 2013: 80).

Historical sources

Historical documents testify that the saltpans on Lavsa Island existed in the second half of the 14th century, when salt trade represented one of the main branches of economic growth of the most powerful Dalmatian families, like the Ljubavac family (Grbavac 2015: 66). Petar Ljubavac, who had saltpans on the island of Pag, also owned the saltpans on Lavsa Island: a document from **1366** attests that he leased his saltpans on Lavsa for one year (Dokoza 2015: 94). A year later he leased them to Božan from Šibenik, again for one year (Grbavac 2015: 55).

With this contract, Božan committed to **rebuild the saltpans**, while Petar promised to pay 55 *librae* for the renovation. According to Dokoza (2015: 94) the saltpans located on remote islands, like Lavsa, were less attracting for tenants and were therefore leased for shorter periods.

In **1399** the Zadar nobleman Juraj Rosa, an important merchant and salt producer, bought 26 saltpans on Lavsa island for 53 ducates (Dokoza 2015: 101) from Petar Ljubavac (Juran 2013: 124). As the saltpans on Lavsa are not mentioned in later documents, it seems that salt making stopped on the island at the beginning of the 15th century (Juran 2013: 125).

Nowadays the fertile field on Lavsa is cultivated only with olive trees, while in the past also figs were growing (Jurić, Skračić 2013: 244). Vines and pastures for sheep are attested on the island from the 17th century (Juran 2013: 147). The different plots on the field were fenced with dry walls, in order to stop the salty dust, brought by strong sirocco winds (Jurić, Skračić 2013: 244). On smaller Kornati Islands, like Lavsa, sheep were let pasture and then shipped to pastures on neighbouring islands. This practice was called *brođenje* (*brod* = boat) (Skračić 2013: 178).

Toponymy

The submerged walls of the saltpans in Lavsa Cove were called *Kučarine*, which is the only toponymic testimony of ancient saltpans in the whole Kornati archipelago (Skračić 2013: 540). The shallow muddy ending of Lavsa Cove, 20-50 cm deep, bordering the remains of the ancient saltpans, is called *Jaz* (Jurić, Skračić 2013: 243).

Fig. 181 Lavsa Island (© Aleš Kobav).

III. SCIENTIFIC RESEARCHES IN LAVSA COVE

Activities conducted on the site during the May 2018 campaign

The project *Saltpans as Anthropogenic Landscape Intervention, a new multidisciplinary Approach for Studying Sea-level changes* started in 2018 with the goal of determining whether the submerged remains of antique saltpans on the Adriatic Sea can represent a new indicator for relative sea level changes over the past two millenia.

The first survey campaign in Lavsa Cove took place on May 25th 2018, with the collaboration of Croatian and Israeli researchers. The team was composed of seven members: prof. D. Sivan and B. Bechor, prof. S. Miko and dr. O. Hasan, prof. A. Brook, T. Ivelja and M. Grisonic. The activities conducted on the site were the following:

- **DGPS measurements** (B. Bechor, D. Sivan) were not ensured because there was no mobile reception;

- **photogrammetric drone mapping** of the cove, with a vertical accuracy of 4 cm, a horizontal accuracy of 2 cm and terrestrial measurement using **LiDAR**. LiDAR also of the medieval wall located close to the shore in the SE part of the cove (A. Brook, T. Ivelja);

- **side-scan sonar bathymetric mapping** of the separation wall and the portion of the cove comprised between the wall and the shore, from 2 m until 0.30 m of depth and **determination of the depth of sediments by taking cores in plastic tubes** (S. Miko, O. Hasan). Side-scan sonar data were collected using Humminbird 999ci HD SI combo echosounder, in combination with Humminbird AS+GPS HS precision GPS with heading sensor. The equipment was mounted on a 4.5 m zodiac boat with outboard engine and trolling motor for use in shallow environment;

- **underwater archaeological survey** of the submerged remains of the saltpans (M. Grisonic).

Activities conducted on the site during the May 2019 campaign

The goals of the second survey campaign were to take geological cores of the sediments in Lavsa Cove and to take mortar?/binder samples from the big separation wall to be sent to radiocarbon dating. Gilberto Artioli and Giulia Ricci, experts in mortar dating, joined us for this purpose. In addition, a more accurate archaeological survey and documentation of the underwater remains was needed.

The team was composed of seven members: prof. G. Artioli and dr. G. Ricci, prof. D. Sivan and B. Bechor, prof. S. Miko and dr. O. Hasan and M. Grisonic.

The whole team worked one day (May 16^{th} 2019). This time DGPS points were successfully taken and five geological cores with PVC tubes were extracted. The whole surface of the saltpans was surveyed and documented, and binder samples from the submerged walls were collected. The main difficulty remained diving in very shallow water (from 0.30 m to 1.5 m), with the risk of compromising the visibility if accidentally touching the muddy sea bottom.

IV. DESCRIPTION OF THE SITE

General plan

From the satellite pictures, a planimetric similarity can be seen comparing the saltpans in Lavsa and Brbinj on Dugi otok (but also Sutomišćica on Ugljan Island, and Ždrelac and Lučina Cove on Pašman Island). All plans are north-facing U-shaped, with two narrow lateral branches parallel to the western and eastern shores, which connect at an almost 90-degree angle to the main southern saltpans' separation wall, oriented E-W. In Lavsa, the western branch of the saltpans is about 100 m long, the eastern is about 90 m long, while the southern separation wall is about 65 m long. The eastern branch is divided into two basins, which is clearly visible also underwater. The western branch of the saltpans was probably also divided into two enclosed pools, as suggest the aerial pictures. It is likely that the crystallization pools were located in the southern part of the saltpans, as it is the case in Brbinj, but in Lavsa they cannot be observed because they are not preserved or they are buried under the sediments.

The whole exploitable surface of the saltpans in Lavsa was about 1 hectare (10.000 m^2), divided as following:

- exploitable surface on the western branch of the saltpans: ca 2.000 m^2;
- exploitable surface on the eastern branch of the saltpans: ca 1.200 m^2 (N basin: ca 550 m^2, S basin: ca 650 m^2);
- southern (central) part of the saltpans: ca 6.800 m^2.

The saltpans in Lavsa were therefore half as big as the saltpans in Brbinj.

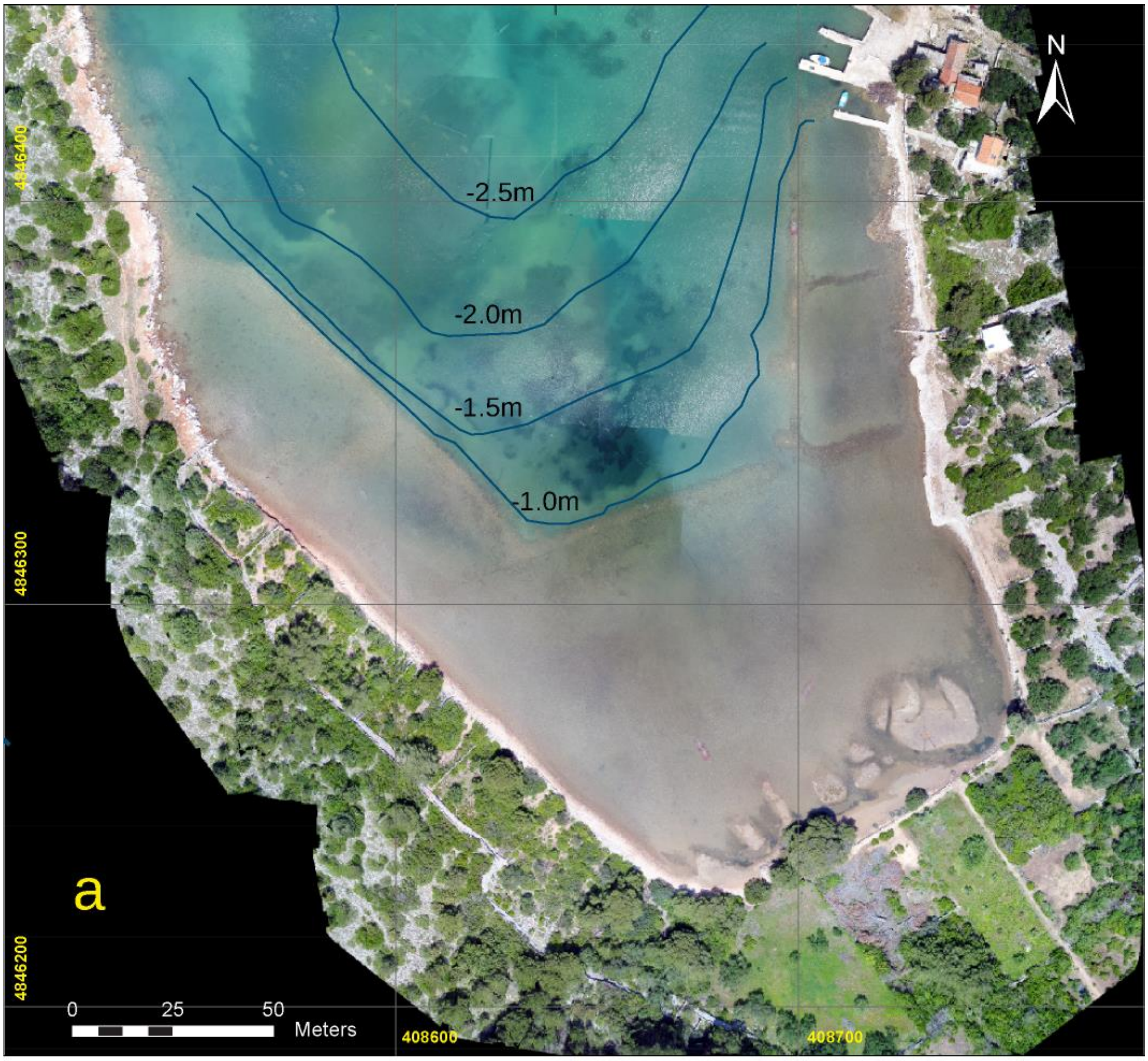


Fig. 182 Digital surface model of the saltpans in Lavsa Cove (Bechor et al. *2020, fig. 7a).*

Fig. 183 3D model of the saltworks area (B. Bechor, A. Brook, T. Ivelja).

Side-scan interpretation

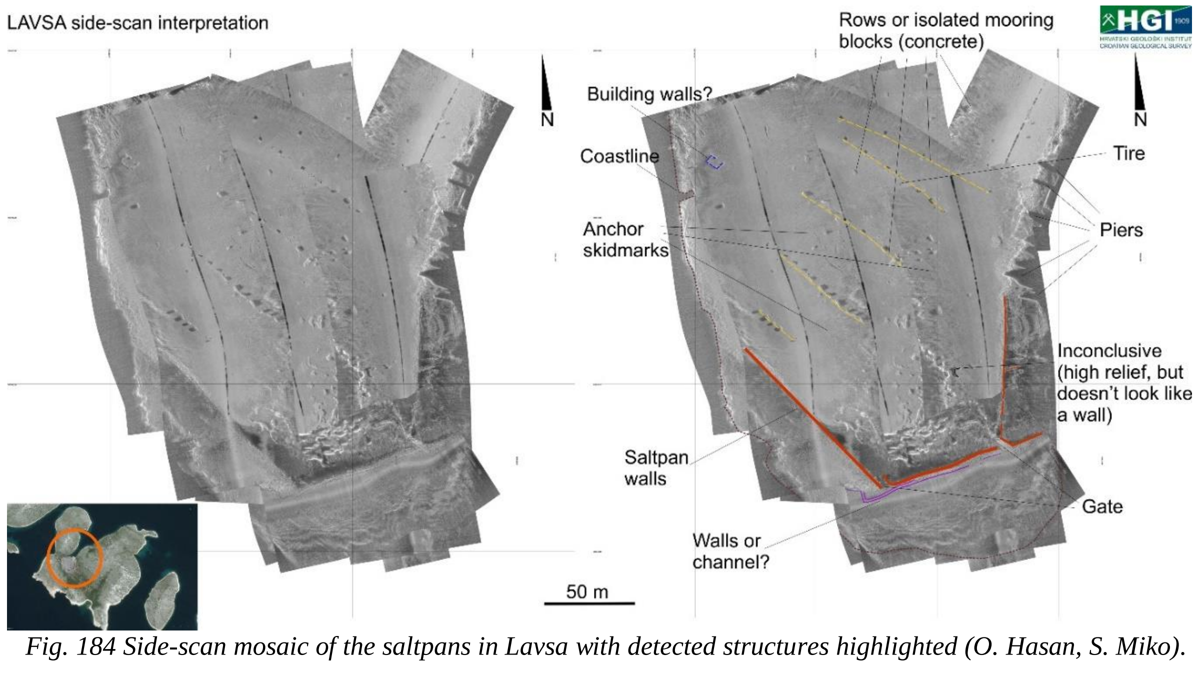


Fig. 184 Side-scan mosaic of the saltpans in Lavsa with detected structures highlighted (O. Hasan, S. Miko).

Side-scan data show one set of thick walls running parallel to the coastline, with one smaller wall perpendicular to the eastern wall. Two thin walls are visible at the southern corner of the large wall. As those walls are parallel and close to each other, they might have functioned as a channel leading to the gate or to the salt pools. The side-scan sonar identified two sluice gates, on both the SE and the SW corners of the main separation wall. The latter sluice gate was not found during the underwater archaeological survey.

The E part of the saltpans

In the eastern part of the saltpans, there are two pools, encircled between walls that are laying at 60-70 cm depth. The walls are embankments built with an accumulation of scattered rocks of small and medium dimensions. On top of the external embankment (= the eastern separation wall) there is a wall, built with 2-3 rows of irregularly shaped blocks. Its width varies from 55 cm in the northern part to 110 cm in the southern part, and its height above the bathymetry is 45-50 cm. The wall is very well preserved at some spots. Contrarily to what stated by the archaeologists from Šibenik who first surveyed the cove in 1971, there is **no mortar binding the blocks: these are dry walls**, with blocks that concreted together due to biological activity. There is another wall following the eastern separation wall on the internal side: in between them, there was an about 1.5 m wide channel, also visible from aerial pictures.

The northern pool has approximately the following dimensions: 16 x 40 x 20 x 36 m (with an internal exploitable surface of about 550 m^2), while the dimensions of the S basin are ca 20 x 32 x 22 x 33 m (with an internal exploitable surface of about 650 m^2). No sluice gates are visible on the eastern part of the saltpans.

However, from the aerial pictures it is clear that on the external side of the southern basin, there are two different accumulations of stones/platforms: one in the middle of the basin, and the second close to its SW corner. The function of these two features is unknown.

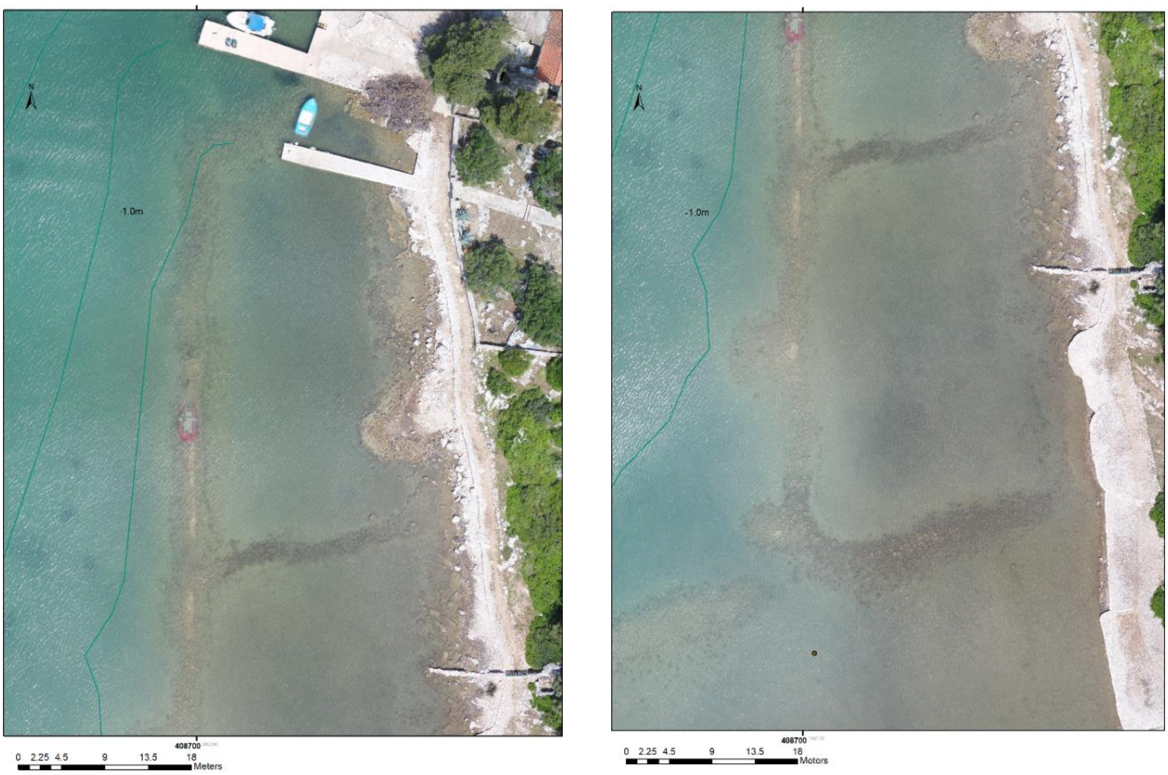


Fig. 185 Eastern part of the saltpans: the two basins (B. Bechor, A. Brook, T. Ivelja).

Fig. 186 Internal side of the eastern separation wall (M. Grisonic).

Fig. 187 Channel on the internal side of the E separation wall (a) and detail of the wall (b) (M. Grisonic).

The S part of the saltpans

The central separation wall is about 65 m long and 2 m wide, with an average depth of -0.70 m. It is a dry wall built with different rows of irregular blocks. At some spots it is less preserved, because it is hit by boats that try to enter the cove (there are no signs signaling the presence of underwater walls).

There is an about 2 m wide and -0.97 m deep opening in between the eastern end of the wall and the southern enclosed basin on the eastern branch of the saltpans. It is interesting to note that this opening is located in front of the medieval building on the coast (see below).

The central separation wall is better preserved further to the W. Here, there is a portion of the wall constructed with several rows of regular blocks that during low tide sticks above water. At first sight, it may seem that it has a nucleus in mortar and pottery fragments, which made the archaeologists who previously surveyed the cove think that this was a Roman wall, also because its base lays at about - 1.5 m depth. After the second survey campaign, it is clear that this wall is just the concreted part of the separation wall of the saltpans. A whole block was extracted out of this wall and there was no mortar on it.

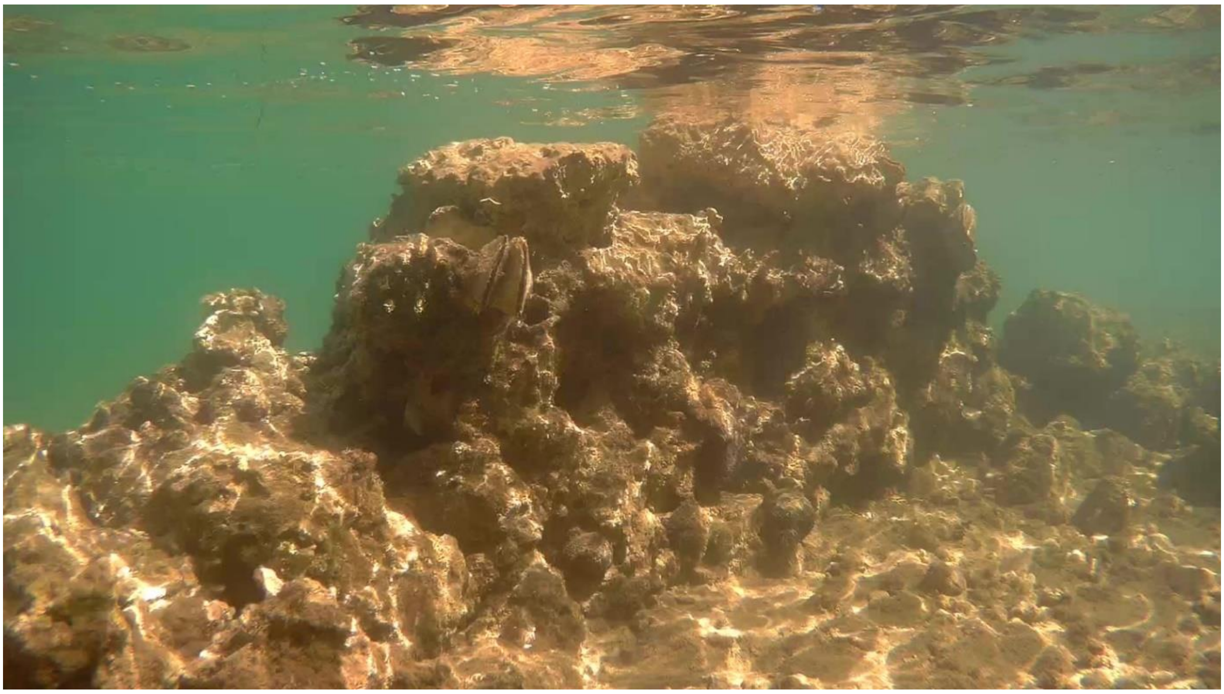


Fig. 188 Best preserved part of the southern separation wall seen from its internal side (M. Grisonic).

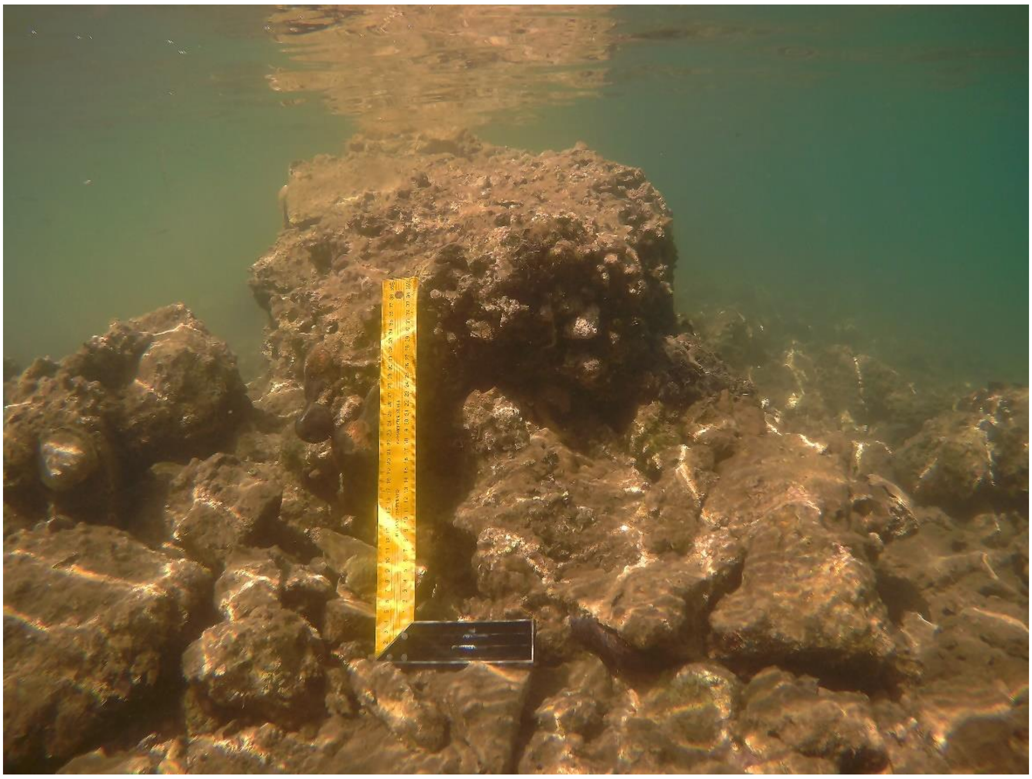


Fig. 189 Best preserved part of the southern separation wall seen from E towards W (M. Grisonic).

We can imagine that on the flat surface created between the central separation wall and the shore there were both the evaporation basins and the crystallization pools. Preliminary investigation of the sediments' depth and their composition in the central part of the saltworks area was performed by stabbing probes (plastic tubes) of 60 cm of diameter, perpendicularly to the southern separation wall:

Point	North	East	Water depth (cm)	Sediment thickness (cm)	Description
A	43°45.074'	15°21.969'	85	120	3 m S of the wall: includes marine sand overlying dark clay with organic remains, including a wooden fragment. The last 10 cm comprise dark clay with broken shells.

B	43°45.067’	15°21.97’	79	105	10 m S of the wall: includes marine sand, dark clay with shells. Looks like wetland.
C	43°45.059’	15°21.98’	52	80	Top to bottom: marine sand, dark clay with organic material.
D	43°45.047’	15°21.991’	35	65	0-15 cm: marine deposition; 15-22 cm: soil.

Fig. 190 Preliminary analysis of the sediments’ depth in the saltworks area (B. Bechor).

The W part of the saltpans

The western separation wall of the saltpans is a massive embankment built with rocks and stones of all dimensions. On top of the embankment, in its NE part, two parallel badly preserved dry stone walls delimiting a channel were spotted. It is possible that on the flat surface created between the separation wall and the shore more (probably evaporation) salt pools were located.

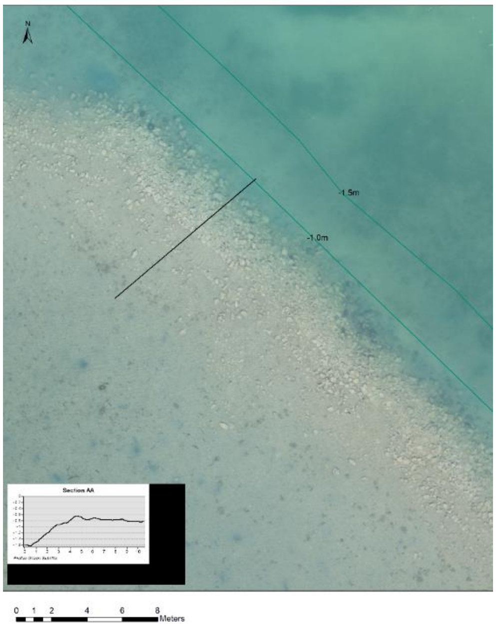


Fig. 191 Western branch of the saltpans: zoom on channel that follows the contour of the separation wall (B. Bechor, A. Brook, T. Ivelja).

From the aerial pictures, it is evident that there were two basins on this branch of the saltpans, symmetric to the basins located on the eastern part of the cove. No sluice gates were found in the western separation wall, but we can presume that seawater flew through the channel on top of it, maybe reaching the central part of the saltpans. A similar situation was found in Brbinj.

Fig. 192 Digital surface model of the western branch of the saltpans (B. Bechor, A. Brook, T. Ivelja).

Fig. 193 The western separation wall underwater (M. Grisonic).

Fig. 194 Channel on top of the western separation wall (M. Grisonic).

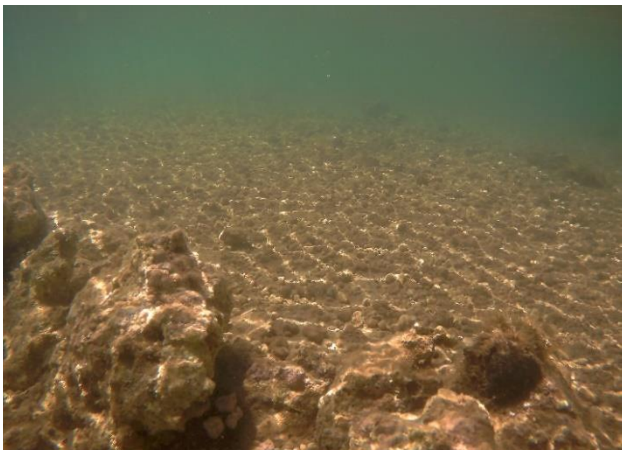


Fig. 195 Flat surface on the W branch of the saltpans (MG).

The side-scan sonar detected a channel in the SW part of the saltpans, which is visible from the digital surface model. This about 2 m wide channel started somewhere on the western branch of the saltpans and then continued running along the internal side of the southern separation wall. It was not observed during the underwater survey.

Survey on land

It was very easy to find the wall mentioned in the 1971 report: “On the eastern side of the cove, on land, there are the remains of a wall, preserved for a length of 8 m and more than 2 m high. It was built with rows of square blocks and can be easily dated to Roman times.” This is the same wall mentioned by Filipi in 1968, who assumed that it was part of a Roman salt warehouse. All other scholars who wrote about the history of Kornati Islands agree that this wall is medieval.

The wall is oriented E-W, it is 60 cm wide and it is built with rows of square blocks bound by mortar. It is still well preserved and there is a wooden cross on top of it. At 1.5 m height, there are two ventilation openings of about 15 x 15 cm.

Hilje surveyed the site in the 1990s. In the central part of the preserved wall, its whole height of 2.5 m was conserved, with the hole for the roof timber. According to him, the wall’s building technique can be dated to the second half of the 14^{th} century (Hilje 1996: 498), contemporary to the saltpans mentioned in the archival documents. As the documents never mention churches on Lavsa Island, Hilje stated that it most likely belonged to a profane building, and because it is located just in front of the saltpans, it is likely that it is what remains of a salt warehouse. Hilje is probably right.

Fig. 196 Medieval wall that possibly belonged to a salt warehouse (M. Grisonic).

In front of this medieval building and along the whole eastern shore of the cove there are many scattered ceramic fragments: pieces of roof tiles, but also fragments of Late Roman pottery, like African amphorae and African *terra sigillata*. Behind the wall with the wooden cross, a fragment of a late antique African *terra sigillata* was recovered.

Fig. 197 Roman pottery scattered along the shore (a) and the field south of Lavsa Cove (b) (M. Grisonic).

In the southern part of the cove there is a fertile field cultivated with olive trees. On the field there is an old, today abandoned karstic pool, an about 10 x 10 m hole enlarged to collect rain water (Magaš 2013: 44).

Fig.198 Southern shallow part of Lavsa Cove, called Jaz *(M. Grisonic).*

On the opposite, NW side of the cove, there is another ruined structure on the shore. There was no time to inspect it.

Binder analysis

One of the major achievements of our research campaigns was to understand that all the submerged walls in Lavsa Cove are dry stone walls. Gilberto Artioli and Giulia Ricci collected several binder samples from different walls, demonstrating that the blocks concreted together due to strong biological activity.

Fig. 199 G. Artioli taking samples of binder on rocks in the W part of the saltpans (M. Grisonic).

V. CONCLUSIONS

The preserved saltpans in Lavsa are late medieval, probably built during the second half of the 14th century, and abandoned at some point at the beginning of the 15th century, after the spread of Venetian control and salt monopoly over Dalmatia. Relative sea level (RSL) at the time of construction and operation of the saltpans was in between -86 ± 8 cm> RSL > -122 ± 8 cm (Bechor *et al*. 2020).

The plan and the functioning of the Lavsa saltpans was very similar to the saltpans in Brbinj, with a channel running along the separation walls of the saltpans, probably leading to the central part of the saltpans, where the crystallization pools were most likely located. Like in Brbinj, no sluice gates were found on the site. The Lavsa saltpans were half as big as the ones in Brbinj, with an estimated exploitable surface of 1 hectare. Kulušić (2001: 89, n. 78) compared the exploitable surface of the preserved saltpans in Lavsa with those in Šibenik and Nin, and calculated that in Lavsa four to six salt workers were needed.

The whole plan of the Lavsa saltpans looks uniform: there are no clear evidences showing different construction phases. At the same time, it is possible that the 2 m wide passage in the SE part of the saltpans could had been opened later in time and that the two basins on the eastern branch of the saltpans might had been rearranged as fishing traps. The U-shaped saltpans (Lavsa, Brbinj, Sutomišćica, Ždrelac and others) need to be studied more in depth to understand how their original plans looked like and how they functioned.

The Late Roman pottery scattered on the eastern shore of the cove indicates that Lavsa was frequented much earlier as well. According to older scholars, a Roman *villa* was located on the island, exploiting the fertile field south of Lavsa Cove, as well as its shallow waters for salt making. At present, no Roman buildings were found on the island, although a local man described the finding of a body inhumed in an amphora. We can only suppose that Romans started to produce salt on the island and that salt making continued on the same spot during the Middle Ages.

4.1.4. Case study 4:

SVETI ANDRIJA COVE
ON VRGADA ISLAND

Fig. 200 The saltpans on Vrgada Island, (https://www.pakostane.hr/vrgada, accessed 02.02.2021).

I. INTRODUCTION

Vrgada is the southernmost inhabited island of the Zadar archipelago. It is a very small island, having a surface of about 3.7 km^2. It is located in the central part of the Croatian Adriatic. There is a dolomitic fertile valley in the central part of the island, surrounded by pine forests (Faričić, Magaš 2009: 13).

Fig. 201 Vrgada Island with the Island of Pašman in the background (https://www.pakostane.hr/vrgada, accessed 02.02.2021).

The biggest cove on the island, located in its northern part, is called Sveti Andrija (Saint Andrew), while the neighboring Luka Cove to the east is the main harbor on the island. The only settlement, also called Vrgada, is located around and south of Luka Cove. Luka harbor is protected from all winds except from the strong NE *bura.* During periods of strong *bura*, the alternative harbor in Sveti Andrija Cove is used for docking (Faričić, Magaš 2009: 23).

In the southern shallowest part of Sveti Andrija Cove ancient saltpans were located (Domijan 1983: 123; Faričić, Magaš 2009: 20-21; Sorić 2009: 70). The separation wall of the saltpans was also used to trap fish (see below). Later, this site was known for the presence of healing

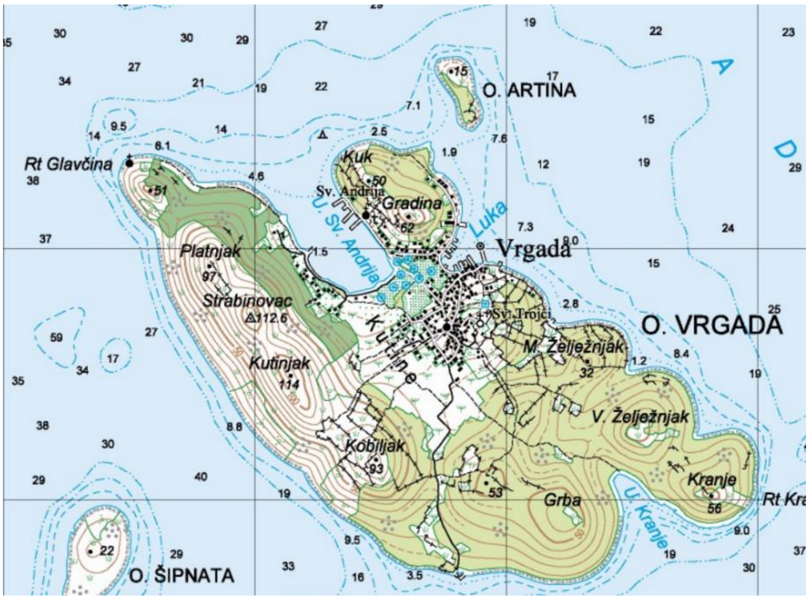


Fig. 202 Vrgada Island (www.arkod.hr).

mud (Zalović 1973: 261). In the neighboring Luka Cove, there are also some underwater remains, which could belong to ancient saltpans or other harbor structures.

II. HISTORY OF THE COVE

Vrgada is mentioned for the first time in the *Cosmographia* of the Anonymous from Ravenna (6^{th}-7^{th} century), where it is called *Rubricata* (Čače 2009: 63-65), meaning red island, because of the abundant presence of fertile *terra rossa*. In the 10^{th} century *De administrandio imperio* written by the Byzantine Emperor Constantine VII Porphyrogenitus, the island is called *Lumbrikaton*, while in the 1095 document appears as *Castrum Lubricata* (Vuletić 2009: 112-113). In later times, it was known as *Levigrada Insula* and Lapkat (Vuletić 2009: 112-116).

Vrgada was located in a strategic position at the entrance of the Pašman Channel, a compulsory passage on the eastern Adriatic seafaring route (Faričić, Magaš 2009: 11). According to Čače (2009), Vrgada already held a strategic importance in prehistoric times (from the 10^{th} century BC), when a big Liburnian hillfort existed on the NE part of the island. He assumes that this hillfort was part of a unified system that controlled the navigation through the Pašman Channel, led by the main Gradina hillfort (*Colentum* in Roman times) located on the nearby island of Murter, which had connections with the Hellenistic centers in central and southern Dalmatia (Čače 2009: 62).

Vrgada gained importance in Late Antiquity, when a Justinian fortress (*castrum*) was built over the ruins of the prehistoric hillfort. Another *castrum*, Pustograd, was built on the nearby island of Pašman. Both of them served to control the entrance in the Pašman Channel (Čače 2009: 63). The fortress on Vrgada included a massive perimetral wall with five towers, a cistern and some residential buildings, which hints to the fact that the garrison might had lived permanently on the island (Sorić 2009: 71).

During the 9th century, Sveti Andrija church was built underneath the Byzantine fortress, on the eastern part of Sveti Andrija Cove, likely on an early-Christian building (contemporary to the fortress), as some early-Christian *spolia* walled in the early medieval pre-Romanesque church seem to suggest (Domijan 1983; Čače 2009: 63).

In AD 923, after five centuries of Byzantine administration, Vrgada Island started to be administrated by the first Croatian King Tomislav, like the other islands and coastal towns that were included in the Theme of Dalmatia (military-civilian Byzantine province), when from approximately AD 1069, at the time of King Petar Krešimir IV, it was included in the Croatian Kingdom. By then the Vrgada fortress lost its importance. A document from AD 998 attests that the peasants from Vrgada swore to the Venetian doge (Skok 1950: 140; Faričić, Magaš 2009: 14).

After AD 1409, Vrgada was included in the Venetian domain. The inhabitants of the island sustained themselves with fishing, agriculture, cattle breeding and coral fishing on their and the surrounding islets (Faričić, Magaš 2009: 33, 42).

Archaeological researches

Only the early medieval church of Sveti Andrija was researched (Domijan 1983), while the remains of the Gradina hillfort and Byzantine *castrum* were only surveyed (Sorić 2009).

Historical sources

A document from **AD 1095** attests that the inhabitants of *Castrum Lubricata* or *Levigrada Insula*, how Vrgada was known in the Middle Ages, were **producing salt at the end of the 11th century** (Rački 1877: 175 – document dated to 1096; CD I, 205-206 – document dated to November 24th 1095; Jakić-Cestarić 1995).

In this document it is stated that Dragus, the prior (the highest secular authority) of the Commune of Zadar, gave to the Benedictine monastery of S. Chrysogonus (Sveti Krševan/San Crisogono) from Zadar the right to collect all incomes on salt and fishing that the *priores* of Zadar held on Vrgada Island **from remote times** (*antiquitus*) (Klaić, Petricioli 1976: 65). Therefore, **the document tells us indirectly that salt production on the island started much earlier** (Hocquet 1978: 84). We do not know how much earlier because the origin of the Dalmatian *priores* is not yet fully explained (Klaić, Petricioli 1976: 54) and we do not know which possessions they had and when they got them. Nevertheless, we can suppose that the *priores* of Zadar obtained the rights on salt and fishing on Vrgada at least a century earlier, at the time of the prior Madius, the first known member of the Madijevac family from Zadar, attested in AD 986 (see below). The only known prior of Zadar before Madius of whom we know the name was Andrija, who wrote the testament in AD 918 (Nikolić 2005: 3).

The 1095 document shows that Vrgada was included in the territory of the Commune of Zadar and that its inhabitants payed taxes to the city of Zadar (Čolak 1963: 481) and to the bishop, to whom they had to give an amount of fish (Klaić, Petricioli 1976: 65).

Solicited by Madius, the abbot of the S. Chrysogonus monastery, and the Zadar nobles, the prior Dragus gave to the monastery the right to collect salt produced on Vrgada Island and two fishing spots (*piscationes*) (CD I, 205-206). This document states that every house on Vrgada used to produce nine *modii* of salt in one year (Čolak 1963: 481; Jakić-Cestarić 1995: 119). According to Čolak, the mentioned *modii* of salt should be considered the Roman *modii* (1 *modius* = 8.73 l, see also Vlajinac 1968: 622-631; Herkov 1971).

Vesna Jakić-Cestarić (1995), who studied in depth this document from 1095, thinks that all the signees, except for the judge and the tax collector, were members of the important Madijevac family (Madijevci in Croatian, or Madii in English). During the 10th-11th centuries, this family held the most important positions in the Zadar Commune (many of them were *priores*) and in the Byzantine Theme of Dalmatia in general, as *proconsuls* (Jakić-Cestarić 1995: 118). The prior Dragus was a successor of Madius, the first known member of the Madijevac family, who was prior of Zadar, proconsul of Dalmatia and the restorer of the S. Chrysogonus monastery in AD 986 (Jakić-Cestarić 1995: 119-120; Nikolić 2005). Madius, the abbot of the S. Chrysogonus monastery (the only male monastery in Zadar at that time) was also a member of the Madijevac family, as it was Cika, the abbess of the feminine monastery of Saint Mary, founded or restored by the Madijevci approximately in AD 1065 (Jakić-Cestarić 1995: 122; Nikolić 2005). The signees of the document from 1095 were the ones who held the right to collect incomes on salt and fish, and their heirs. It was signed by the actual prior of Zadar Dragus, the previous two priors Candidus and Vitača (Vitaça), and other members of the Madijevac family (Jakić-Cestarić 1995).

No later archival documents concerning salt or saltpans on Vrgada are known.

The cadastral plan of Vrgada Island from mid-19th century shows the embankment (separation wall of the saltpans) in the southern part of Sveti Andrija Cove. At that time, the embankment was used to trap schools of fish that enter the cove at the end of summer/in early fall (Faričić, Magaš 2009: 21).

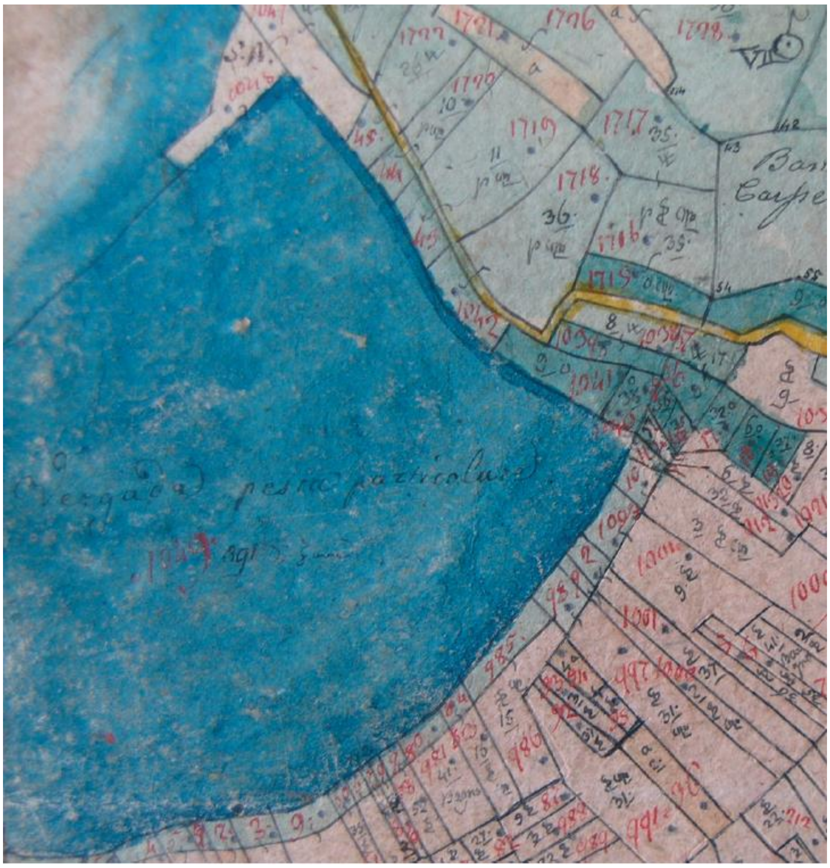


Fig. 203 State Archives in Zadar (DAZD), fond Katastarske karte: Vergada (Faričić, Magaš 2009: 21, fig. 8a).

Toponymy

The shallowest part of Sveti Andrija Cove is called **Kvasilo** or **Plandišće** (Faričić, Magaš 2009: 20). Kvasilo is the shallow part of the cove that is submerged during high tide, while Plandišće means "which stays dry" during low tide. According to an elderly inhabitant of Vrgada, who was interviewed about the toponyms on the island, salt was produced in this shallow enclosing in the southern part of Sveti Andrija Cove (Jurić *et al*. 2009: 84-85).

III. SCIENTIFIC RESEARCHES IN SVETI ANDRIJA COVE

Activities conducted on the site in May 2018

The project *Saltpans as Anthropogenic Landscape Intervention, a new multidisciplinary Approach for Studying Sea-level changes* started in 2018 with the goal of determining whether the submerged remains of antique saltpans on the Adriatic Sea can represent a new indicator for relative sea level changes over the past two millenia (Bechor *et al*. 2020).

The survey campaign in Sveti Andrija Cove on Vrgada Island took place on May 24th 2018, with the collaboration of Croatian and Israeli researchers. The team was composed of seven members: prof. D.Sivan and B. Bechor, prof. S. Miko and dr. O. Hasan, prof. A. Brook, T. Ivelja and M. Grisonic. The activities conducted on the site were the following:

- **DGPS measurements** of the separation wall and other points for geo-referencing purpose, in order to align the DTM coordinates in the Croatian Terrestrial Reference System - HTRS 96, based on the Geodesic Reference System - GRS 80 (B. Bechor, D. Sivan);

- **photogrammetric drone mapping** of the separation wall, with a vertical accuracy of 4 cm and a horizontal accuracy of 2 cm and **LiDAR** from two points in the west side of the cove (A. Brook, T. Ivelja);

- **side-scan sonar bathymetric mapping** of the separation wall and the portion of the cove comprised between the wall and the shore, from 2 m until 0.30 m of depth (S. Miko, O. Hasan). Side-scan sonar data were collected using Humminbird 999ci HD SI combo echosounder, in combination with Humminbird AS+GPS HS precision GPS with heading sensor. The equipment was mounted on a 4.5 m zodiac boat with outboard engine and trolling motor for use in shallow environment;

- **underwater archaeological survey** of the submerged remains of the wall and its surroundings (M. Grisonic). Because of the lack of time, just the eastern part of the cove was surveyed, where the separation wall is better preserved.

Fig. 204 Sveti Andrija (west) and Luka coves (east) (Google Earth).

IV. DESCRIPTION OF THE SITE

General plan

The separation wall of the saltpans is well visible from the aerial pictures and from the coast: it runs from east to west, it is 250 m long and its top is on average -29 cm below the datum (Bechor *et al*. 2020). It is better preserved in the eastern part of the cove, while it is quite damaged in the western part. Unlike in Brbinj and Lavsa, it seems that on Vrgada the saltpans did not have a U-shaped plan, with two lateral branches parallel to the western and eastern shores. On Vrgada the saltpans were positioned in the shallow southern part of the cove, enclosed between the separation wall and the coast, having an estimated exploitable surface of about 2 ha (similarly to the saltpans of Brbinj). The saltpans on Vrgada were oriented towards NW: they were therefore protected from the strong NE *bura*, but exposed to the NW mistral.

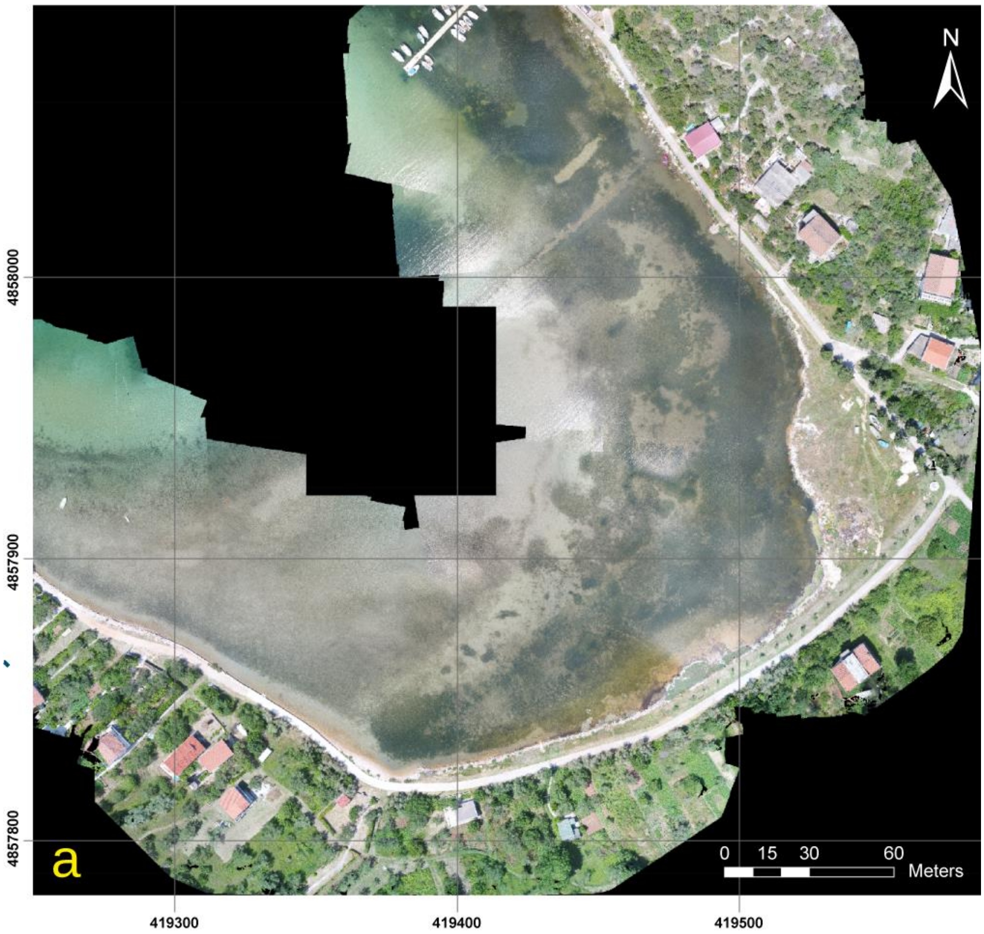


Fig. 205 Digital surface model of the saltpans in Sveti Andrija Cove, Vrgada Island (Bechor et al*. 2020, fig. 8a).*

When looking at the satellite pictures, in the NW part of the cove there is a submerged feature that could belong to a huge breakwater built to create a safe harbor for the boats and to protect the saltpans. On the satellite pictures, it looks like there are some submerged buildings in the western part of the cove as well. No underwater archaeological surveys were performed yet in these parts of the cove.

Side-scan interpretation

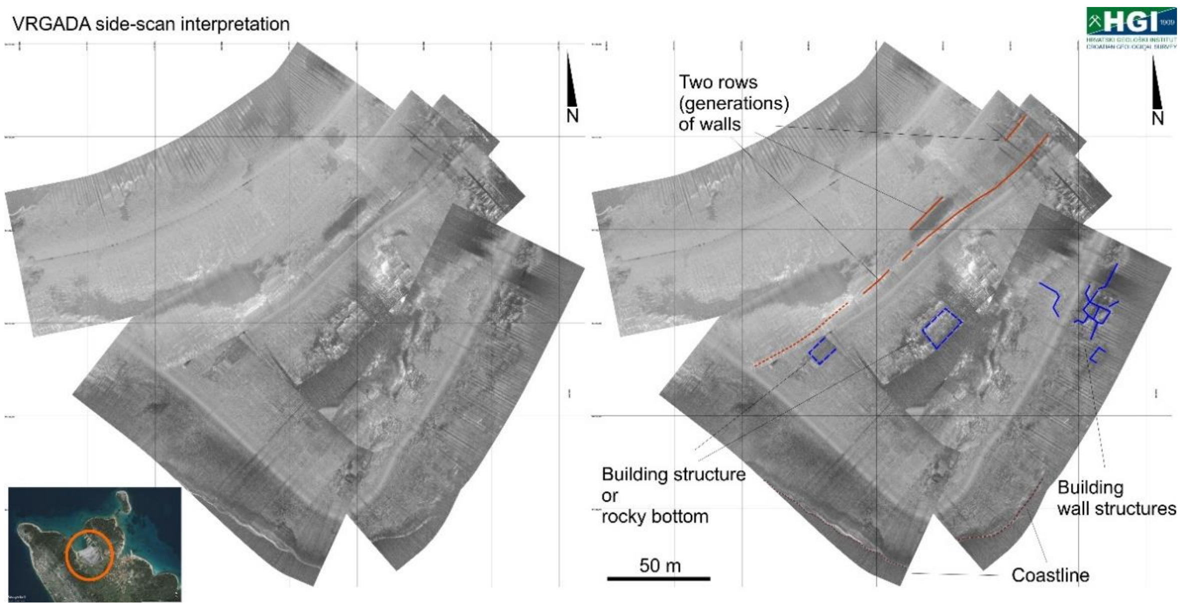


Fig. 206 Side-scan mosaic of the saltpans on Vrgada Island with detected structures highlighted (O. Hasan, S. Miko).

Side-scan data shows a wall perpendicular to the coastline, spanning to both sides of the cove. The wall is missing at three spots in the central part of the cove. Another wall, parallel to this one, is visible only in the NE part of the cove, near the coast, and in the central part of the cove.

Inside the shallow SE part of the cove several structures are visible. They might be ruined walls. Two regular structures are located in the central and western part of the cove. From the mosaic, it is not clear whether these are structures or rocks.

Fig. 207 Saltpans in Sveti Andrija Cove (B. Bechor, A. Brook, T. Ivelja).

Fig. 208 Digital surface model of the eastern part of the saltpans (B. Bechor, A. Brook, T. Ivelja).

Two parallel walls on the E side of the cove

From the satellite and aerial pictures two parallel walls can be seen in the shallow waters of Sveti Andrija Cove on Vrgada Island: the better preserved separation wall, which crosses the cove (**W1**), and a shorter parallel wall or rather embankment (**W2**), located 12 m north of it. W2 can be spotted only on the eastern part of the cove: it is 24 m long and 5 m wide, made of an accumulation of smaller stones and pebbles. The western limit of W2 is very clear, outlined by the sea grass, which is not present on the stones, but grows in the mud west of W2. W2 is most likely what remains of the jetty that appears on the cadastral plan of Vrgada Island from mid-19th century.

The remains of the saltpans are situated at very shallow depth (40-50 cm), which made the survey very challenging. Due to the very short time we had on Vrgada, only the eastern part of the cove was inspected, until the stone mound with the metallic stick, used as mark for the passage of boats, located somewhere in the middle of the cove. The sea bottom is full of organic sediment brought from the nearby field, nowadays cultivated with olive trees. The sea floor is very muddy, with plenty of sea grass.

The separation wall W1 from E to W

The separation wall is an embankment built with irregular blocks of quite big to medium dimensions, stacked one on top of another, without mortar. The upper side of the wall lays at 29 cm depth.

At its eastern corner, the wall W1 is about 110-120 cm wide, and it enlarges toward the western part. At about 40 m from the eastern shore of the cove, there is a **sluice gate**, also visible from the aerial pictures. On the western side of the sluice gate the wall W1 measures 3.1 m, on the eastern side of the sluice gate it measures 3.3 m. On the eastern side of the sluice gate there is a bedrock that was cut and shaped into a rectangular block, oriented E-W. The distance between the bedrock and the western edge of the sluice gate is 55 cm, which should correspond to the width of the sluice gate.

Towards west, there are two other openings in the wall W1. It is interesting that both openings have the same dimensions, 55-60 cm the first one and 55 cm the second one. They could be casual or what remains of two sluice gates.

Further to the west, the wall is destroyed: the stones of the wall lay scattered over a larger area. In the middle of the cove, there is a mound of stones holding a modern metal stick, probably to mark a passage for boats. The mound of stones was probably constructed during the Modern period, using blocks from the separation wall.

No mortar, wood or any artifacts were found on the site.

The side-scan sonar outlined the remains of possible structures inside the cove, located at approximately 30 cm depth. They were not detected on the field. The presumable continuation of W2 in the central part of the cove, north of the separation wall W1, was not spotted during the underwater survey.

VI. CONCLUSIONS

Compared to other saltpans' separation walls that we surveyed, the separation wall on Vrgada is less preserved. The exploitable surface on the internal side of the wall was about 2 hectares, almost the surface of the saltpans in Brbinj. The building technique of the wall (an accumulation of irregular stones one on top of another) and the very shallow depth at which it is located (30-50 cm) indicate that it is medieval. Relative Sea Level (RSL) at the time of construction and operation of the separation wall was between -45 ± 12 cm > RSL > -80 ± 12 cm (Bechor *et al*. 2020).

According to one archival document, these saltpans were in use during the 11th century. The same document attests that salt production on the island started much earlier (possibly at least a century earlier). No other more recent documents attest salt exploitation on Vrgada: we can imagine that like the majority of minor saltpans on the eastern Adriatic coast, the saltpans in Sveti Andrija Cove were abandoned or transformed into fishing traps after 1409, when Dalmatia came under Venetian rule. The use of the separation wall as a fence for fishing purposes is attested on the Habsburg cadastral map dated to mid-19th century.

Due to the presence of a probably stable garrison on the island during the 6th century and the great potential for salt exploitation of Sveti Andrija Cove, it is possible that saltpans already existed in Justinian times, although we have no elements to confirm it.

Underwater archaeological surveys are needed in the western and NW parts of Sveti Andrija Cove, to understand the nature of the submerged remains that can be seen on the satellite pictures.

4.1.5. General conclusions on the field researches

Three of the four surveyed ancient saltpans can be dated to medieval times, while the site of Makirina encompasses a medieval, Late Antique and maybe a Roman Imperial phase.

The sites of Brbinj, Lavsa and Vrgada present submerged walls built of an accumulation of stacked irregular stones of various dimensions. No mortar binder was used to link the rocks of the walls, but we can assume that, like in modern saltpans, clay-rich mud was massively used for this purpose, reinforced, in the case of the external separation walls, by the planting of the tamarisk (*Tamarix gallica*) (Koludrović, Franić 1954: 54) or other reeds and rushes. An interesting parallel of this building technique can be found in Piran in Istria, when a rare document from 1342 provides precious information regarding the procedure of building saltpans. In Piran, the dams built in the lagoon, where the saltpans were later installed, were 10 (3-3.5 m) or 6 Venetian feet (1.7-2.1 m) wide (Hocquet 1978: 120). Because of the abundance of stone in the area, the carpenter *maestro* Folco, son of the master Giovanni from Padova, used rocks to build half-height of the wall, consolidating the external façade of the dam, which was directly in contact with the sea. This wall was surmounted by *barinis*, a word deriving from Venetian *barena* = fluvial deposit that emerges in the form of dry and solid islands, which can be reduced to pasture or cultivation if sheltered against the tides by low banks (Giardina *et al*. 2015: 291). In the document from Piran this term probably indicated the natural materials that could be found on the *barene*, such as woven rushes (*Juncus effusus*) and other branches consolidated with mud (Hocquet 1978: 120; cf. LLMEI: 107). In the case of the saltpans in Brbinj, Lavsa and Vrgada, which are smaller and located at the end of coves and not in lagoons, the separation walls/embankments served as the main barrier between the sea and the saltpans. They were most likely built similarly to the dam described in Piran: thanks to the abundance of stone, which can be easily found almost everywhere in coastal Dalmatia, dry walls were raised, and we can imagine that on top of them mud was added, held together by the roots of local marsh plants. Over the centuries, the sea, winds and rain destroyed the organic covering of the walls of the three saltpans in Brbinj, Lavsa and Vrgada. The sea level rose, flooding the walls, and the rocks with which they were built concreted together due to the strong biological activity in shallow marine water.

The two saltpans of Brbinj and Lavsa make a U-shape facing north, with two lateral (west and east) branches running parallel to the coast, one on each side of the cove. The lateral pans are connected to the main southern saltpans at an almost 90-degree angle. This layout was observed also on several other sites in the Zadar archipelago and needs to be further researched to understand the origin and functioning of this type of saltpans.

The calculated exploitable surface of the saltpans in Brbinj is approximately 2.2 hectares, on Vrgada Island is 2 hectares, while the saltpans in Lavsa were smaller (1 hectare).

The building technique of the observed saltpan structures in Brbinj, Lavsa and Vrgada is clearly medieval. The shallow depths at which these saltpans are located also indicate that they were in use during the Middle Ages. Archival documents testify that the saltpans in Brbinj, owned by the powerful monastery of S. Chrysogonus from Zadar, were constructed at the end of the 12th century (1196) and then rebuilt in the second half of the 14th century (1370) by salt masters from Trieste. The saltpans in Lavsa were built during the second half of the 14th century (1367) and then probably rebuilt in 1399. They were possessed by the Ljubavac noble family from Zadar and sold to Juraj Rosa, another nobleman from the same city, in 1399. The saltpans on Vrgada Island were in use during the 11th century, when the Commune of Zadar gave to the monastery of S. Chrysogonus from Zadar the right to collect the salt produced on Vrgada. All these saltpans were probably gradually abandoned or transformed into fishing traps during the 15th century, with the spread of Venetian rule and salt monopoly in Dalmatia. At the same time, small quantities of salt maybe continued to be produced and smuggled, under both the Serenissima and the Habsburg Empire, as hinted by the story of an elderly inhabitant of Vrgada, who still bears the memory of local salt production on the island.

The sites of Brbinj and Lavsa present few evidences that hint to the existence of earlier phases of salt production. In Brbinj, the central separation wall of the late medieval saltpans includes several fragments of Roman amphorae, which were probably collected from nearby places and piled up with rocks to build the big separation wall. From the aerial pictures, it looks like there is an unknown early-Christian church on the SW coast of the cove, right next to the medieval saltpans. Another early-Christian church is located on the Utran Islet on the northern side of the cove. Nothing else is known of the Late Antique or older Roman settlement in Brbinj, which very likely existed around the fertile field south of the saltpans. In Lavsa Cove, there is a big quantity of Late Roman pottery scattered on the eastern shore. According to older scholars, a

Roman *villa* was located on the island, which exploited the fertile field south of Lavsa Cove, as well as its shallow waters for salt making. At present, no Roman buildings were found on the island, although a local man described the finding of a body inhumed in an amphora. We can only suppose that Romans started to produce salt on the island and that salt making continued on the same spot during the Middle Ages.

On Vrgada Island, no artifacts dating to Roman times were found, maybe also due to the short time available for the archaeological survey. Nevertheless, the presence of a probably stable garrison on the island during the 6th century and the great potential for salt exploitation of Sveti Andrija Cove, suggest that salt exploitation might had taken place here also in Justinian times.

At all three sites, possible saltpans from Roman times were most likely located deeper. Later, when the sea level rose, all the still-usable elements probably continued to be employed in the medieval structures, as attested in Pantan in central Dalmatia (Radić Rossi 2008: 494-496). The ongoing study of sediment cores from Brbinj and Lavsa could bring important data, showing different phases of hypersaline environments connected to anthropic action, interposed by wetland/marine sedimentation.

Compared to the Brbinj, Lavsa and Vrgada sites, Makirina Cove is more complex, with underwater and coastal remains that belong to different chronological periods. Makirina saltpans are known from archival documents from the end of the 13th and the beginning of the 15th centuries, when the lateral western branch with a channel, similar to the ones remarked in Brbinj and Lavsa, was most likely added. The limits of this medieval addition are unclear, as well as the destination of the already existing 230 m long saltpans' separation wall during the Middle Ages. The dating of the wall before the 7th century AD is already hidden within the toponym *Makirina*, which originates from the Latin *maceria*, meaning dry stone wall, and indicates the Romanic-Slavic symbiosis of the name, occurred during the 7th century AD (Vuletić 2010: 337). Consequently, the wall can be dated before this date, as supported by its construction technique (a careful selection and assemblage of blocks employed in different, solidly built rows) and the depth of 1.25 m at which its lower part, together with other annexed structures, lay today. Radiocarbon dating was performed on two wooden timbers, which were found at two different spots close to the separation wall. The first one (T1) was recovered in the western part of the cove, few cm west of the beginning of the separation wall of the saltpans and perpendicular to it. The second timber (T2) laid in the central part of the cove, in the portion where the separation wall is destroyed, aligned with it.

Both timbers were cut during the 5th-6th century. Their employment in the saltpans' structure could have been contemporary to the construction of the early-Christian buildings on the coast, comprised in the archaeological site of Ivinj with Saint Martin's church: the earlier *domus ecclesiae* from the first half of the 5th century AD, or the later three-nave-church from the second half of the same century, or the interventions applied to the early-Christian church in Justinian time (AD 527-565). The two timbers were part of the saltpans' structure, but it is not clear what functional connection there was between them and the separation wall. Therefore, at this point of research, we cannot understand whether the two timbers were part of the original saltpans' structure, which included the separation wall, or they were later additions or modifications: we do not know whether the timbers represent a *terminus ante* or *post quem* for the construction of the separation wall. Lacking the archaeological excavation, nothing about the foundations of the wall is known.

Another absolute dating was obtained by sending a third timber to radiocarbon dating. This timber (T4) was recovered in the central part of the cove, and was included in a structure that can be most likely interpreted as the foundations of a wall (W6), at the western part of which a channel flew. This wall was perpendicular to the separation wall W1, and began immediately south of Timber 2, dated to the 5th-6th century.

The timbers found in Makirina have direct parallels with several wooden elements recovered on the Roman saltpans of Cervia: the sluice gate provided with a timber that has a groove to fit the wooden sluice plank and several timbers with mortises (Guarnieri 2019: 117-118; Caporali 2019: 135-137, 142, 145, 152-153). In Cervia, two vertical timbers with mortises, in which the two tenons of the horizontally placed third timber with a groove were fitted, created the solid base for the sluice plank, which was raised or lowered, depending on the fact whether the water needed to flow in or stay trapped to start the evaporation (Ch. 2.5, Fig. 48).

Radiocarbon dating showed that Timber 4 from Makirina was cut during the 2nd century AD, but for the moment this dating must be taken with a reserve, due to the different, less reliable sampling technique. Even if this dating cannot yet be taken as certain and no other finds from the Roman Imperial period have been found in the proximity of the saltpans' separation wall, it is reasonable to think that the wall was chronologically and functionally connected to the nearby Roman *villa*, whose first implantation dates to the 1st century AD. If this hypothesis is right, the beginning of salt exploitation in Makirina Cove should originate in the Roman Imperial period. The choice of Makirina Cove for the location of the *villa* was certainly not casual, and obviously, the salt-making potential of the cove was already evident at that time. This does not mean that the saltpans were part of the original plan of the *fundus*: they could have been built sometime later, but probably long before the period of Late Antiquity. The comparison between the different building techniques of the submerged walls in Makirina and Elaia Bay in western Anatolia seems to point in this direction as well, although of course the possibility of different building traditions and material availability should be considered.

In Elaia Bay, in front of a salt marsh, there are six parallel submerged walls, located at 1 m depth (Seeliger *et al*. 2014). The walls are 1 m wide and are built with two parallel rows of reused ashlars and quarry stones, with the space in between filled with smaller stones and debris. The walls were constructed without solid foundations and most of them date between the 4th and 6th centuries AD, with possible later reuses. They were interpreted as walls of ancient saltpans, built, as observed by the authors, in a fast and economic way, without foundations, reusing available blocks from demolished city buildings (Seeliger *et al*. 2014). The walls in Elaia are typical, rapidly built Late Antique walls, with no foundations and no mortar used as binder. On the other hand, the separation wall in Makirina is a compact dry wall: its building technique required mastery, time and economic availability. It has been demonstrated (Bechor *et al*. 2020) that the wall did not move through centuries, therefore it is highly probable that it has solid, man-made foundations: the wall does certainly not stand on a natural rocky substratum, because the sediment that accumulated on the internal side of the wall reaches 1 to 3 m of depth. The foundations of Wall 6 in the central part of the cove show the use of abundant mortar, wooden poles and timbers, roof tiles and stone slabs. Similar or probably more solid materials were most likely employed in the foundations of the separation wall as well. Consequently, it seems more likely that the original saltpans in Makirina were constructed during Roman Imperial times and that they were successively restored during Late Antiquity.

The most delicate wooden and mortar remains, which have been just superficially uncovered on the seabed, have been covered with geotextile to allow their preservation and are awaiting future excavations. The two timbers (T3 and T4) englobed in the foundations of Wall 6 in the central part of the cove have the potential to be sampled for dendrochronological dating, which would provide a narrow chronology of their employment (or reuse) in the saltpan structure. The excavation would also shed light on the foundations of the separation wall, uncovering its construction methods and, in the fortunate case of possible ceramic, wood or mortar finding, the dating of the wall could be revealed.

4.2. Catalogue of presumed ancient saltpans on the eastern Adriatic coast

Archaeological remains that belong to saltworks from Classical Antiquity have been found at several sites across the Mediterranean (Carusi 2008: 45-148; Işik, Atik Korkmaz 2012; Canal 2013; Marzano 2013: 126-138; Morelli, Forte 2014; Seeliger *et al*. 2014; Grossi *et al*. 2015; Moinier, Weller 2015: 58-152; García Vargas, Martínez Maganto 2017; Guarnieri 2019; Guarnieri *et al*. 2021) and the northwestern Iberian shore (Castro Carrera 2006; Currás 2017; Castro Carrera *et al*. 2022; Martins 2019; Brochado *et al*. 2022), where the climate, tidal range and salinity are slightly different. On the Croatian coast, a few possibly Roman saltworks' sites have been surveyed or tentatively researched. At some of these locations, research is currently ongoing and will certainly bring new valuable data about the planimetry of ancient saltpans and ancient salt production techniques.

4.2.1. Presumed saltpans from Classical Antiquity based on archaeological research

This catalogue includes five sites that have been partially excavated or tentively surveyed by the University of Zadar, the Archaeological Museum of Zadar, the Archaeological Museum of Pula and the Institute of Archaeology in Zagreb, in collaboration with other national and international institutions. Similarly to the site in Makirina Cove, which has been presented in Ch. 4.1.1, all the following sites preserve archaeological remains that can be directly associated with salt and/or some other kind of marine exploitation in the period of Classical Antiquity.

The sites are organized in chronological order of discovery, starting from the site of Pakoštane that was partially excavated in 2005, until the most recent excavations in Bijeca Cove, being researched since 2014. This site is extremely interesting, because it shows that in the same productive complex salt exploitation was complementary to the salting of olives.

Jaz Cove, Pakoštane, Zadar County, HR

Geographical position: 43°54'25.2"N 15°30'19.4"E

Toponymy: Jaz Cove.

The town of Pakoštane is located on the coast between Zadar and Šibenik, bounded by Lake Vrana to the NE and the Adriatic Sea to the SW (Fig. 209b). It is one of the most important maritime and geographic points on the Croatian coast, although in the archival documents it appears only from the 15th century (Faričić 2018: 153). On the south side of the newly constructed harbor, west of the old center of Pakoštane, there was a shallow cove named Jaz (= enclosed shallow seawater), a toponym that is often connected to salt production. This cove is visible on an aerial picture and topographic maps from mid-20th century (Fig. 209a, Fig. 210). On the southern side of the cove a road separated it from the sea. In later periods it was filled and transformed into a parking lot.

Fig. 209 a: Mid-20th century aerial picture of Pakoštane with the still-existing Jaz Cove on the left side of the picture (Radić Rossi et al. *2018, p. 244).*
209 b: Aerial photo of Pakoštane, with the Lake Vrana in the backgroung (Municipality of Pakoštane Tourist Board, courtesy of I. Radić Rossi).

Archaeological evidence: remains of four rectangular wooden basins, channels with bottoms lined with wooden planks, parallel lines of poles and planks, stone embankment.

The area of Pakoštane is still not well explored archaeologically, except for the seabed in front of the town, which is very rich in finds. On the Veli Školj Islet, there are remains of a hillfort, while another prehistoric site is located at Janice, in between the beach and S. Justina Islet (Vujević, Meštrov 2018) (Fig. 211). About 100 m to the SW there was a Roman harbor, most active from mid-1st to the early 3rd centuries AD (Parica 2018). The Roman wharf, built with stones and wood, is located about 2 m below the current sea level.

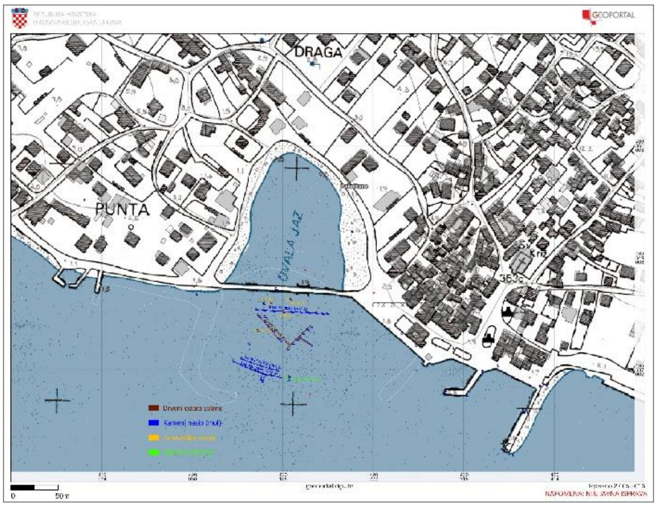


Fig. 210 Mid-20th century topographic map of Pakoštane with Jaz Cove and sketch of the recorded structures in 2005 (courtesy of I. Radić Rossi).

The excavations revealed the presence of rich archaeological deposits, with organic remains and ceramics from the Eastern Mediterranean (70 % of total finds), Africa and northern Italy. This harbor most likely supplied with goods coming from all Mediterranean the wider hinterland with the ancient towns of *Asseria* (present Podgrađe near Benkovac), *Burnum* and others (Parica 2018). About 90 m NE of the islet of Veli Školj, at 2.5 to 2.75 m depth, a Late Roman (final quarter of the 4th to the mid-5th century AD) shipwreck was excavated (Radić Rossi, Boetto 2018).

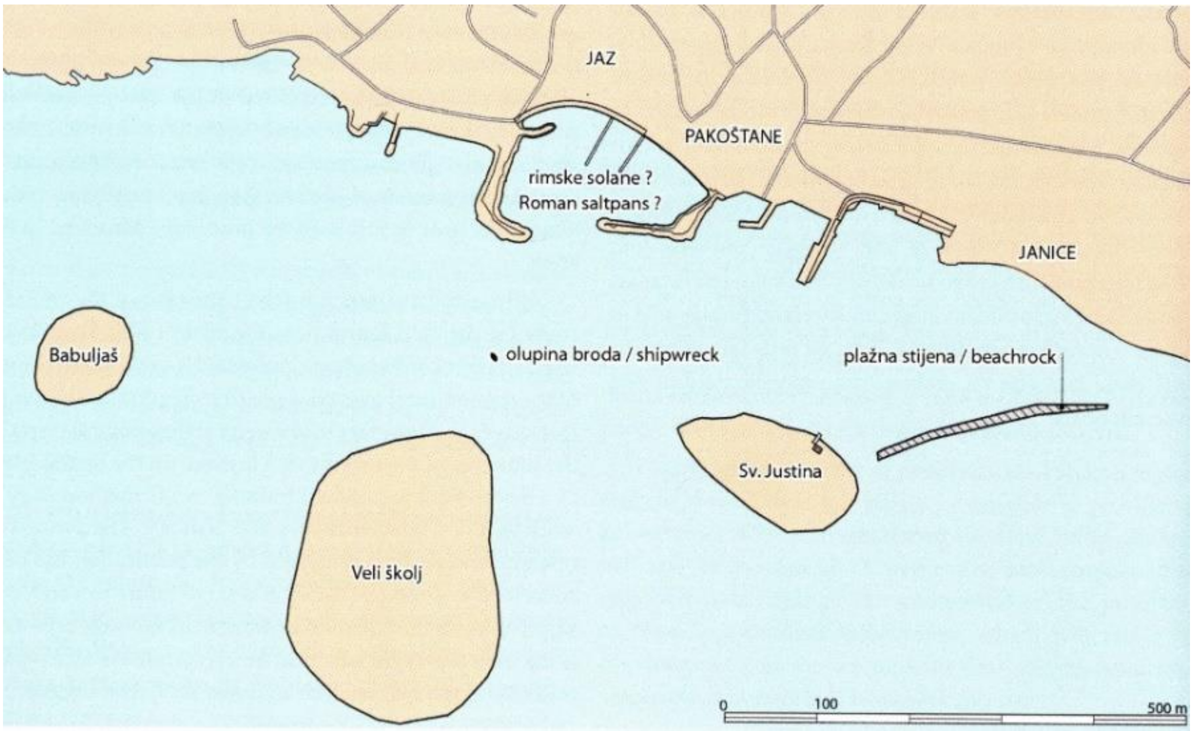


Fig. 211 Map of Pakoštane (V. Dumas, from Radić Rossi, Boetto 2018, fig. 3).

In 2005, archaeological test excavations were carried out in the area of the present-day harbor in Pakoštane (Fig. 212). During two short campaigns led by Krunoslav Zubčić, archaeologists unearthed the remains of a submerged structure, split into three different units, laying at a depth of 2.05 to 2.15 m (Radić Rossi *et al.* 2018: 237-238). The first structure is an embankment of stones, progressively rising from the seabed (Fig. 213a). Just a few meters south there is a structure made of perpendicularly set planks and poles vertically driven into the sea bottom (Fig. 213b, Fig. 215b). This structure preserves similarly built channels linked at right angles with planks reinforcing their bottoms (Fig. 124b, Fig. 215a). Poles have a diameter of 5 to 20 cm, while the planks have a width of 3 to 10 cm. Among these remains, four rectangular pools have been outlined, with 1.6 - 2 m wide canals between them. The eastern and western limits of the pools have not been excavated. The canals linked at right angles and were reinforced by a diagonal board, sustaining the vertical sides of the pools, while poles vertically driven in the seabed additionally supported the diagonal reinforcements (Fig. 214a, Fig. 216a-b).

Fig. 212 Structures recorded in 2005: blue = stone embankments, brown = wooden remains of the probable saltpan, yellow = archaeological probes, green = ballast stones (K. Zubčić, from Radić Rossi et al. *2018, fig. 9).*

The third unit comprises the southern embankment, made of broken stones rising 50-70 cm above the seabed. An archaeological probe was dug on its external side, without identifying any artifacts. Only a consistent quantity of ballast stones is present on its eastern side.

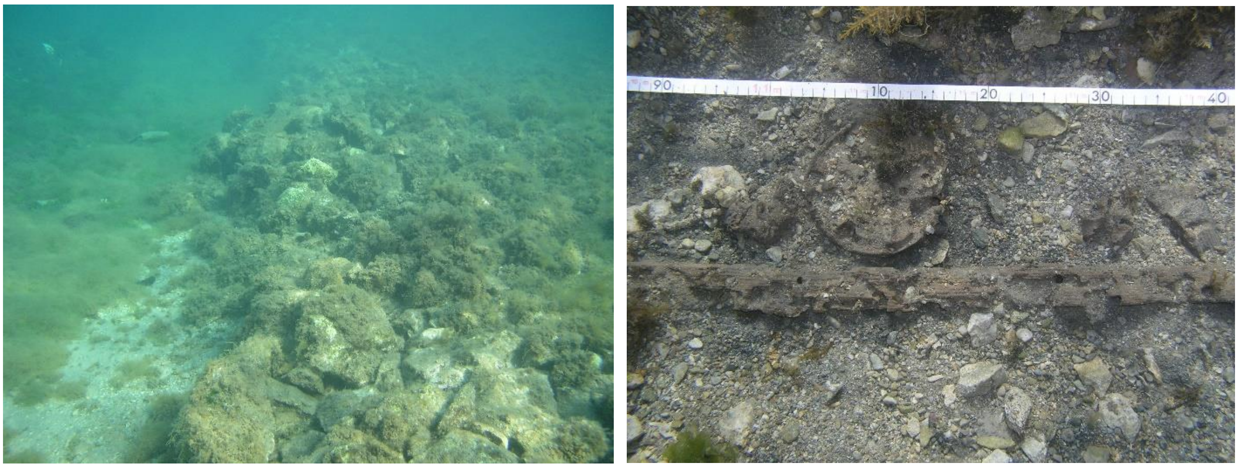
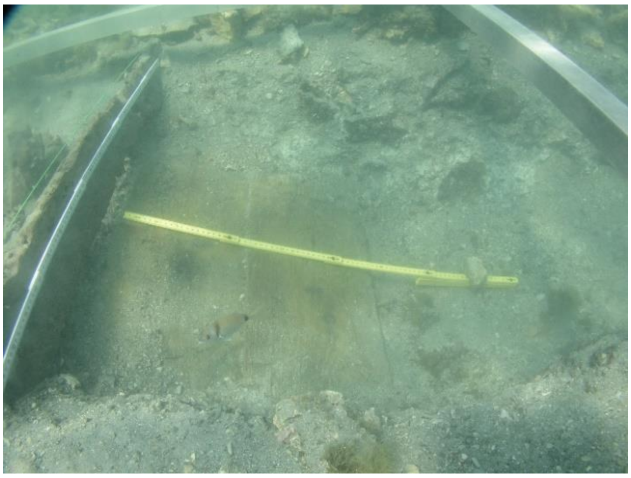


Fig. 213 Southern embankment (a). Remains of wooden poles and planks on the seabed (b) (courtesy of I. Radić Rossi).

Fig. 214 a: Southern part of the canal (below), reinforced by a diagonally placed board (above), in turn supported by a pole (Radić Rossi et al. *2018, fig. 10, c).*
214 b: Northern part of the canal with planks covering its bottom (Radić Rossi et al. *2018, fig. 10, d).*

During the excavations, ceramic artifacts were not found, but the radiocarbon analyses of wooden remains dated the construction to the $1^{st}/2^{nd}$ centuries AD. According to the researchers, the rectangular wooden structures bear a strong resemblance to saltpan pools, but due to the small extent of the test excavations, we cannot exclude that these structures were used for some other kind of marine exploitation (Radić Rossi *et al.* 2018: 237-238). Jaz Cove was located in a very suitable spot for salt production, in a very shallow bay protected by the islets of Veli Školj and S. Justina. Recently, similar wooden structures with planks and poles have been found in Bijeca Cove in Istria and interpreted as remains of saltpans (Koncani Uhač 2020; see below). I believe that in Pakoštane salt exploitation might have coexisted with additional aquaculture activities, hinted by the presence of channels paved with wooden planks. Archaeological evidence from Cervia and Vigo shows that on the saltpans the channels were usually simply dug in the ground, as Rutilius Namatianus explained (I, 477: *terrenis canalibus*).



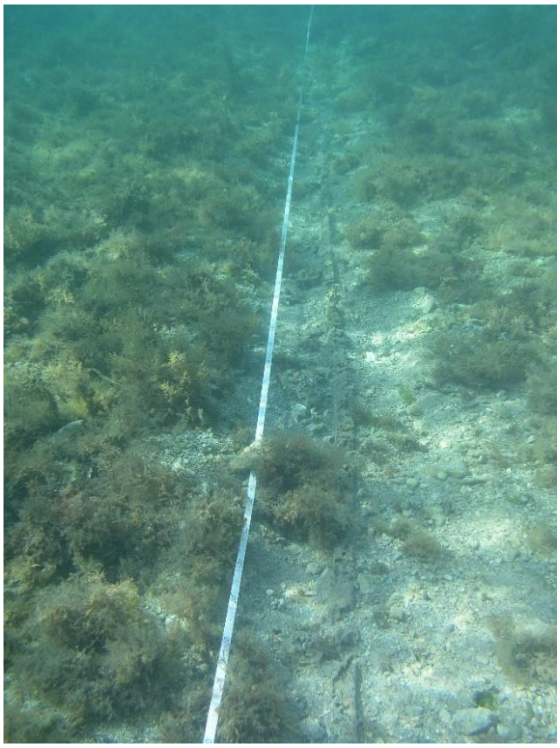


Fig. 215 a: Section of the 2 m wide canal.
215 b: Remains of wooden planks on the sea bottom (courtesy of I. Radić Rossi).

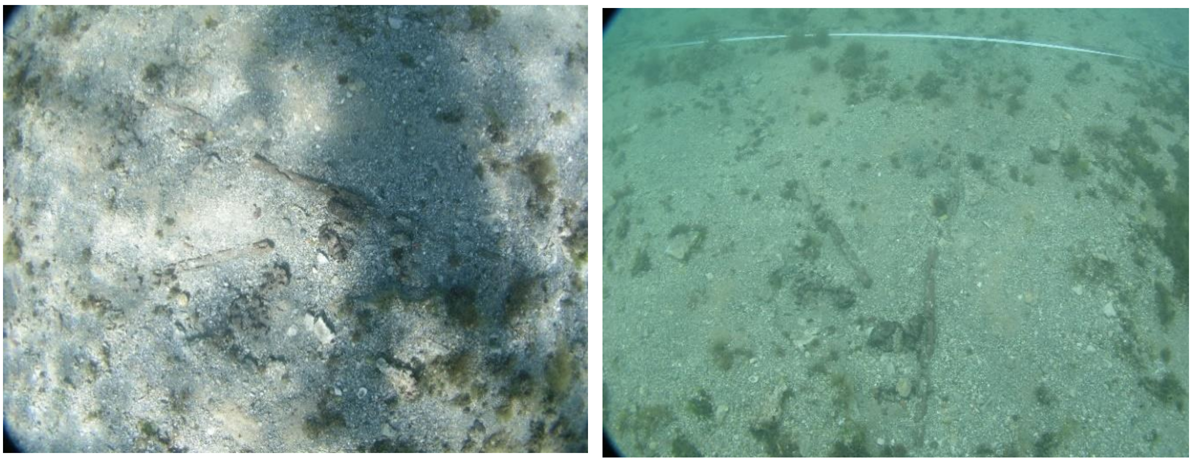


Fig. 216 Diagonally positioned boards reinforcing the angles of the pools (courtesy of I. Radić Rossi).

Dating: Roman period (1st/2nd centuries AD).

References for saltpans: Radić Rossi *et al.* 2018.

Pantan/Blato and Kopilice near Trogir, Split-Dalmatia County, HR

Geographical position: 43°31'31.7"N 16°16'26.7"E and 43°31'14.0"N 16°15'43.9"E

Toponymy: Pantan/Blato.

The site of Pantan/Blato is an inshore brackish lagoon located about 3 km east of the Greek *emporion* of *Tragurion* (present Trogir), in the Bay of Kaštela in central Dalmatia. *Pantano* or *pantana* in Italian and *blato* in Croatian mean marsh, mud.

Historical sources:

This was an area with numerous mills, attested from the Middle Ages (Ostojić 1980: 165, 172; Babić 2014: 277). The marshy shoals in Pantan were exploited for salt making for centuries. *Salinae comunis de Blato* are attested in the area and a document from 1416 mentions the existence of *salinae comunis de sancto Clemente* (Babić 2014: 37; 2017: 467). In 1606, the saltpans in Pantan were reconverted into farming land, because by then they were producing only poor quantities of salt and they were causing insalubrious air (Babić 2014: 38).

Archaeological evidence: stone embankment, parallel lines of poles and planks, palisade, wooden gutter/trough.

From the satellite pictures, a more than 500 m long embankment parallel to the coast can be seen in the shallow waters south of the Pantan marsh, which at some spots seems to be up to 10 m wide. In 2003 an underwater archaeological survey, led by Smiljan Gluščević from the Archaeological Museum of Zadar, confirmed the presence of a stone embankment made of irregular piled stones and wooden constructions. The latter were made of vertically positioned poles and planks with their longer side upright, probably associated with channels of either fish traps or saltpans (Gluščević 2004: 126-131; Radić Rossi 2008: 494). Certain poles flanked the planks on their external side (Fig. 217a). Other rows of just poles (palisades) were discovered, some of them running in N-S direction and others E-W, parallel to the embankment. The distance between two rows of poles oriented E-W was about 4 m. In addition, a narrow wooden gutter has been discovered, 13 cm wide, with an internal width of 9 cm, raising 10 cm above the seabed (Fig. 217b, 218). Similar wooden gutters have been recently unearthed in Bijeca Cove in Istria (see below). Samples of wooden constructions located close to the mouth of the Rika creek were sent for radiocarbon analysis to the Institute Ruđer Bošković in Zagreb. It revealed that the planks dated to the 1st century BC, while the poles were early medieval, from the 8th century. The analysis demonstrated the continuity of exploitation of marine resources from Classical Antiquity to the Middle Ages (Radić Rossi 2008: 496).

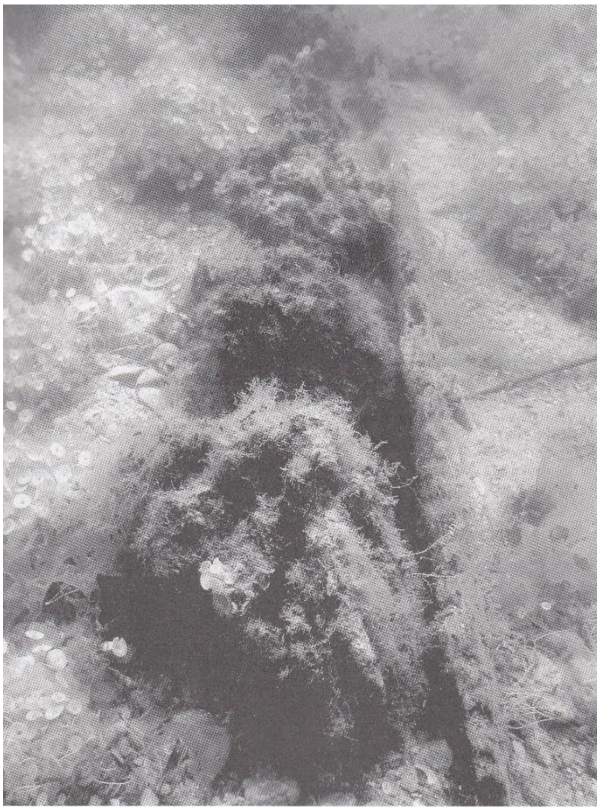


Fig. 217 Wooden remains at Pantan: poles reinforcing planks (a) and the wooden gutter (b) (Gluščević 2004).

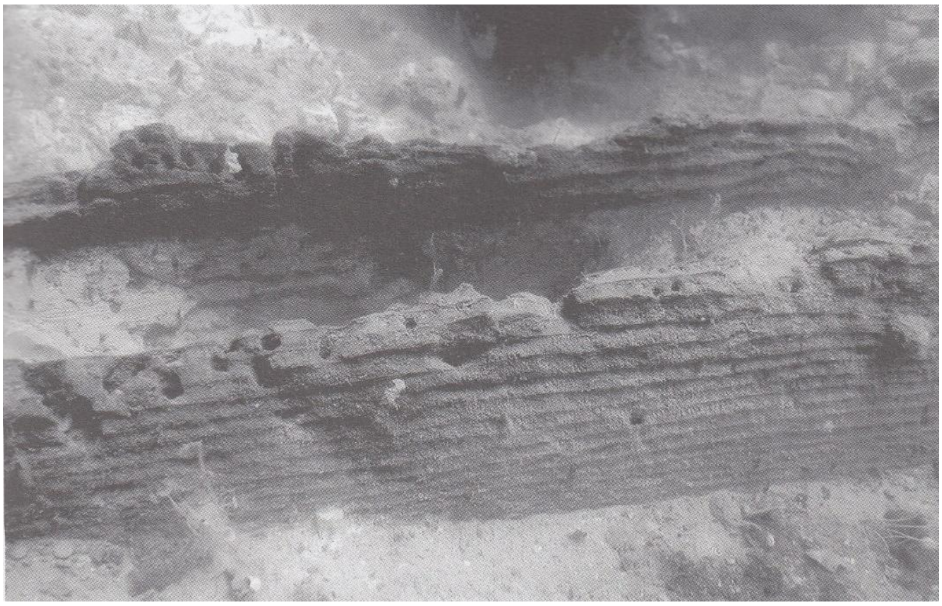


Fig. 218 Detail of the wooden gutter at Pantan (Gluščević 2004).

Similar constructions made of vertically driven planks and poles delimiting channels and an external stone embankment have been found at the nearby site of **Kopilice**, about 1 km east of the historical center of Trogir, where the land reclamation from the last decade has deeply transformed the coastal landscape, devastating the natural and historical heritage of the Bay of Kaštela. In 2007, a rescue archaeological excavation has been performed at the western part of the site of Kopilice (Fig. 219), under the direction of Irena Radić Rossi and Krunoslav Zubčić (Radić Rossi 2008: 496-497). Several linear constructions ("canals") were discovered (Fig. 220). The longest of these structures extended over 116 m and then turned at a right angle towards the coast (Radić Rossi 2008b: 294). The edges of the structures were 2.2 m distant one from another and were made of 30 cm wide planks, flanked by poles. The preserved wooden poles excavated in one archaeological probe reached the height of more than 1 m. The radiocarbon analysis carried out at the Institute Ruđer Bošković in Zagreb showed that one plank was from the 4th century AD, while the pole was from the 7th/8th century AD (Radić Rossi 2008: 496-497).

Dating: Classical Antiquity (1st century BC and 4th century AD), Early Middle Ages (8th century), Middle Ages, Modern period.

References for saltpans: Gluščević 2004; Radić Rossi 2008; 2008b; Babić 2014; 2017; Džino 2020.

Fig. 219 Aerial photo of Kopilice - Brigi in 2007, with the position of linear wooden structures (photo of I. Šuta, from Radić Rossi 2008b: 289, fig. 4).

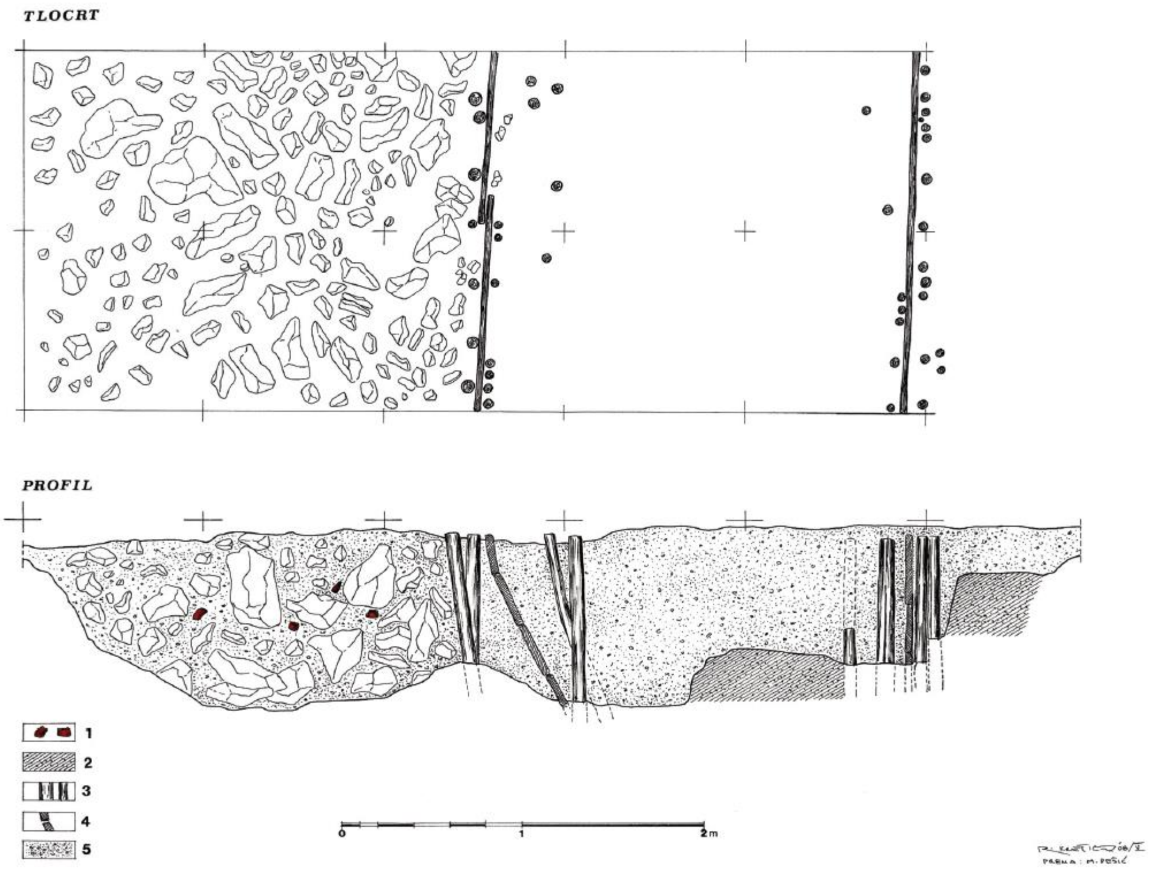


Fig. 220 Kopilice - Brigi: plan and cross-section of the wooden structure composed of planks and poles: 1 - ceramic fragments, 2 - terra rossa, 3 - poles, 4 - planks, 5 - mud. (drawing of K. Rončević according to M. Pešić, from Radić Rossi 2008: 494, fig. 5).

Soline Cove, S. Klement Island (Pakleni archipelago, Hvar), Split-Dalmatia County, HR

Geographical position: 43°09'46.4"N 16°21'50.1"E

Toponymy: Soline Cove.

Historical sources: Salt exploitation on this site is evoked by the toponym Soline, attested from the 15th century. Medieval saltpans are attested on the site at the end of the 14th century (M. Petrić, personal communication).

Archaeological evidence: medieval? parallel submerged walls, *villa*, fish processing vats?

In Soline Cove on the small S. Klement Island, close to the bigger island and town of Hvar in central Dalmatia, there are the remains of a Roman maritime *villa*, built on the southern coast of the island, on the main eastern Adriatic seafaring route, close to a fertile field. The site is being excavated since 2007, including researchers from the Hvar Heritage Museum, the Institute of Archaeology in Zagreb, the University of St. Thomas, Minneapolis and other institutions (Kirigin *et al.* 2010; Begović *et al*. 2012; Ugarković *et al*. 2016; Ugarković, Konestra 2018; Ugarković *et al*. 2019). The *villa* has different chronological phases, dating from the late 2nd/1st century BC to the 6th century AD. It includes residential, productive and storage spaces, as well as remains of saltpans in the shallow waters of the cove. The site was most intensively frequented during Late Antiquity (Ugarković *et al*. 2019: 223). In the multi-phase *pars rustica* of the *villa* remains of an oil press have been discovered and earlier basins lined with fine waterproof plaster have been reused for oil production. According to the researchers, the original function of these basins might have been salt exploitation or more likely the production of salted fish and fish sauces (Ugarković *et al*. 2019).

The cove in front of the *villa* is a safe harbor, with the islet of Dobri protecting its entrance from the scirocco wind and waves. In the shallow waters of the cove there are four parallel underwater walls, delimiting a flat area of approximately 4.500 m^2 (Fig. 223). Three parallel walls (B, C, D) are visible on the aerial picture from 1968 (Fig. 221) and on a contemporary drone photo (Fig. 222), while the shallowest wall A is less preserved. The first three parallel walls (A, B, C) are 3-4 m wide, while the outermost wall (D) is 6-7 m wide and has a 3 m large opening. These walls have been interpreted as partition walls of Roman saltworks and salt has been suggested being the most important product of this *villa* (Kirigin *et al.* 2010; Ugarković, Konestra 2018: 85). In 2012 an underwater archaeological survey was conducted in the cove, which determined that due to the shallow depth at which the partition walls are located (20 to 50 cm), they likely belong to medieval saltworks. Nevertheless, because they are located in front of the Roman *villa* and because conspicuous Roman artifacts lay scattered across the surface, it is very likely that the Roman saltpans were located on the same spot (Brusić *et al.* 2012). The confirmation of this hypothesis must wait for underwater archaeological excavations.

Dating: Roman period?, Middle Ages.

References for saltpans: Kirigin *et al.* 2010; Brusić *et al.* 2012; Ugarković *et al*. 2019.

Fig. 221 Aerial photo of Soline Cove from 1968 (courtesy of M. Petrić).

Fig. 222 Aerial photo of Soline Cove from 2008 (courtesy of M. Petrić, I. Schrunk, A. Konestra).

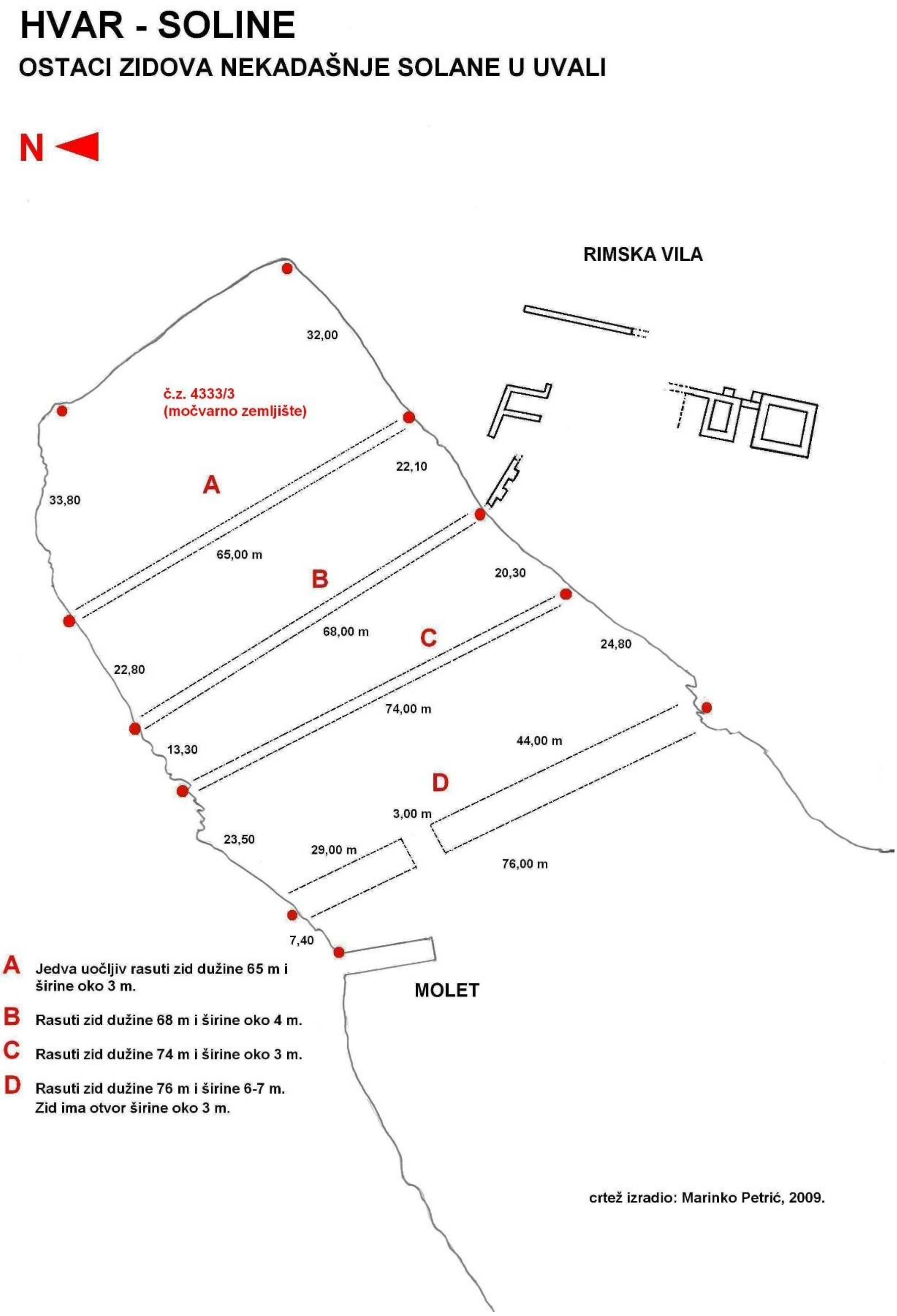


Fig. 223 Plan of the saltworks' remains in Soline Cove (M. Petrić, courtesy of M. Ugarković).

A: Barely spottable detached wall, 65 x c. 3 m; **B**: Wall measuring 68 x c. 4 m;
C: Wall measuring 74 x c. 3 m; **D**: Wall measuring 76 x 6-7 m, with a c. 3 m wide opening.

Bijeca Cove, Medulin, Istria County, HR

Geographical position: 44°48'47.0"N 13°55'52.2"E

Toponymy: *Peschiera di Bieci/ Pescheria di Biece*.

Bijeca Cove is located on the eastern side of the Medulin Gulf in southern Istria (Fig. 224), south of the present town of Medulin and the archaeological park of Vižula, which includes a huge Roman maritime *villa* with different structures spread over an area of 20 hectares (Doneus *et al*. 2020, with previous bibliography). This area is full of Roman monuments, both on the coast and under the present sea level. Thanks to local divers, the underwater site in Bijeca Cove was recently added to the list of Roman sites of the area. From 2014, systematic archaeological researches are carried out in the cove, under the direction of Ida Koncani Uhač from the Archaeological Museum of Pula. While it is still early in the excavation process, it is evident that this site shows great promise for obtaining data regarding the functioning of a saltpan from Roman times, thanks to the exceptionally preserved finds.

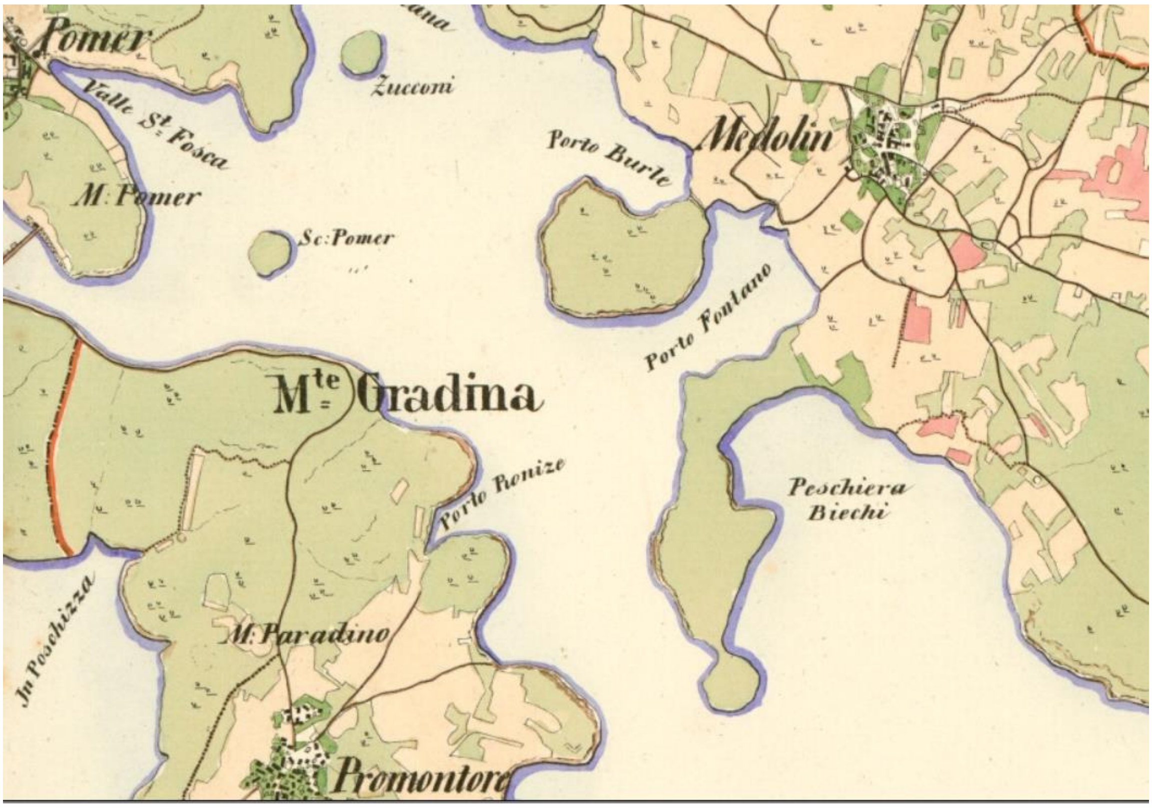


Fig. 224 Extract of Catasto Franceschino, Carta corografica del litorale n. 57, first half of the 19th century (http://www.catasti.archiviodistatotrieste.it/Divenire/ua.htm?idUa=10653154).

Archaeological evidence: remains of wooden rectangular basins, channels, wooden gutters/troughs, parallel lines of poles (palisade), pier.

The site was part of a larger Roman productive complex with **salt and olive production facilities**, while some remains hint to the presence of additional aquaculture activities (Koncani Uhač 2020). According to the researchers, the complex can be dated from the end of the 1st century BC to the beginning of the 5th century AD.

The surface of the site covers about 10 hectares and is located at 1 to 2.5 m depth. The productive complex is composed of remains of a salt production facility with channels, square shallow basins delimited by wooden planks, a warehouse, ruins of a productive structure probably connected to oil processing and elements of an oil press (Koncani Uhač 2020).

In the western side of the cove, there are the remains of a probable warehouse of about 18 x 31 m. It is composed of four spaces, of which one is located on the northern and three on the southern side. Originally, it was located on the shore (Koncani Uhač 2020: 28-29). In very shallow waters to the east there is a 48 m long canal, built with regular squared stone blocks and *spolia*, among which there is also an inscription, bound by mortar. Waterproof mortar is visible on some blocks. Wooden planks, placed on wooden poles, pave the bottom of the canal. The planks have been dated by radiocarbon between AD 130-255 and AD 295-320, with 95 % probability (Koncani Uhač 2020: 30-31).

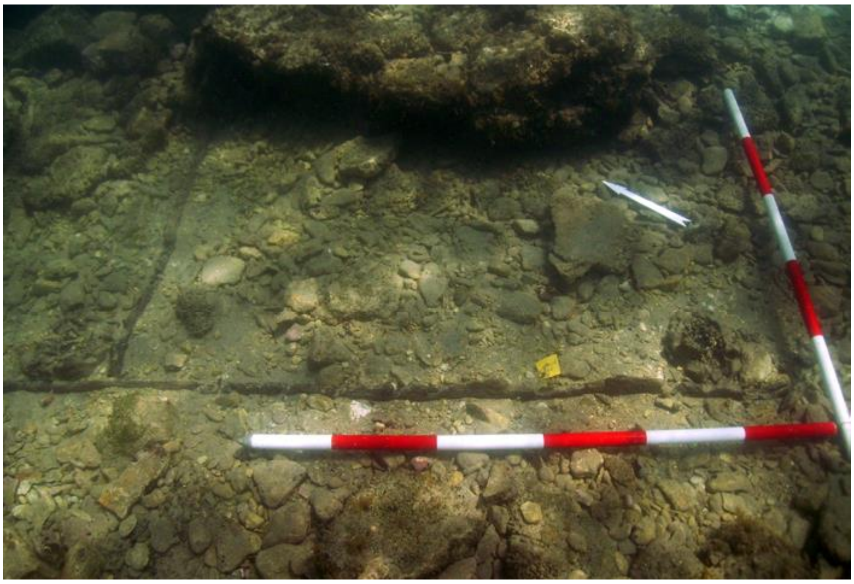


Fig. 225 Wooden rectangular basins at the external side of the canal (photo of I. Koncani Uhač, from Koncani Uhač 2020: 30, fig. 10).

On the western external side of the canal there are wooden rectangles, with their sides delimited by vertically positioned planks, with corners reinforced on the internal side by vertically driven poles (Fig. 225), which resembles the remains unearthed in Pakoštane (Radić Rossi *et al*. 2018).

This area has not yet been excavated. East of the canal there are the remains of walls, which probably belonged to the salt production facility (Koncani Uhač 2020: 32).

Fig. 226 The poles of the palisade (photo of Lucio Lorencin, from Koncani Uhač 2020: 31, fig. 12).

Across the central part of Bijeca Cove, there is a palisade made of hundreds of poles placed in two parallel lines, oriented E-W and N-S, forming a 175 m long grid (Fig. 226). The southern double line of poles is oriented E-W, while there are four series of N-S oriented double lines of poles, preserved for 6.8 to 35 m in length. The total number of poles is greater than 2000: they are 10-20 cm wide and located at 1 to 1.4 m depth. Radiocarbon analysis of a pole yielded dating to a period in between AD 265-275 and AD 330-420, with 95 % probability. This of course only refers to the dating of one pole and cannot date the whole palisade (Koncani Uhač 2020: 32-33).

The excavators think that these are the remains of one part of the saltpans' pools (or rather of the external embankment of the saltpans or of the dykes in between the salt basins). They were located on the 3rd-5th century tidal zone. The hypothesis is strengthened by the presence of a 4.4 m long wooden gutter (Fig. 227), which follows the direction of the grid. The entire profile of the wooden gutter is preserved, measuring 44 cm. This gutter could have had the function of distributing the brine between the pools of different salinity stadiums, or contrarily it could have represented a drainage gutter to expel the

Fig. 227 The wooden gutter in Bijeca (photo of Jerko Macura, from Koncani Uhač 2020: 32, fig. 13).

rain and runoff water from the pools into the canals (Koncani Uhač 2020: 33). Another similar wooden gutter, preserved for 6.85 m in length, has been partially uncovered during the 2015 archaeological campaign on the western part of the palisade (Koncani Uhač 2020: 34). These wooden gutters resemble the one found on another salt-making site: that of Pantan close to Trogir in central Dalmatia. The use of wooden gutters for moving brine is attested in several inland saltpan sites, of which the most spectacular certainly are the Salinas de Añana in the Basque Country, where they are made for the most part out of hollow pine trunks (Plata Montero 2006: 90-112; 2022) (see Ch. 1, Fig. 5).

In some spots of the palisade in Bijeca, entangled vine branches have been found among the poles. The remains of dykes of saltpans and other structures from the Venetian lagoon (Canal 2013) show that branches, twigs and rushes were commonly employed to build the embankments (see Ch. 2.5). The same is attested in a document describing the separation wall of the saltpans of Piran in the 14th century (Hocquet 1978: 120) (see Ch. 4.1.5).

In the SW part of Bijeca Cove, at about 1.2-1.4 m depth, there is a 38.5 m long and 1.25 m wide wall, around which eight circular millstones (*molae*) have been found. At 2.6 m depth, a partially preserved *lapis pedicinus* has been documented (Koncani Uhač 2020: 35). On the eastern part of the cove, there is a 17 x 6.5 m submerged structure in *opus quadratum* with a central space and channels at the southern and western sides, with interesting wooden and stone remains, as well as two troughs in oak (Koncani Uhač 2020: 35-38). On the northern side of the structure in *opus quadratum*, there is an entirely preserved wooden canal of 4.15 x 0.57 m, which has been dated in the period in between 45 BC and AD 75, with 98 % probability (Koncani Uhač 2020: 38). The presence of numerous olive bones in the canal and in the central space of the stone structure suggests the probable use of these remains for olive processing (Koncani Uhač 2020: 39). Olives were preserved in salt, vinegar, *amurca* (the water that is expelled when olives are being pressed), in the cooked must or in oil, with the addition of aromatic plants, especially fennel (Cato, *Agr*., VII, 4, 117-118; Col., XII, 49, 8; Plin., *Nat. Hist*., XV, 16; Pallad., XII, 22). The best olives were those preserved in seawater or brine, called *colymbades* (= washed) (Col., XII, 49, 8; XII, 50, 5; Plin., *Nat. Hist*., XV, 16; Pallad., XII, 22, 1) (André 1961: 92). The excavation of this part of the site will be the focus of further research campaigns.

As highlighted by Koncani Uhač, the productive complex in Bijeca was located on a favorable position on the southeastern side of the Medulin Gulf, which allowed an easy import and export of goods. Remains of an embankment, which probably functioned as a jetty, were discovered in the southern part of the cove. The complex in Bijeca Cove was probably part of a larger private or imperial property inside the territory of the colony of Pula. This property included more maritime villas located in the surroundings: the complex in Pošesi at the eastern side of the cove, Kažela – located south, and the big maritime *villa* of Vižula to the northwest (Koncani Uhač 2020: 39-40). Bijeca was the center of marine salt production, which covered the needs of the property and maybe of a wider area.

Salt from Bijeca could have been used also for fish salting and the making of fish sauces. Fishing in the cove is suggested by the later Italian toponym *Peschiera*, attested on the 19th century maps. Quite a few lead net-sinkers have been found in Roman archaeological layers, indicating fishing activities in the cove during the Roman period (Koncani Uhač 2020: 41).

Dating: Roman period (end of the 1st century BC - beginning of the 5th century AD).

References for saltpans: Koncani Uhač 2020.

4.2.2. Presumed saltpans from Classical Antiquity deduced from indirect indicators

This catalogue includes 18 selected sites, which may had produced salt in the period of Classical Antiquity. This can be presumed based on a combination of facts: toponymy, the existence of saltpans in the Middle Ages, the presence of submerged structures visible from the satellite pictures that can be linked with saltpans, the proximity of productive complexes from Classical Antiquity. They are organized in geographical order, from north to south.

S. Clemente-Stramare, Muggia/Milje, Friuli-Venezia Giulia, IT

Geographical position: 45°36'04.3"N 13°47'18.2"E

Toponymy: Strada delle Saline.

Historical sources:

These saltpans, attested from the 12th century (Oriolo, Ventura 2017: 86), were located at the mouth of Ospo Stream (Rio Ospo), where one of the present-day roads still bears the name *Strada delle Saline*. These were the principal saltpans of the Commune of Muggia, owned by the local nobles and clergy (Selva 1994: 460). They are noted on Pietro Coppo's map of Istria from 1525. These saltpans revived at the beginning of the 19th century, before they were definitively abandoned at the end of the 19th century. The reclamation of the marshy areas, which in the past were occupied by saltpans, was completed in the 1930s, without major changes in the coastline. Nowadays, industrial warehouses and other commercial buildings stand on the spot of the ancient saltpans.

Archaeological evidence: *villa*, harbor, briquetage?, medieval saltpans.

During the second half of the 1st century BC, a Roman *villa maritima* with productive spaces and a richly decorated residential part was built at the western side of the Stramare Promontory, north of the medieval saltpans of S. Clemente and Rio Ospo's mouth (Župančič 1990: 387; Fontana 1993: 186-188, 223; Auriemma *et al*. 2008: 126-133; Oriolo, Ventura 2017: 88, 94-96). In Roman times, the promontory was bigger than it is nowadays, when it is partially submerged (Antonioli *et al*. 2007: 2471; Auriemma *et al*. 2008: 131-133). The coastal remains were partially destroyed by the construction of the nowadays-inactive oil refinery Aquila. The *villa* had an L-shaped pier, known as *Molon* (Civico Museo Archeologico di Muggia 1997: 56-57) and was an important docking site, according to the variety of ceramic findings of various provenances. The Roman *villa* was actively frequented until the end of the 2nd century AD and then again during later periods, until the 5th century. Early medieval ceramic findings could point to the fact that the harbor in front of the *villa* started or continued to serve for the transport of salt from the possibly already existing nearby saltpans (Civico Museo Archeologico di Muggia 1997: 81-82).

Fig. 228 Saltpans of Muggia, extrait of Catasto Franceschino, first half of the 19th century (https://a4view.archiviodistatotrieste.it/).

At the mouth of Ospo Stream, there was a Roman fluvial port and at the southern side of the medieval saltpans, remains of one or more Roman settlements and/or production areas were found (Auriemma *et al*. 2008: 130).

This area probably produced salt since the Neolithic period (Càssola Guida, Montagnari Kokelj 2006; Montagnari Kokelj 2007; Montagnari Kokelj *et al*. 2015). The nearby *castelliere*[36] of Elleri (2nd millennium BC - second half of the 1st millennium BC), overseeing the Noghere Valley from south and located less than 1 km from the coast of the Bay of Muggia, preserves hundreds of broken ceramic vessels' fragments, identified as briquetage pottery for salt production (Càssola Guida, Montagnari Kokelj 2006: 328-330; Montagnari Kokelj 2007: 175-184). It has been supposed that at the same time salt was also produced in Stramare, close to the mouth of Rio Ospo, on the terrace above the Roman remains on the shore (Càssola Guida, Montagnari Kokelj 2006: 330-331; Montagnari Kokelj 2007: 175, 177). Stramare might have

[36] Before the arrival of Romans, the inhabitants of the Histrian Peninsula lived on hillforts, the so-called *castellieri*.

been an open-air site, where the preliminary concentration of brine was obtained and then transported to the *castelliere* of Elleri for further processing.

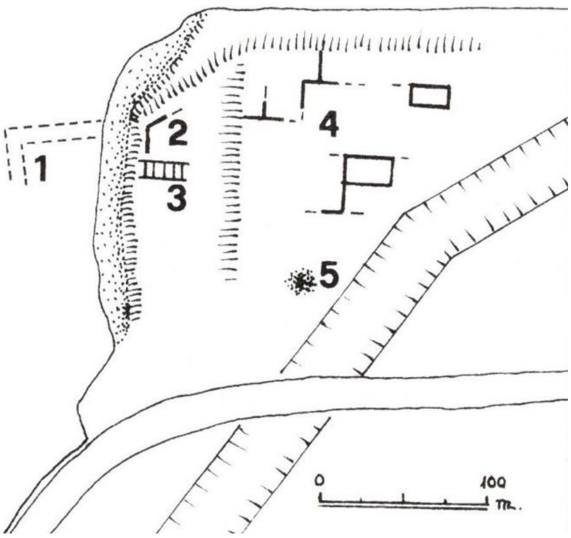


Fig. 229 Roman remains in Stramare:

1. L-shaped pier;

2. Terrace wall;

3. Ramp;

4. Structures of the villa*;*

5. Prehistoric deposit.

(Civico Museo Archeologico di Muggia 1997: 56).

Stramare, a site and harbor located north of the saltpans attested from the Middle Ages, was more or less continuously frequented from Prehistory to the Modern period. Salt production and trade might had played an important role, reiterated through centuries, for the selection and continuation of use of this site, located in a strategic position at the mouth of Rio Ospo and the entrance of the Muggia Valley (Vallone di Muggia), one of the few crossing passages towards the interior of the continent. During the 1st century AD, important commercial links developed between the northern Adriatic territories and the provinces of *Pannonia* and *Noricum* (Civico Museo Archeologico di Muggia 1997: 62-63).

Dating: Neolithic?, Roman period?, Middle Ages, Modern period.

References for saltpans: Župančič 1990; Fontana 1993; Civico Museo Archeologico di Muggia 1997; Càssola Guida, Montagnari Kokelj 2006; Montagnari Kokelj 2007; Auriemma *et al*. 2008; Montagnari Kokelj *et al*. 2015; Oriolo, Ventura 2017.

Jernejev zaliv/San Bartolomeo Cove, Lazaret/Lazzaretto, Ankaran/Ancarano, SLO

Geographical position: 45°35'31.2"N 13°43'20.9"E

Toponymy: predial toponym.

It is interesting to note that in medieval documents the saltpans of S. Bartolomeo were also called the *Paugnan* saltpans (Hocquet 1978: 81), a name that derives from a predial toponym, which indicates that in Roman times the area was included in the property of *Paconius* (Civico Museo Archeologico di Muggia 1997: 64).

Historical sources:

During the Middle Ages and later, saltpans were located in present Lazaret/Lazzaretto, in between Punta Sottile/Tanki rtič in present-day Italy and Debeli rtič/Punta Grossa in present Slovenia, probably at the eastern side of S. Bartolomeo Cove, at the mouth of the S. Bartolomeo stream (Hocquet 1978; Selva 1994).

Archaeological evidence: *villa*, *vivarium*, harbor, medieval saltpans.

From the satellite pictures, submerged walls are visible at this spot: probably the biggest one of them is the separation wall of early modern saltpans. Auriemma *et al*. 2008 have already suggested that these remains could belong to saltpans, while for Gaspari *et al*. 2008 this could be an early modern fishery, although they underlined that proper recording has not yet been done. In the central part of the bay, there is a small peninsula known as Carigador (probably early modern loading platform of the nearby quarry), which buried some Roman walls that are still partially visible nowadays. Only few meters west, there are two Roman wharfs, also known as Molere (Župančič 1990: 388; Stokin *et al*. 2008: 70-72; Auriemma *et al*. 2008: 140). Just few dozens of meters west, there is a still well preserved Roman *vivarium* probably from the beginning of the Roman imperial age, with two pools and a curvilinear landing branch (Stokin *et al*. 2008; Auriemma *et al*. 2008: 140; Antonioli *et al*. 2007: 2473), while a Roman *villa* was located on the slope behind.

Dating: Roman period?, Middle Ages.

References for saltpans: Hocquet 1978; Selva 1994; Stokin *et al*. 2008; Auriemma *et al*. 2008.

Fig. 230 S. Bartolomeo Cove.

Fig. 231 Remains of Roman wharfs (Molere) in S. Bartolomeo Cove (https://enavtika.si, accessed 15/12/2019).

Velike Soline, Črvar Bay, Poreč/Parenzo, Istria County, HR

Geographical position: 45°16'36.2''N 13°35'01.5''E

Toponymy: Velike Soline, Punta Soline, Soline Cove, Punta del Saltarel.

Črvar Bay (Luka Črvar/Porto Cervera) is located more or less in the central part of the western Istrian coast, in between the municipalities of Tar Vabriga/Torre Abrega and Poreč/Parenzo. At the southern entrance of the bay, there are Cape/Punta Soline and Soline Cove. The marsh of Velike Soline is located in a sheltered position at the internal, eastern side of the cape, open towards Črvar Bay and connected to the sea by a narrow passage. About 800 m south of Velike Soline there is another smaller coastal marsh named Male Soline. Both locations produced salt, maybe until the end of the Modern era (Zaninović 2007: 127; cf. Carre *et al*. 2012: 131-132).

Fig. 232 Aerial view of Busuja Cove (in the foreground) and the entrance into Črvar Bay (in the background), with the locations of Male and Velike Soline (R. Kosinozić, Rousse et al. *2013, Fig. 10).*

Toponymy seems to indicate fishing activities around Cape Soline: the cape is called *Punta del Saltarel* on the map of the Second military survey of the Habsburg Empire (1821-1824). Saltarel is a tool composed of two nets used for fishing mullets, who jumped (from Ital. saltare) over the perpendicularly set net onto a horizontal net and remained trapped (Cigui 1996: 297).

Historical sources: Zaninović 2007: 127; cf. Carre *et al*. 2012: 131-132.

Archaeological evidence: *villae*, *vivarium*, kiln-local amphorae, fish processing?

In Črvar Bay there was a huge Roman maritime estate. It comprised the residential and productive complex of S. Marina and the fishpond in Kupanja on the northern side of Črvar Bay, the *figlina* in Loron on the eastern side of the bay and the *villa* in Červar Porat/Porto Cervera to the southeast, which maybe had a fish processing facility (see below). It is assumed that salt was produced in the neighboring Soline Cove at the southern entrance of Črvar Bay, probably in or close to the enclosed basin known as Velike Soline (Carre *et al*. 2012: 104-106; Koncani Uhač 2020: 42). This implicated a close connection with the saltpans, the probable fish processing facility in Červar and the amphorae workshop in Loron. All these areas formed a unique, first senatorial and later imperial property, spreading over 1000-1500 hectares. During the first half of the 1st century AD, the estate belonged to Statilius Taurus Sisenna, consul in 16 BC and son of T. Statilius Taurus, one of the closest collaborators of Emperor Augustus (Girardi-Jurkić 2011: 60).

Fig. 233 Aerial view of southern Črvar Bay (https://www.hrvaska.net/en/destinations/cervar-en.htm, 27/07/2021).

Later owners were Messalina, Crispinillus, Aelius Crispinillus and Calvia Crispinilla, until it became an imperial property under the reign of Domitianus. All the owners stamped their names on the amphorae, which were produced in the nearby productive complex of Loron.

The *figlina* in Loron was built around AD 10 and functioned until the end of the 5th century. It was one of the most active centers of amphorae production in the northern Adriatic area (Tassaux *et al*. 2001; Rousse 2011; Carre *et al*. 2012; Rousse *et al*. 2018). It produced primarily Dressel 6B oil amphorae, but also other ceramic containers, building materials and objects. Very interesting is the production of small-size Dressel 6B amphorae, which maybe contained *garum* (Marion 2009; Maggi, Marion 2011; Marion, Tassaux 2020: 31).

400 m north of the *figlina* in Loron, along S. Marina Cove, there is a big coastal *villa*, dated to the first half of the 1st century AD (Rousse *et al*. 2018; 2020). The *villa* extends over a sloped area of at least 5000 m^2. Its main building comprises a 100 m long maritime façade and three terraces: the first one is constituted by the *pars urbana*, surmounted by productive and storage spaces of an oil factory (*pars rustica/pars fructuaria*). A huge cistern is located on top of the whole building (Rousse *et al*. 2020). On the other side of the cove, in Kupanja, there are the remains of a large Roman *vivarium*, which was included in the same estate (Carre *et al*. 2012: 83-93).

The productive complex in Červar was partially excavated during the 1970s (Girardi-Jurkić 1979; Džin, Girardi-Jurkić 2005). It included a kiln, which was active at the beginning of the 1st century AD, an oil factory and maybe fish processing installations (Tassaux 2009: 106-108). It seems that this complex did not have a *pars urbana*, although it could have been destroyed in the quarry, which was implanted above parts of the Roman ruins (Carre *et al*. 2012: 103).

It has been supposed that inside the Roman *villa* in Červar Porat/Porto Cervera (Girardi-Jurkić 1979; Džin, Girardi-Jurkić 2005), three round ceramic containers buried in the ground in the space B (6.50 x 4.45 m) served for fish salting (Matijašić 1998: 364; Tassaux 2009: 107; Carre *et al*. 2012: 104-106) (Fig. 234). Two of them have a diameter of 1.4 and one of 1.8 m,

Fig. 234 Červar Porat: containers for garum*?*
(L. Damelet, CCJ-CNRS, Carre et al*. 2012: 104, fig. 21).*

their borders were built with rocks and fragments of *tegulae*, of which two bore a stamp (Girardi-Jurkić 1979: 270). Their internal surface was covered with a pale red plaster. Although the excavators of the site tend to connect these round containers with the preparation of clay close to the nearby kiln (Džin, Girardi-Jurkić 2005: 6), other scholars think that a use connected to the production of *garum* or other fish sauces would be more convincible for these containers (Tassaux 2009; Carre *et al*. 2012: 103-106). Similar round containers have been discovered in Bealo in *Baetica*, and in Portopalo and Vendicari on the eastern coast of Sicily (Botte 2009: 83-88; Carre *et al*. 2012: 104-106). They could be the *Bacchi dolia* mentioned by Manilius (*Astr*., V, 663-675), where *garum* and other fish sauces were made, flavored with salt. The small number of such containers in Červar implies a small local production that could have been stored in the small-sized Dressel 6B amphorae produced in nearby Loron, for which Marion has hypothesized that contained *garum* (Marion 2009; Maggi, Marion 2011; Marion, Tassaux 2020: 31). The dating of the round containers is not clear, they could be contemporary or posterior to the kiln, which was active at the beginning of the 1st century AD (Carre *et al*. 2012: 103).

Dating: Roman period?, Middle Ages?, Modern period?

References for saltpans: Zaninović 2007; Carre *et al*. 2012; Auriemma 2016: 491; Koncani Uhač 2020: 42.

Male Soline, Poreč/Parenzo, Istria County, HR

Geographical position: 45°16'08.1"N 13°34'48.0"E

Less than 1 km south of Velike Soline there is a coastal marsh known as Male Soline. F. Tassaux thinks that according to the toponymy both locations might have produced salt until the Modern era or later (Carre *et al*. 2012: 131-132).

Toponymy: Male Soline, Pličina.

Archaeological evidence: *villa, vivarium,* purple dye workshop.

Male Soline is situated next to Pličina (= shoal) beach, north of the Roman *villa* known as Villa Mozaik/Mosaico, which has been partially excavated at the end of the 19th century (Carre *et al*. 2012: 128-131). Just few parts of the *villa* are known to the scientific community: it was at least 100 m long and other remains are at present hidden underneath a camping. It is most likely to this *villa* that belonged the famous Roman fishpond in Busuja Cove (Rousse *et al*. 2013), while according to F. Tassaux, additional saltpans could have been situated at the bottom of the cove, sheltered from the bora and scirocco winds (Carre *et al*. 2012: 131). In the nearby Fratrija located at the eastern side of Busuja Cove, numerous remains of crushed and pierced marine snails *Murex trunculus* and *Murex brandaris* testimony the existence of a purple dye workshop in the vicinity (Carre *et al*. 2012: 124-128; Machebœuf *et al*. 2013), which must have required large quantities of salt. Tassaux's reconstruction is that the *fundus* of Villa Mozaik exstended from approximately Male Soline to Cape Albareti at the northern side of S. Martin Bay, for a total surface of about 135 ha (Carre *et al*. 2012: 131).

Dating: Roman period?, Middle Ages?, Modern period?

References for saltpans: Zaninović 2007; Carre *et al*. 2012.

Brijuni/Brioni archipelago, Pula/Pola, Istria County, HR

Geographical position: 44°55'00.8"N 13°46'03.9"E

The Brijuni archipelago or *insula Pullaria* on the Tabula Peutingeriana is made of 14 islands, located at the southwestern side of the Istrian Peninsula. From 1984, they are included in the Brijuni National Park. The largest island is Veli(ki) Brijun/Brioni Grande, which preserves the remains of different Roman villas, excavated by A. Gnirs at the beginning of the 20th century.

Toponymy: *Val Saline* (present Ribnjak Cove), Soline and *Salina vecchia* (= Javorika) Cove, Slana Cove, Cape Slanik (W of Ribnjak), Tunjarica Cove (W part of Mali Brijun Island).

Historical sources:

The oldest written source mentioning saltpans in Istria and Croatia in general dates to the 6th century: in AD 543 the bishop of Poreč Euphrasius donated a third of the saltpans on Brijuni Islands to his clergy: *volumus eciam ut ipsi canonici habeant terciam parten de salinis, quas habemus in insula, quae vocatur Brivona* (Hocquet 1978: 83; Zaninović 1991: 259; Bonin 2006: 44).

In 1457 the *Collegio* of the *Provveditori al Sal* mentions the existence of saltpans on the islands. In 1559 the Venetians enlarged the existing saltpans in Val Laura (Javorika Cove) and in Val di Torre (once called *Val Saline*, present-day Ribnjak) (Hocquet 1978: 83). Saltpans on Brijuni were still active in 1625 (Selva 1994: 457). The saltpans in Javorika Cove were in use presumably from Classical Antiquity until the 18th century (Urbis 2019: 44).

Archaeological evidence: unpublished archaeological remains attributed to presumable saltpans, *villae*, ceramic workshop in Fažana.

In the territory of *Pola*, the Brijuni Islands with their villas were owned by the family of the Laecanii Bassi, which counted three generations of consuls (Tassaux 1982; 2005: 143). The property included the Dressel 6B amphorae workshop and other productive complexes in Fažana and Dragonera on the mainland (Bezeczky 2016). They were the biggest producers of olive oil in Istria, which was exported to northern Italy and to the Alpine-Danubian provinces (Bezeczky 1998). In AD 78, after the death of C. Laecanius Bassus, consul in AD 64, his estates on Brijuni Islands and the *figlina* in Fažana became imperial property.

According to Schrunk and Begović, the complexes on Brijuni Islands, centered on the Verige Cove *villa*, produced oil and wine, salt and extracted construction stones (Schrunk, Begović 2000: 265). Six Roman productive complexes have been discovered so far on the Brijuni archipelago.

On the northwestern part of Veliki Brijun Island, on Kolci Hill/Monte Collisi, there was a big oil production complex, with four presses, a vat (*lacus*) and an oil cellar with approximately 156 *dolia* (Bezeczky 2016).

At the eastern part of the island, in Verige/Val Catena Cove, an original, probably Late Republican *villa* was built in the southern part of the cove (Schrunk, Begović 2000: 256-257). During the first half of the 1st century AD, a majestic *villa maritima* with an imposing maritime façade, decorated with colonnaded promenades (*ambulationes*), *cryptoportici*, *exedrae* spreading over four terraces was built over the whole cove. At the western wing there were luxurious living quarters and *thermae*, while at the eastern wing there were the oil (Bezeczky 2016) or wine (Schrunk, Begović 2000) productive areas. At the bottom of the cove, there were three temples: according to Gnirs, they were dedicated to Venus, Neptun and to an unknown divinity (Schrunk, Begović 2000: 262). In late 1980s and early 1990s, a systematic architectural survey and archaeological probes have been performed (Schrunk, Begović 2000: 253-255).

At the northern side of Verige Cove, there is a submerged rectangular structure, which has been interpreted as a fishpond (Jurišić 1997). Other scholars think it served for another purpose, because it is completely different from all known fishponds along the Adriatic and Thyrennian coasts. Besides, it is located at too shallow depths and in front of the *thermae* of the *villa* (Antonioli *et al*. 2007: 2473; Auriemma, Solinas 2009: 138, fig. 6; Carre *et al*. 2012: 37). The sea level in Verige Cove has risen for 1.60 m from Roman times (Antonioli *et al*. 2007: 2473).

At the western side of Veliki Brijun Island, in Dobrika/Val Madonna Cove, there is a multi-stratified archaeological site, known in scholarly literature as *Castrum*, inhabited continuously from the 1st century BC to the 7th century AD (Bezeczky *et al*. 2015). The oldest construction on the site, located on the most sheltered part of the island, was a Roman *villa*, built in the second half of the 2nd or the first quarter of the 1st century BC. It was a productive complex that was probably destroyed during the civil war between Antony and Octavian (Vitasović 2005). In the 1st century AD, the *villa* was rebuilt and enlarged by the new owner, most likely Laecanius Bassus, as the amphorae stamps from Fažana seem to suggest (Bezeczky 1998: 68-

69). Oil (Bezeczky 1998; 2016), rather than wine (Vitasović 2005) was produced in the *villa* at this time. Additionally, its workers maybe extracted stones from the quarry situated about 1 km north and exploited salt in nearby Javorika (Soline) Cove (Vitasović 2005). After AD 78, this property also fell into imperial hands, while at the end of the 2nd century AD Marcus Aurelius Iustus, whose name appears on the amphorae in Fažana and whose votive inscription dedicated to Flora has been recovered in Dobrika Cove, used the *villa* (Vitasović 2005; Bezeczky 2016). The *villa* flourished at the beginning of the 3rd century (Bezeczky 1998: 68). According to Tassaux (2011: 434), it was probably transformed into a settlement of colonists who payed taxes in return of the exploitation of the natural resources on the island. During the Late Roman/Byzantine period, the settlement was enclosed with walls and became a fortress (*castrum*), while S. Mary's church was built next to it. During the Early Middle Ages, the Benedictines annexed a monastery. The clergy left the island in 1348 (Vitasović 2005).

According to most scholars, the saltpans on Brijuni Islands were located in **Javorika Cove** (Soline, Val Laura/Valdaura, 44°54'26.9"N 13°45'39.2"E) on the southern part of the Veliki Brijun Island, where there are the remains of a Roman productive complex with a wharf, with spaces interpreted for the production and storage of salt (Begović, Schrunk 1999: 434-435; Koncani Uhač 2020: 40). It is generally believed that the salt workers lived in the nearby *Castrum*. The first surveys on the site were carried out by Puschi (1897-1911) and Degrassi (in the 1920s), who interpreted them as remains of piers (De Franceschini 1998: 502-503). At the beginning of the 1980s, after a storm, some walls enclosing spaces paved with compact clay have been discovered (Vitasović 2005: 178). The discoverer formulated the hypothesis that these remains were connected to salt production. Never published underwater investigations carried out in 1985 by M. Orlić and M. Jurišić, revealed the presence of a large pool, connected to the sea by a channel, and two small communicating pools. A third small pool located nearby was interpreted as the salt harvesting pool (Schrunk, Begović 2000: 269). A pier is located in front of this structure. An underwater excavation was never carried out at this site.

These presumable Roman saltworks are located at the eastern inlet of Javorika Cove (Schrunk, Begović 2000: 266, fig. 12). According to the published plan (Fig. 235), these structures seem to have had a different purpose than salt making, but the latter might had taken place nearby. On the map of the Second military survey of the Habsburg Empire (1821-1824) "*Salina vecchia*" is marked above the western inlet of the cove, north of the present shore, where there are two marshes nowadays (Fig. 236, 237). These saltpans were active until the end of the 19th century (Schrunk, Begović 2000: 268).

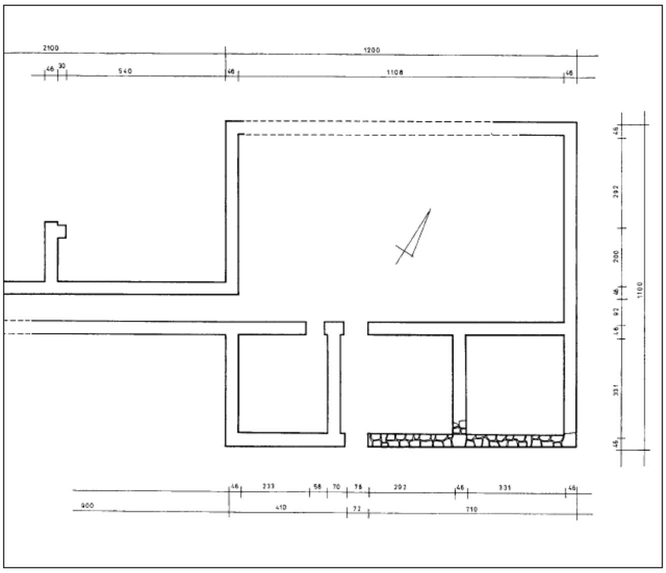


Fig. 235 Presumable remains of "saltpans" in Javorika Cove (Begović, Schrunk 1999, fig. 14).

18th century maps designate with the toponym *Val Saline* also the present Ribnjak (= fishpond) Cove at the northern part of Veliki Brijun Island (Selva 2009: 433, 438, 461, 477). Continuous salt exploitation activity in Ribnjak probably stopped at the end of the 17th century (Zalin 1981: 246).

The toponym *Tunjarica* Cove on Mali Brijun Island (44°55'58.2"N 13°43'52.4"E) indicates the presence of tuna fishing in the area, which also required salt supplies for the preservation and storage of an extremely perishable product.

Pliny mentions that *Histria* was known for its wool (*Nat. Hist.*, VIII, 191). The Laecanii Bassi also owned a *saltus* in Materija on the Karst in present-day Slovenia (*CIL* V 698), where they most probably elevated sheep (Tassaux 1982: 248), an activity that required salt supplies.

Dating: Roman imperial period?, Late Antiquity, Middle Ages, Modern period.

References for saltpans: Hocquet 1978; Zaninović 1991; Selva 1994; 2009; Begović, Schrunk 1999; Schrunk, Begović 2000; Vitasović 2005; Urbis 2019; Koncani Uhač 2020.

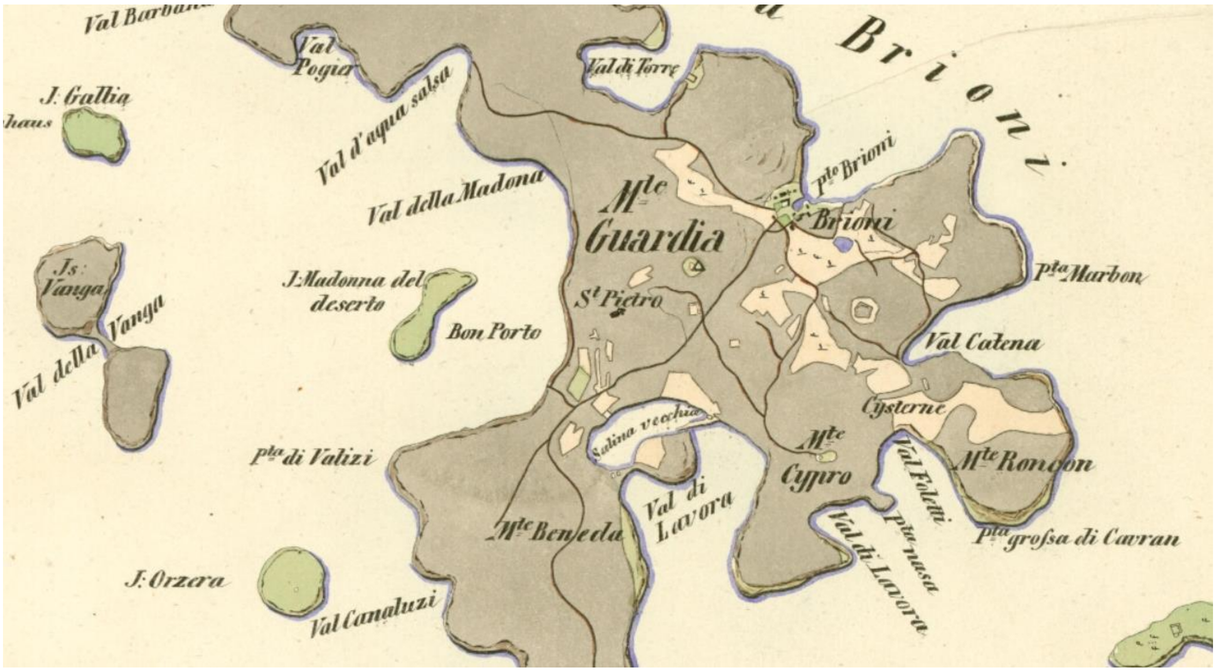


Fig. 236 Extract of Catasto Franceschino, Carta corografica del litorale n. 50, first half of the 19th century (https://a4view.archiviodistatotrieste.it/).

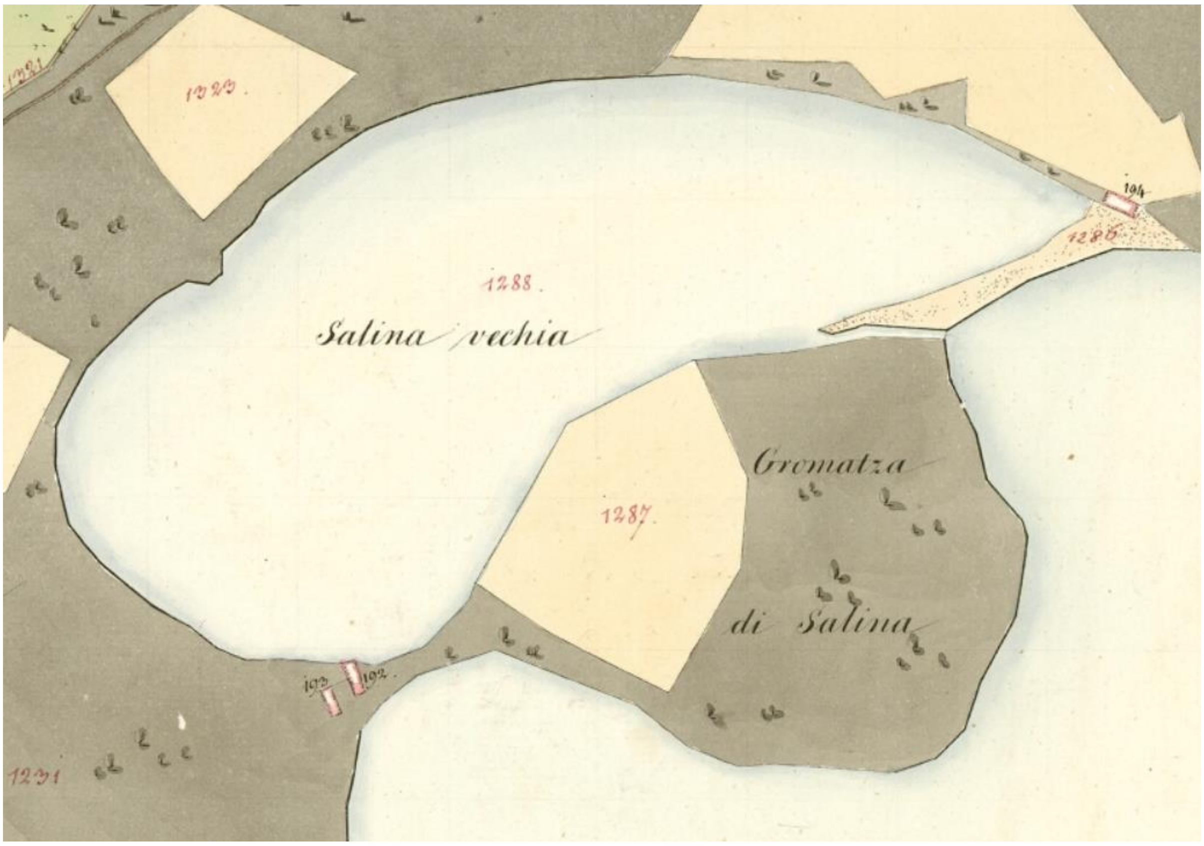


Fig. 237 Extract of Catasto Franceschino, Carta corografica del litorale (https://a4view.archiviodistatotrieste.it/).

Soline Bay, Dobrinj, Island of Krk, Primorje-Gorski kotar County, HR

Geographical position: 45°9'14,46" N 14°36'1,61" E

Soline Bay, about 3 km long and 2 km wide, was the only safe anchorage on the eastern part of the island of Krk (Grisonic 2022). The bay is oriented NE-SW and has a narrow entrance between two promontories that protect it from winds of all directions. It is shallow and has a sandy and muddy bottom. On its western side there is a seasonal stream flowing in the bay, called Veli potok (Šiljeg 2017: 104). On the beach at the bottom of the bay there is abundant **healing mud**, which was analyzed in 1965 (see Šunjić 2003). The beach is still visited today for its therapeutic properties.

Toponymy: Soline Bay (Porto Saline), Soline (Saline) village, Magazini.

Historical sources:

Krk is the ancestral property of the famed noble family of the princes of Krk (1115-1480), who since the 15th century have been called Frankopans. Soline Bay is located 2 km north of the Frankopan castle of Dobrinj, a site where there was a Liburnian settlement. At the time of the Frankopans, big saltpans were located in Soline Bay. In 1412, king Sigismund confirmed to the prince Nikola Frankopan and his successors the possession of the island of Krk, among which saltpans (*maritimas solanas*) were also included (Klaić 1901: 34, 39, 203, 304). From 1451 to 1480, Ivan VII Frankopan ruled over the whole island, a semi-indipendent princedom, called the Principality of Krk. In 1461 the doge forbade to Ivan VII Frankopan, the last prince of Krk, to produce salt. The prince agreed to this on the condition that the doge would regularly send a certain amount of salt (*uno maran di sale*) for the needs of the island. After that, these saltpans were never rebuilt (Jelenović 1973: 172) and Krk imported salt from Koper. In 1480 the Venetians invaded the island and this was the end of the Principality of Krk. In 1481 the prince was “replaced” by the Venetian secretary Antonio Vinciguerra, who wrote that the saltpans located around the island of Krk were excellent (*saline excellentissime*) (Ljubić 1876: 92).

The saltpans in Soline Bay were not only located in the southern part of the bay, in front of the present village of Soline (Klaić 1901: 34), but probably they extended over the whole surface of the bay, which is flat, shallow and rich in peloids. The microtoponym *Magazini*, which refers to the northernmost point of the bay next to the shore, in the hamlet of Meline, suggests that the Frankopan salt warehouses were probably located at this spot (Jelenović 1973: 172).

Archaeological evidence: probable separation wall of medieval saltpans, nearby Roman pottery workshop, possible ties with the pottery manufacture in Crikvenica.

Remains of **walls under water**, which most likely belonged to saltpans, can be noticed not far from the estuary of the stream, by the small Meline Cove, where the water depth is less than 1 m. Satellite pictures of the area, taken in 2018 and freely available on www.arkod.hr, show a wall about 165 m long in the shallow waters of the bay, oriented NW-SE (Fig. 239). In August 2019, after the beach had been given to a concession for touristic purposes, just a small part of the wall, 4.2 m long, was still preserved (Fig. 241), laying at -0.70 m (relative to the local Datum). It is a dry stone wall, about 0.70 m wide, made of 20-30 cm long limestone blocks, conserved on three rows. The rest of the blocks that once belonged to the wall had been removed to several mounds in order to facilitate the passage of swimmers and pedal boats. Because of the shallow depth of the wall today and its similarity to the walls observed at different medieval saltpan sites in Dalmatia, I believe that it was a functional wall of a medieval saltpan. In Meline there was apparently also an ancient dock where salt was loaded onto ships (Šunjić 2003: 185).

We can suppose that the **Roman saltpans** in Soline Bay were located somewhere close to the medieval ones, perhaps even buried underneath them. These saltpans may have had a connection with the nearby Roman site in S. Peter's Cove on the western side of Soline Bay. The abundant presence of ceramic material and of kiln pottery waste close to the ruins of the medieval church suggests the presence of another pottery workshop. Two *tegulae* bearing the stamp of Sextus Metilius Maximus, the owner of the pottery manufacture in Crikvenica, were found on the site, indicating a commercial link with the big regional-scale workshop on the mainland (Lipovac Vrkljan, Starac 2007).

Dating: Middle Ages, Roman period?

References for saltpans: Ljubić 1876; Klaić 1901; Jelenović 1973; Šiljeg 2017.

Fig. 238 Extract of Catasto Franceschino, Carta corografica del litorale n. 42, first half of the 19th century: Porto Saline *(Soline Bay) and the village of* Saline *(at the SE part of the bay) (http://www.catasti.archiviodistatotrieste.it/Divenire/ua.htm?idUa=10653139).*

Fig. 239 Submerged wall in Soline Bay on Krk Island (www.arkod.hr [consulted on 12/10/2018]).

Fig. 240 Soline Bay: the area in front of the preserved submerged wall (M. Grisonic).

Fig. 241 Preserved part of the submerged wall in Soline Bay (L = 4.2 m, W = 0.7 m) with the Velebit mountains in the background (Grisonic 2022, fig. 7).

Supetarska Draga/San Pietro Valley, Island of Rab, Primorje-Gorski kotar County, HR

Geographical position: 44°47'59.4"N 14°43'37.7"E

Toponymy: Soline.

Historical sources:

In 1199, the pope Innocent III confirmed to Ugo, the abbot of the S. Peter's Benedictine monastery on Arbe (Rab), all the possessions of the abbey, among which there were the valleys with saltpans and fishponds in between the churches of S. Cyprian and S. Peter (CD II, 320). Saltpans in Supetarska Draga are attested in the 14th century (Zaninović 1991: 261; Mlacović 2005: 531). During the 16th century, there were still saltpans in the valleys of Maran (S. Euphemia) and San Pietro (Supetarska Draga) (Hocquet 1978: 83). These saltpans are depicted on the Cadastral Map of the Habsburg Empire from 1828, when they were owned by the Dominis family (Piplović 2003: 325). The saltpans, whose surface was about 123.498 m^2, existed until 1903 (Koludrović, Franić 1954: 139).

Archaeological evidence:

The earliest available evidence indicates that the saltpans were owned by the Benedictine monastery, which was located in the same valley. Remains from Classical Antiquity are not known in the area. These were nevertheless the biggest saltpans on the island of Rab during the Middle Ages and the Modern period (Mlacović 2005: 532), which might have been continuously exploited from earlier periods. Roman estates were located 3 km further NE, in Kaštelina, while in the northern area of the island of Rab, in Lopar-Podšilo and Lopar-Mahućina there were Roman ceramic kilns (Lipovac Vrkljan, Šiljeg 2012; Lipovac Vrkljan *et al*. 2018). The area of the saltpans is 4.5 km distant from the town of Rab, the ancient *municipium* of *Arba*. If a continuity of salt production from Classical Antiquity can be postulated, salt would probably had been shipped to *Ortopla* (present-day village and ferry port of Stinica on the mainland) and traded with inland populations (Zaninović 1991: 261).

Dating: (Roman period?), Middle Ages, Modern period.

References for saltpans: Peričić 1983b; Koludrović, Franić 1954; Hocquet 1978; Piplović 2003; Mlacović 2005; 2008.

S. Fumija (Eufemija) Bay-Kampor, Island of Rab, Primorje-Gorski kotar County, HR

Geographical position: 44°46'07.4''N 14°44'04.9''E

Toponymy: Soline, *Saline*, *Sc*(oglio) *Tonera*, Marano (predial toponym).

These were the oldest saltpans on the island of Rab (Mlacović 2005: 532). Saltpans in Marano (present Kampor Field) are attested from the 14th century. *Marano* is probably a predial toponym, which derives from *Marius* (Vuletić 2020: 241).

The area at the bottom of the bay is called *Soline*, where the Pidoka seasonal stream flows in the sea. On the map of the Second military survey of the Habsburg Empire (1851-1854) the basin east of the fishpond in front of the monastery is denoted as *Saline*, at the mouth of a seasonal stream, while the present-day S. Juraj Islet south of the entrance of the Rab harbor and S. Euphemia Bay is called *Sc*(oglio) *Tonera* (Fig. 242).

Fig. 242 Second military survey map of the Habsburg Empire: S. Euphemia Bay (https://a4view.archiviodistatotrieste.it/).

Historical sources:

On the southern side of the central syncline of the island of Rab and the fertile Kampor Field, at the bottom of the S. Euphemia Bay north of the town of Rab, the S. Bernardine from Siena Franciscan monastery in Kampor was built in the 13th century (Braut *et al*. 2020). The monastery possessed saltpans, a tuna-watching tower and a fishpond, attested from the end of the 18th century (Braut *et al*. 2020: 63). The saltpans in the bay were smaller, with a surface of around 8524 m^2 and existed until 1903 (Koludrović, Franić 1954: 139).

Archaeological evidence:

From the satellite pictures, several submerged walls are visible in the shallow parts of the bay: they are most likely the separation walls of the saltpans from the Modern period. It is not known whether there were Roman buildings in the area of the saltpans. For the town of *Arba*, which was 2.5 km away, this was the closest bay suitable for salt exploitation. In the absence of material evidence, the continuity of salt production in S. Fumija Bay from Classical Antiquity to the Modern period remains a matter of conjecture.

Dating: (Roman period?), Middle Ages, Modern period.

References for saltpans: Peričić 1983b; Koludrović, Franić 1954; Mlacović 2005; 2008.

Stara Novalja, Island of Pag, Lika-Senj County, HR

Geographical position: 44°34'16.6"N 14°53'18.4"E

Toponymy: /

Historical sources:

In the 12th century, saltpans existed in Stara Novalja Bay (Peričić 2001: 47). They were owned by the S. Chrysogonus Benedictine monastery from Zadar. In the 13th century (some?) saltpans of Stara Novalja found themselves under the Rab Commune, which had saltpans in the neighboring Novalja.

Archaeological evidence: probable archaeological remains of medieval saltpans (visible from the satellite pictures), *villa rustica*, *villa maritima* and traditional tuna fishing in Caska.

The saltpans of Stara Novalja were probably located in the area of the Škoplje marsh south of the present-day beach of Trinćel, where a seasonal stream flows. From the satellite pictures, numerous neighboring basins of various dimensions can be seen at this spot (Fig. 243). A Roman *villa* was located in Trinćel and the neighboring area of Kumić, close to the church of the Holy Cross. The inscription of a man (AE 1994, 1373 from AD 51-150) was found in the area, in which he remembered the construction or extension of his home (Kurilić 2011: 78). Stara Novalja is located just 1 km north of Caska, a village that is traditionally devoted to tuna and mackerel fishing (Basioli 1962), an activity that needed substantial supplies of salt for the preservation of the surplus of fish. In the early Roman imperial period, members of the powerful senatorial family of the Calpurnii Pisones had their maritime estate in Caska (Radić Rossi, Boetto 2020). The *villa* produced wine and maybe also processed the surplus of fish (Grisonic, Stepan 2022).

Dating: Roman period?, Middle Ages.

References for saltpans: Peričić 2001.

Fig. 243 Probable remains of the medieval saltpans in Stara Novalja.

Soline Cape, Privlaka, Zadar County, HR

Geographical position: 44°16'43.0"N 15°07'52.5"E

Toponymy: Cape Soline, *Valle Soline*.

Historical sources:

14th century documents mention the saltpans in Privlaka, which were located next to the churches of S. Christopher and S. Peter (Brusić 1973: 435-436; Raukar 1970: 50; 1977: 207; Dokoza 2015: 93, n. 92; Dubolnić Glavan 2015: 441, n. 1420). In the Middle Ages a road known as *via communis* connected Nin, Privlaka and the island of Vir in front. In the area in between the capes Soline and Kulina, including the islet of Školjić, there were numerous medieval saltpans. Their remains were partially destroyed in 1810, during the French administration of Dalmatia, when the passage between the island of Vir and Privlaka (Privlački gaz) was dug, to shorten the voyage between Pag and Zadar (Usmiani 1984: 159, n. 17). The area between the capes Soline and Kulina was still called *Valle Soline* on the 1826 Cadastral map of the Habsburg Empire. The basins and dykes of the saltpans in the shallow sea are still visible from the satellite pictures.

Fig. 244 Medieval salt pools and warehouse on Cape Soline in Privlaka (© Jure Šućur).

Archaeological evidence: medieval salt pools and warehouse, Roman maritime *villa*, pier.

Excavations of a probable salt warehouse, located on the coast of Cape Soline in Privlaka north of Zadar (Fig. 245a), were conducted in 2016 by the Department of Archaeology of the University of Zadar, led by Jure Šućur (Šućur, Mustać 2019). Based on ceramic artifacts, the warehouse dates to the mid-14th to 16th centuries. Cape Soline is surrounded by numerous salt ponds, which are very well preserved (Fig. 244). They are located at -0.70 m (relative to the local Datum) and should be contemporary to the salt warehouse (Šućur, Mustać 2019). West of the storehouse the ruins of a Roman complex (Fig. 245b) with a harbor are located (Brusić 1973: 424-426), which may have previously exploited the shoals around Cape Soline for salt-making. A large Roman structure built with blocks bound by mortar, of which two sides of 260 x 194 m are preserved, is located on the neighboring islet of Školjić, both on the coast and underwater (Dubolnić Glavan 2015: 442-445). It probably belonged to a maritime *villa*.


Fig. 245 Cape Soline: the excavated medieval salt warehouse (a) and the remains of Roman walls at the W part of the cape (b) (M. Grisonic).

In Roman times, most parts of the passage between Privlaka and the island of Vir were not underwater. The Roman complexes on Školjić and Cape Soline were in use from the end of the 2nd/1st century BC until the 2nd century AD, although Late Roman ceramic artifacts and some differently oriented structures point to the continuation of use in later periods as well (Dubolnić Glavan 2015: 441-442). In the area there was also a temple or shrine, probably dedicated to Silvanus, god of the woods and shepherds, as suggested by two altars (*CIL* III 14322, 2-3, from AD 1-300 and AD 1-150) offered by the members of the autochthonous family of the Curticii from Nin (Dubolnić Glavan 2015: 191).

The underwater survey revealed that the embankment, which separated the salt pools from the sea, is 2.5 to 3 m wide. It is built with an accumulation of irregular stones of various dimensions, as observed on other sites of medieval saltpans in Dalmatia. A 1 m wide opening for the sluice gate has been identified at the eastern side of the embankment.

Dating: Roman period?, Middle Ages.

References for saltpans: Šućur, Mustać 2019; Brusić 1973; Raukar 1970; 1977; Dokoza 2015; Dubolnić Glavan 2015.

Vruljine - Sita - Taline Coves, Island of Pašman, Zadar County, HR

Geographical position: 43° 58' N, 15° 20' E, 43° 58' N, 15° 21' E, 43° 57' N, 15° 21' E

Toponymy: *Solniz,* Taline.

On the 1824 Cadastral map of the Habsburg Empire the bottom of Taline Cove is designated as *Solniz*. Taline derives from "talla/tale", the third stage evaporation basins on the saltpans.

Historical sources: Saltpans are attested during the Middle Ages (Dokoza 2015: 92, n. 72).

Archaeological evidence: Roman *villae* and harbor, medieval saltpans and fish traps?

These three coves are located between the two small towns of Neviđane and Barotul, where different structures, which belong to one or more maritime villas, together with piers, were found (see Nedved 1990: 229; Čače 2006: 37).

Vruljine Cove is where the beach of Neviđane is located. The cape of S. Mihovil separates Vruljine Cove from Sita Cove: here, close to the local cemetery, a Roman pier was found, probably connected to a nearby Roman estate (Nedved 1990: 229).

Sita Cove is located by the Mrljane harbor.

Taline Cove is the beach of the small agglomeration of Barotul. The remains of saltpans are located on the eastern side of the cove (Fig. 248, 249), in between the Taline harbor and the outlet of a small seasonal stream (Magaš 2006). Very close to the saltpan remains, at the location called Garma, there was a big Roman estate, to which probably belonged the harbor at the neighboring islet of Garmenjak (Nedved 1990: 229; Čače 2006: 37).

Dating: Roman period?, Middle Ages.

References for saltpans: Magaš 2006; Dokoza 2015.

Fig. 246 Neviđane – Vruljine/Tratica? Cove (Ervin Šilić, Novena doo).

Fig. 247 Sita Cove on the right side of the picture (Ervin Šilić, Novena doo).

Fig. 248 E part of Taline Cove (Ervin Šilić, Novena doo).

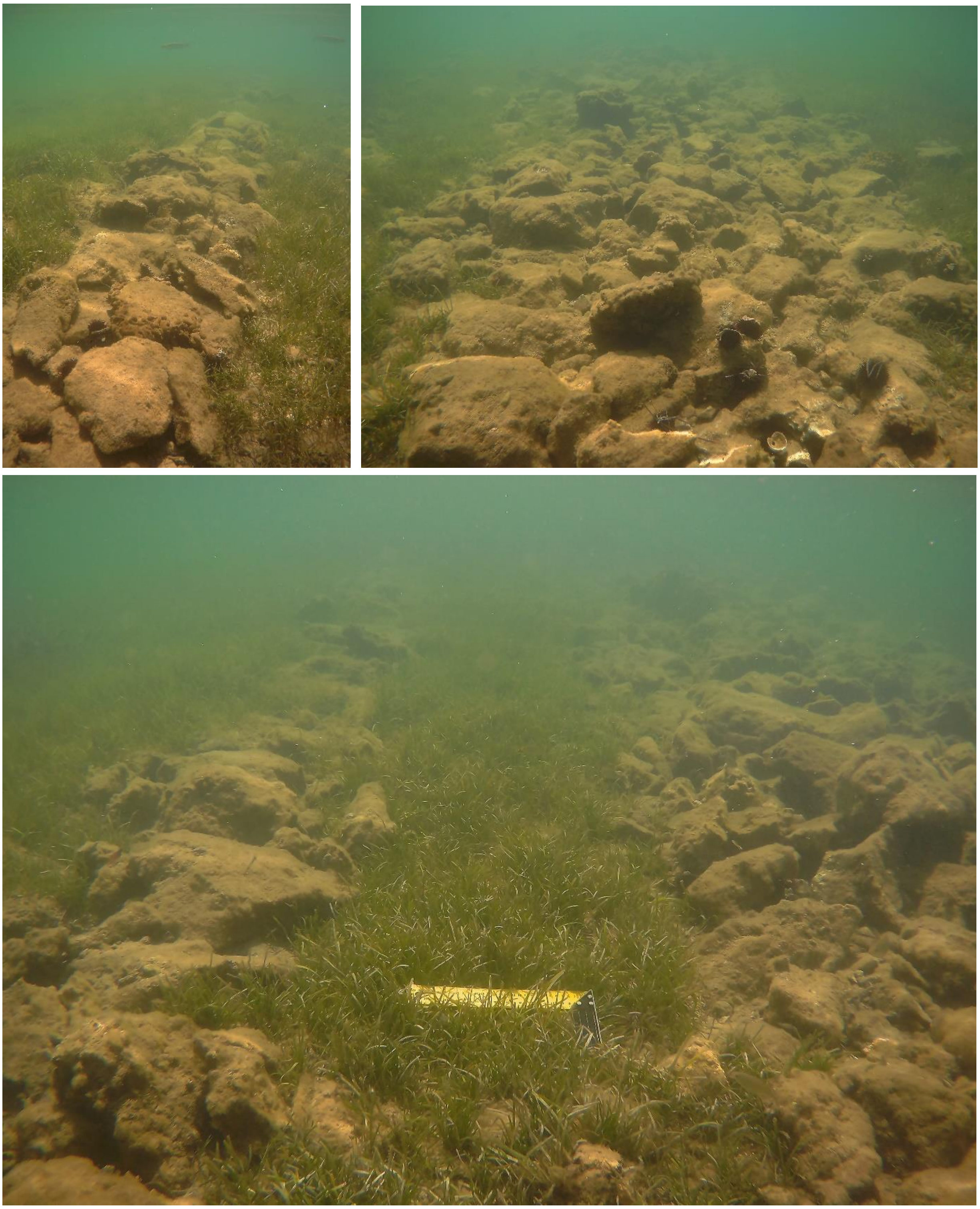


Fig. 249 Underwater walls in Taline Cove (M. Grisonic).

Polačine Cove, Island of Pašman, Zadar County, HR

Geographical position: 43° 56' N, 15° 23' E

Toponymy:

The toponym *Polačine* derives from Lat. *palatium* and usually indicates the presence of an ancient building (Vuletić 2011: 688), in this case the remains of a Roman maritime *villa*.

Historical sources:

Somewhere in Polačine SE of the town of Pašman and close to the sea the church of S. Peter is believed to have been located. The documents attest that this church had saltpans in 1396 (DAZd, ZB, Petrus de Serçana, B III, F 60, fol. 11: "… posite in insula Pissimani prope ecclesiam Sancti Petri ... de trauersa sunt saline…") and still in 1658 (DAZd, SZK, Antonio Zen, 1658-1660., Vol. unico, fol. 36: "A Pasman vicino alla chiesa di San Pietro saline diuerse con un magazeno per seruicio del sale…") (Hilje 2006: 72, n. 94, 95).

Fig. 250 Polačine Cove (Ervin Šilić, Novena doo).

Archaeological evidence: *villa,* harbor.

Polačine Cove is located between Pašman and Kraj. This part of the coast is protected by a series of islets in the central part of the Pašman Channel. Submerged remains of a Roman *villa* are located in the cove. Its walls were probably reused in later medieval times to build saltpans. Enclosures that probably belonged to saltpans span over an area of 500 m in length, for a surface of about 2 ha (Magaš 2006: 19).

Dating: Roman period?, Middle Ages.

References for saltpans: Hilje 2006; Magaš 2006.

Dužica and Tratica Coves, Kraj, Island of Pašman, Zadar County, HR

Geographical position: 43° 56' N, 15° 23' E

Toponymy: Tratica.

Historical sources:

The Grisogono noble family from Zadar had its properties in Kraj. Among them there were saltpans, mentioned in the testament of Maur, son of Franjo Grisogono, from 1370. He wanted the church of S. Duje (S. Domnius) to be built as an ex-voto next to the saltpans (Hilje 1989: 136). His mother Pelegrina Grisogono built it on the property of the family in 1384. She gave these lands to the Franciscans who were expelled from Bosnia, indicating them to build a monastery next to the church in her testament from 1392 (Hilje 1989: 135). The saltpans of the monastery are mentioned in a document from 1404: "…que sunt prope salinas monasterii Sancti Duymi de Pissimano…" (DAZd, ZB, Petrus de Serçana, B I, F II/1, fol. 450; Hilje 2006: 74).

Archaeological evidence: remains of medieval saltpans? (from the satellite pictures), possible connection with the *villa* in Polačine.

In Dužica Cove, just few meters from the shore, a 128 m long and 9-10 m wide submerged wall is visible from the satellite pictures. On the northern side of the wall there is a clear passage in the wall, about 3.5 m wide. The enclosed basin measures 5000 m^2. Right underneath the S. Duje (S. Domnius) monastery, in the western part of Tratica Cove, there is another submerged structure, having the outer wall preserved for about 210 m. Some other partitions can be seen on the internal side of the wall. According to Hilje (2006), these are probably the remains of the saltpans mentioned in the archival documents. If these same locations were already exploited for salt production during the Roman period, they probably belonged to the above mentioned major *villa* in Polačine Cove, about 1.5 km NW.

Dating: Roman period?, Middle Ages.

References for saltpans: Hilje 1989; 2006.

Fig. 251 Dužica and Tratica coves around the Sv. Duje monastery in Kraj on the island of Pašman.

Soline and Kumenat, Biograd-na-Moru, Zadar County, HR

Geographical position: 43°55'47.9"N 15°26'59.5"E and 43°55'21.2"N 15°27'30.4"E

Toponymy: Soline (area south of Biograd), Soline Cove, Slanica Cove.

Historical sources:

Biograd-na-Moru was the capital of the Croatian Kingdom (AD 925-1102). There were at least two salt-making sites in the surroundings of the town, owned by the monastery of SS. Cosmas and Damian/Rogova from Ćokovac on Pašman Island, which was located on the opposite side of the Pašman Channel. One location of the Biograd saltpans was in Sošina (CD VII, 27-31), southeast of the town: in 1291 the abbey leased them to Lucas Mani, citizen of Zadar. The second saltpan site was in Bošana Cove, where the present marina in Biograd is located: in 1362 a peasant of the monastery of Rogova sold one fourth of a saltpan that he owned *ad Belgrad* (Biograd) *in loco vocato Boxana* (CD XIII, 214-215).

Archaeological evidence: *villa*, fish processing site (Kumenat)?, harbor.

For the moment, no archaeological evidence of saltpans has been found in the area of Soline and Kumenat, but the surviving toponymy and the presence of medieval saltpans close to a possible fish processing site from the Roman imperial period, speak in favor of the continuation of exploitation of the same resources in different historical periods. The Roman province of *Dalmatia* had all the natural characteristics to develop an important fish processing industry, of which we are lacking direct archaeological evidence (Borzić 2011: 82; Parica 2017: 93-95; Lipovac Vrkljan, Konestra 2017: 54-55). Kumenat, located south of Biograd-na-Moru, in between Soline Cove and Crvena Luka, could be an exception to this statement. The toponym Kumenat probably derives from the Latin verb *caedo* (cut, grub) and the site is essentially a big grubbed plot, which preserves ruins of various Roman structures, mosaic floors, a cistern, canalization and two piers that were protecting the harbor from the southern winds (Ilakovac 1992; Vrsalović 2011: 96-97; Parica 2017: 93-95, fig. 6-7). In the 1970s Ilakovac identified dozens (the author actually wrote “ten thousand”) square shallow pools hollowed in the coastal rock, organized in an orthogonal grid. Some pools were located underwater. According to him, these pits were filled with fertile humus for the intensive cultivation of vines. The whole area was included in the *fundus* of a Roman estate, active between the 1st and 4th centuries AD

(Ilakovac 1992). The plantation of vines was supposed based on the abundant findings of amphorae internally coated with pitch, which nowadays does not automatically represent a reliable argument for wine content (see Garnier *et al*. 2011; Brughmans, Pecci 2020, with previous bibliography). Suić (1976: 214), Borzić (2011: 82) and Parica (2017: 93-95) identified the pits at Kumenat as remains of *cetariae* or Roman fish salting vats. A picture of the pits at Kumenat published by Ilakovac resembles to fish tanks known in other parts of the Mediterranean (Lagóstena *et al*. 2007; Botte, Leitch 2014; Trakadas 2015).

Systematic archaeological researches are needed to unveil the purpose of this intriguing site, which was located in between Soline and Slanica coves, both deriving from Latin *sal*.

Dating: Roman period?, Middle Ages.

References for saltpans: CD, Ilakovac 1992.

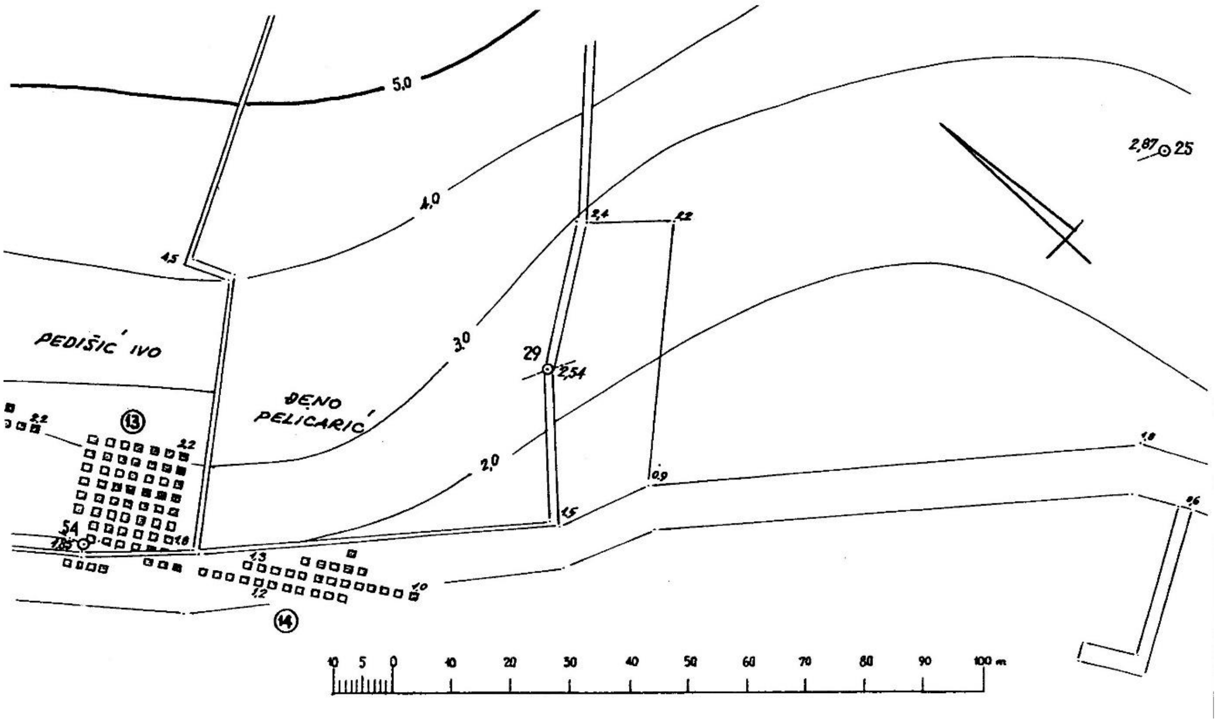


Fig. 252 One section of the site of Kumenat with partially submerged square pits (Ilakovac 1992: 283, fig. 2).

Šipnate, Kornati archipelago, Šibenik-Knin County, HR

Geographical position: 43°50'57.3"N 15°14'51.0"E

Toponymy:

The toponym *Šipnate/Šipnata* indicates brackish water and can be found almost exclusively in the Zadar archipelago (Skok 1950: 60, 136, 139).

Historical sources: not known.

Archaeological evidence: submerged wall, possible connection with the *villa* in Mala Proversa.

The Kornati archipelago gains importance during Roman times, mainly as a fishing area. During the 1st and 2nd centuries AD, a bigger residential-productive complex was built on the passage of Mala Proversa between the Katina Island and the neighboring SE promontory of Dugi otok. On the island of Katina the residential part of the complex was built, with mosaics (Brusić 2005: 94), while the productive part, comprising a cistern and *vivaria*, was built in the narrow passage on Dugi otok, which has a strong current. There was also a *vivarium* on the island of Vela Svršata and another on the islet of Trimulić, at about 2-3 miles NE from the complex of Mala Proversa.

Šipnate Cove is located on the northwestern part of Kornat Island. It is a small cove sheltered from all winds, except from the northern ones. In 1971 a team from the Archaeological Museum of Šibenik surveyed its shallowest part, from the jetties in front of the restaurant until the end of the cove. Immediately south of the jetties there is a 68 m long wall, laying at c. 1 m depth (Gunjaća 1971: 15-17), which closes the cove. There is an opening in the central part of the wall. This wall is probably the separation wall of the saltpan, the foundations of which lay at 2 m depth (Vrsalović 1979: 109; Radić Rossi, Fabijanić 2013: 79). According to the researchers, the blocks of the wall were bound by mortar: they had stated the same for the saltpans in Lavsa, where the recent researches showed instead that the blocks of the walls simply concreted together due to the biological activity in shallow marine water. In Šipnate the archaeological team from 1971 recovered some fragments of 1st century AD (Radić Rossi, Fabijanić 2013: 79) amphorae from the Eastern Mediterranean (Vrsalović 1979: 109).

On the W side of the jetty on the N side of the cove, a mound of stones, probably the remains of a wall, with few Roman ceramic fragments was found. A neck with the handle of an amphora was dated to the 2nd-1st century BC (Gunjaća 1971: 15-17).

The archaeologists from Šibenik presumed that the remains in Šipnate, also due to their similarities with the site in Lavsa, were to be put in relation with an ancient saltpan. Šipnate might have been used as a saltpan in Classical Antiquity and later transformed into a fishing trap (Radić Rossi, Fabijanić 2013: 79). This site probably had some connections with the near Roman *villa* in Mala Proversa (Vrsalović 1979: 109).

Dating: Roman period?, Middle Ages?

References for saltpans: Gunjaća 1971; Vrsalović 1979; Radić Rossi, Fabijanić 2013.

Fig. 253 Šipnate: remains of the submerged wall (https://enavtika.si, accessed 15/12/2019).

Jersani and Hramina Coves, Island of Murter, Šibenik-Knin County, HR

Geographical position: 43°49'52.1"N 15°34'31.7"E and 43°49'21.1"N 15°35'24.9"E

Toponymy: /

Historical sources:

The abbot Alberto Fortis wrote about the tunas that used to pass in the waters around the island of Murter: many of them lost their way and stayed also in the winter time in the shallow waters close to the *Ràmina* hamlet, where in former times there were saltworks (Fortis 1774: 147). *Ràmina* can be identified with the present Hramina Cove in front of the town of Murter, the most urbanized cove on the island.

Saltpans around the Seremiz Island are mentioned for the first time in 1332. The Venetian Seremiz/Srimaz or Croatian Srimač was the old name of Murter Island (Juran 2010: 63). The noble ser Francisco de Lompre from Zadar fought against the Šibenik Commune for these saltpans (Juran 2010: 64-65). Another document from 1407 attests that the holders of Murter divided the saltpans on the island in two parts: the first one comprised those in Jersani Cove and the area around the two islets of Veliki and Mali Vinik (*saline in Iarsan et saline posite in Vinich Magno et Vinich Paruo*), while the second part comprised the salpans of Luka, Črno and Betina or Butina (*saline posite in Srimaz in Lucha et in Zerno et Betin*). The location of Črno (*Zerno*) remains unknown, while Betin could stand for the present Betina or Butina. In conclusion, most saltpans were located in the northern part of the island: in Jersani Cove and along the coast to the southwestern or southern (Luka) and then southeastern (Butina) part of Hramina Cove (Juran 2010: 64, 79). The saltpans on Murter are mentioned also in various documents from 1419-1429, where the saltpan holders were obliged to invest in their reparation. A document from 1450 still mentions the saltpans in Jersani Cove (*salinas vocatas Iarsam*) (Juran 2010: 64). Apparently, in the location known as Pod Butinom in the SE part of Hramina Cove the remains of salt pools could be seen before the coastal land reclamation occurred (Kulušić 2006: 197; Juran 2010: 65).

Archaeological evidence: archaeological remains of medieval saltpans, nearby *Colentum*, tuna fishing.

Fig. 254 *Places of salt production on the island of Murter.*

Presumable saltpans from Classical Antiquity were situated next to *Colentum*, a Roman settlement located on the Gradina Promontory in between the two towns of Murter and Betina, north of Hramina Cove and facing the three islets of Tegina, Mali and Veliki Vinik. *Colentum* was, together with Zadar, one of the most important late Liburnian settlements in the southern Liburnian region (Kurilić 2010: 35). A village on the Gradina Promontory probably existed from the 11th century BC and before the transformation into a Roman *civitas peregrina* it grew into a big settlement, which had contacts with *Daunia* and other western Adriatic regions. The Roman settlement (end of the 1st century BC - 6th century AD), grew on the western side of the promontory, including a harbor, coastal operational structures, luxurious coastal villas, numerous buildings set on various uphill terraces, roads, ancient cisterns and a necropolis. Archaeological researches were numerous (see Kurilić 2010: 38-43) and this area is today converted into an archaeological park and beach. The main harbor of *Colentum* was probably in the well protected Hramina Cove, the present-day marina of the town of Murter (Kurilić 2010: 45). During the 6th century, an early-Christian church existed in *Colentum* and life continued until the middle of the 7th century (Kurilić 2010: 47-48).

The most numerous saltpans were most likely those who can still be seen in the adjacent Jersani bay, to the NW.

Dating: Roman period?, Middle Ages.

References for saltpans: Fortis 1774; Kulušić 2006; Juran 2010.

Salona, Split-Dalmatia County, HR

Geographical position: ?, 43°31'57.6"N 16°28'36.4"E (presumed)

Toponymy: /

Historical sources:

Salona maybe preserved some of her ancient saltpans during the Middle Ages: in 1080, Petar Črne (*Petrus Zerni*), a big land owner, built the monastery and church of S. Peter in Selo, giving them multiple goods, among which there was a property in *Salona* and a valley, which bordered with the sea and the saltpans. All this bordered with *Satilia* and all the goods of the monastery extended until a place called *Saline*. The toponymy does not prove that saltpans were still exploited during the 11th century, but the document tells us that Črne acquired all the lands for the monastery from different sellers, paying them with money, wheat, barley and salt (Rački 1877: 127-137). According to Hocquet, Črne was most probably an owner of saltpans rather than a salt merchant, and there were most likely the saltpans of ancient *Salona* that procured him an important part of his revenues (Hocquet 1978: 85-86).

Archaeological evidence: /

Dating: Roman period?, Middle Ages.

References for saltpans: Rački 1877; Hocquet 1978.

Soline, Island of Mljet, Dubrovnik-Neretva County, HR

Geographical position: 42°46'03.1"N 17°23'07.6"E

Toponymy: Soline, Soline channel and cove, Solinska glavica hill.

Historical sources:

From the 13th century, smaller quantities of salt were being produced next to the Benedictine monastery on the island of S. Mary on the Lake (Sv. Marija na jezeru), present Mljet Island (Taljeran 1935: 89; Di Vittorio 1981: 292; Krsić 2005).

Archaeological evidence: possible connection with the *villa* in Polače.

Fig. 255 Possible saltpans on the island of Mljet.

Mljet is located in a very important strategic position: it is the southernmost Dalmatian island on the eastern Adriatic seafaring route. It is provided with safe harbors and it is the last outpost before sailing towards the Pelješac Channel and the important markets on the Neretva River.

Soline Channel is located in the NW part of Mljet Island, 2 km south of the imperial *villa* of Polače, which in AD 489 Odoacer (as the legitimate successor of the Roman emperors), donated together with the entire island, to the *comes Pierius*, in repayment of a loan (Begović-Dvoržak 2003). The *villa* has two phases: the first one, in diversified blocks, dates back to the early imperial period, while the late antique (5^{th}-6^{th} century) *villa* has a cross-shaped plan, with polygonal towers at its angles. The late antique fortified settlement that developed around the *villa* had one of its two harbors in Soline Cove.

Dating: Roman period?, Middle Ages.

References for saltpans: Begović-Dvoržak 2003.

Conclusions

Salt has been important to humanity from all ages. Along all Mediterranean coasts most of salt was produced in artificially built solar evaporation saltpans. Although salt is vital for all human and animal beings and constituted an essential ingredient for the preservation of foodstuffs, granting their transportation and commerce, saltpans are one of the less studied marine exploitation facilities. This is due to their extremely perishable nature: they are built mostly of mud, and to a lesser extent of stone and wood, they need constant maintenance for proper functioning and have to deal with the fury of severe weather and surges.

The much better-known fish processing sites of the Mediterranean (Lagóstena *et al*. 2005; Botte 2009; Marzano 2013; Botte, Leitch 2014; Trakadas 2015), which needed big amounts of salt, had direct relationships with salt-making areas. Studies of the connections between saltpans, fish processing workshops and fishing spots should be further developed in the future. Roman fish salting and processing activities in *Histria* and *Dalmatia* are still unknown, but new evidence is gradually emerging, along with the progress in ceramological studies of locally produced, supposably fish amphorae.

Salt was not only obtained in successive-basin solar evaporation saltpans, but it was also collected on coastal rocks and other shallow surfaces by the sea (the so-called primitive saltpans), where salt formed naturally by the action of the sun and winds. On the eastern Adriatic coast the waves of the strong northeastern *bura* and the southeastern *jugo* winds bring seawater that accumulates on natural cracks, where it evaporates, leaving salt crystals behind (Skračić 1996). Pliny's discussion on salt (*Nat. Hist.*, XXXI, 73-105) indicates the coexistence both of natural and artificial exploitation of salt along the Mediterranean shores (Morère Molinero 2008: 369). In fact, peasants and fishermen continued to exploit this naturally available resource that they collected along the shore until several decades ago. Therefore, salt could be harvested from several kinds of salt sources, not exclusively from artificially built saltpans, although the latter constituted the main source of salt in coastal areas.

The remains of saltpans along the eastern Adriatic coast were built in flat muddy coves, located mainly on the western Istrian coast, on the northern Adriatic islands of Krk, Rab and Pag, in the northern part of Dalmatia (mainland and islands, where they were most numerous), in the

Gulf of Kaštela in central Dalmatia and on the Pelješac Peninsula in southern Dalmatia. Archival documents attest the existence of saltpans at these locations starting from the Early Middle Ages. During the High and Late Middle Ages, the city of Zadar possessed many saltpans, located both on the mainland and on the numerous islands of its archipelago (Raukar 1977; Hocquet 1978: 83-85; Grgin 1996; Dokoza 2015), while the saltpans of Šibenik were built in the coves and lakes south of the city (Kolanović 1995: 190-227; Brakus 2019). In the same period and later, the cities on the central and southern Dalmatian coast – Trogir, Split and Dubrovnik – produced salt in the marshy coastal areas in their neighborhoods (Hocquet 1978: 85-87). The central and southern Dalmatian islands, which lack terrains suitable for salt exploitation, were producing very little salt. During Roman times, Zadar was the colony of *Iader*, while Šibenik, founded by the Croats during the Middle Ages, was probably included in the territory of ancient *Scardona*, present Skradin. Trogir, Split and Dubrovnik and their territories were part of the *agri* of the ancient colonies of *Salona*, *Narona* and *Epidaurum*. At the same time, numerous villas, not necessarily included in the *agri* of the urban settlements, were widespread in the territory and produced foodstuffs and other goods for their own needs and for trade. The ancient Romans were known for their capacity of obtaining the maximum from the available natural resources, choosing distinctive areas for specific agricultural and marine exploitation, among which we can include salt making. The continuity of exploitation of the same coves for salt production from Classical Antiquity to the Middle Ages based on toponymy has already been evoked by numerous scholars (Skok 1950; Zaninović 1991; Matijašić 1998; Šimunović 2005), as well as their installation in the same locations through centuries (Zaninović 1991; Auriemma 2016). One of the most significant examples of exploitation of marine resources from Classical Antiquity until the Modern era is Fizine on the Slovenian coast, in between Piran and Portorož, where a Roman settlement and fishpond are located next to the 19th century salt warehouses (Gaspari *et al*. 2007; Auriemma 2016). The Makirina Cove case study shows that combined archival, cartographic, toponymic, archaeological and geoarchaeological researches can prove the continuity of salt production at the same locations from Classical Antiquity to the Middle Ages and later.

The remains of saltpans along the eastern Adriatic coast are nowadays partially submerged because of the rise in sea levels. In Croatia, they are located at a maximum depth of -1.5 m. They constitute of large dry-stone separation walls (embankments) that were closing entire or parts of larger shallow coves, provided with suitable flat-bottom muddy substratum. This was employed to build the bottoms of the salt pools, their delimiting dikes and the channels, which were dug directly in the sediment. Inside the enclosed space in between the saltpans' separation wall and the coast, various parallel or perpendicular walls can be found, some of which constituted the limits of channels. Certain channels were used to bring seawater in the saltpans and to move the brine among various compartments, while others drained rain and runoff water from the salt pools back to the sea. Various saltpans preserve the openings for sluice gates that were introducing the seawater in the saltworks and regulating the water flow among the various salt basins. Certain saltworks still preserve well-delimited salt pools that are visible from the aerial pictures (in the case of the medieval saltpans, which are located at lower depths) or on the field (it is the case of the Roman saltpans in Bijeca and possibly in Pakoštane as well). Remains of wooden poles and planks were also found at several sites, as well as mortar layers in Makirina.

Aerial pictures can identify the remains of medieval or more recent saltpans (although most of them were abandoned because of the Venetian monopoly at the beginning of the 15th century), which are located at lower depths (-0.3 to -0.8 m). Saltpans from Classical Antiquity, which were often probably located at the same spots, can only be identified with archaeological fieldwork. Archaeological investigations of the saltpans along the Croatian coast have shown a difference in building techniques of the walls and embankments, depending on the historical period in which they were built. The medieval walls were dry-walls, built with a disordered assemblage of calcareous rocks of various dimensions. Roman saltpans could have included dry-walls and walls bound by mortar: in both cases, they were built with blocks that had more regular shapes and that were carefully assembled in various rows.

As highlighted by Carusi (2008; 2018), before the monopolisation of salt production, which began during the Middle Ages and was consolidated after the 15th century Venetian conquest, in Classical Antiquity saltpans were probably widespread along all Mediterranean coasts, including the Eastern Adriatic, and belonged to urban settlements, *villae* or fish-salting facilities. On the eastern Adriatic coast, the latter two were often closely related, as it seems they quite commonly shared the same owner.

Various possible salt making sites from Classical Antiquity were identified along the eastern Adriatic shore. Saltpans in Bijeca Cove seem to have been complementary for the needs of preservation of olives and maybe additional marine exploitation activities. Similarly, channels paved with wooden planks instead of simply being dug in the ground in the site of Pakoštane hint to the fact that salt exploitation might have coexisted with additional aquaculture activities. Other sites seem to have supplied salt for fish processing: it is the case of Jernejev zaliv/San Bartolomeo Cove (medieval saltpans and nearby *vivarium*), Velike and Male Soline in Črvar Bay (salt-related toponymy, nearby *vivaria*, fish processing vats?, locally produced fish amphorae?, purple dye workshop), Stara Novalja and/or Caska on the island of Pag (medieval saltpans in Stara Novalja, traditional fishing activities, remains of coastal structures covered in *opus signinum*, presumable local amphorae for fish products in Caska) and Soline Cove on S. Klement Island (salt-related toponym, medieval saltpans, possible fish processing vats inside the Roman *villa*). The possible Roman saltpans in Soline Bay on the island of Krk (at present the medieval saltpans' separation wall has been identified) were located not far from the Roman ceramic kiln in S. Peter's Cove on the island and the pottery workshop in Crikvenica on the mainland, which presumably produced amphorae for fish sauces. The shallow and clayey Soline Bay was the closest larger surface suitable for salt production in the wider area around Crikvenica.

The progress of the typo-chronological and archaeometric studies of locally produced types of amphorae could reveal indirect data on salt production. In effect, it has been postulated that three locally produced types of amphorae (the small-size Dressel 6B amphorae from Loron, the Crikvenica fish amphorae and the Caska 1 type amphorae) possibly contained fish sauces. The distribution of these and/or other (if the proposed hypotheses will turn out to be wrong) not yet identified fish amphorae, could help locate the production sites and reveal the distribution patterns of the fish products, which required considerable amounts of salt and with whom salt probably shared the same markets.

An interesting discovery highlighted by this study is that one path (embankment) inside the still-working saltpans of Ston can be identified with the boundary of the behind centuriated field, which was included in the territory of the colony of *Narona*. A similar situation, with internal paths and channels that follow the directions of the *limites* of the *ager centuriatus*, occurs in Cervia. This parallel, although it does not prove the existence of Roman saltpans in Ston, nevertheless suggests that these might had been located inside the centuriation grid and that saltpans might had been assigned to colonists as any other agricultural land.

For decades scholars have evoked the close relationship between saltpans and Roman villas, but there were not enough elements to prove it. This relationship has been shown in Makirina Cove (Šibenik-Knin County), a site included in the project *"Saltpans as Anthropogenic Landscape Intervention, a New Multidisciplinary Approach for Studying Sea-level Changes"*. The exceptionally preserved remains of the saltpans in Makirina, a part of which has been dated with radiocarbon to the 5th/6th century AD, are located just in front of a Roman *villa*, which has been in use from the beginning of the 1st century AD to the first half of the 6th century. The wooden timbers that have been employed in the construction of the saltpans have been cut more or less at the same time when the early-Christian buildings were erected on the spot of the preceding *villa* from the Early Imperial period. In support of the radiocarbon dating, the sea-level studies and the mortar analyses that have been performed on the site, the separation wall of the ancient saltpans in Makirina Cove can also be dated linguistically before the 7th century AD.

The site of Makirina also proves the continuity of use of the saltpans at least from Late Antiquity to the Middle Ages, as ascertained by archival documents, but also by the archaeological remains on the site, which find direct parallels with other medieval salt-making complexes on the eastern Adriatic coast. Makirina Cove has only been systematically surveyed: I believe that with the continuation of research, which will hopefully involve a project with more resources, this site will reveal new interesting data on ancient salt production.

Another achievement of the archaeological researches, included in the above-mentioned project, has been the understanding that the saltpans on Lavsa Island on the Kornati archipelago are the result of a unitary plan and that they were probably constructed during the second half of the 14th century, as suggested by the archival documents and the sea-level studies. The dating of these saltpans to Roman times, firstly proposed by D. Vrsalović in 1979, still finds place in numerous scientific and non-scholarly publications. Although nearby concentrations of Roman ceramics show the frequentation of Lavsa Cove in earlier periods, we can only suppose that Romans started to produce salt on the island on the same spot where this was taking place in the Late Middle Ages.

The archaeological surveys performed at various saltpan sites has been challenging, because the methodology of underwater suveys needed to be adapted to the very shallow environment (-0.3 to -1.5 m of depth). The use of tanks was very limited, most of the time snorkeling surveys were performed. Buoys were used to move the measuring, drawing and photo equipment in the very shallow parts, to prevent to compromise the delicate underwater visibility in such sites, which can quickly diminish after the muddy sea bottom has accidentally been touched.

Although the present research focuses on the period of Classical Antiquity, it has shown great potential for the development of a diachronic approach on the study of salt history, with a better understanding of the salt production techniques that might also shed new light on the hypothetical quantities of salt produced during the past centuries. This would infer wider economic implications of this vital resource. I am convinced that archaeological fieldwork at medieval salt production and trade sites could provide new important contributions, completing the picture denoted from historical studies. Saltworks along the eastern Adriatic coast left several traces in the archaeological record. In many cases the massive separation walls stayed in situ, also because they were reused as fishing traps after the Venetians imposed the monopoly on salt in the region, and they are well visible in the landscape and from the aerial pictures. These installations have differently shaped plans, which would deserve the creation of a typology that would be comparable with similar complexes in the rest of the Mediterranean.

On the eastern Adriatic coast, quite a few sites have preserved traces of ancient and medieval saltworks and have the potential of narrating more about the history of this essential economic activity. Further research in Makirina Cove and other promising sites, compared with the data from currently excavating remains in Bijeca Cove in Istria, will hopefully bring new elements to understand the ancient salt production techniques in the Adriatic Sea and the Mediterranean.

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AE – L’Année épigraphique, Presses Universitaires de France, 1888–

CD – *Codex diplomaticus regni Croatiae, Dalmatiae et Slavoniae,* 14 vol., 1903-1990, Zagreb.

CIL – *Corpus Inscriptionum Latinarum*, Berlin-Brandenburgische Akademie der Wissenschaften, 1863–

CIS – *Corpus Inscriptionum Semiticarum,* Paris 1881–

EAA – Enciclopedia dell'Arte antica classica e orientale, Treccani, 1958-1977 (https://www.treccani.it/enciclopedia/elenco-opere/Enciclopedia_dell%27_Arte_Antica)

EDCS – Epigraphik-Datenbank Clauss-Slaby (http://www.manfredclauss.de)

EDR – Epigraphic Database Roma (http://www.edr-edr.it/default/index.php)

HD – Epigraphische Datenbank Heidelberg (edh-www.adw.uni-heidelberg.de)

I. *Ephesos* Ia – H. Wankel, *Die Inschriften von Ephesos,* Ia, Bonn, 1979.

IG – *Inscriptiones Graecae,* Berolini 1903–

IP – F. Hiller von Gaertringen, *Inschriften von Priene*, Berlin 1906.

LIMC – *Lexicon Iconographicum Mythologiae Classicae* (http://www.limc-france.fr/)

LLMEI – *Lexicon latinitatis medii aevi Iugoslaviae*, Zagreb, 1973-1978.

SupplIt – *Supplementa italica*. Nuova serie, Roma, Quasar, 1981-

ThesCRA - Thesaurus cultus et rituum antiquorum, Paul Getty Museum, Los Angeles, 2004-2014.

TLL – *Thesaurus Linguae Latinae* (https://tll.degruyter.com)

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Tabula Peutingeriana:

https://www.tabula-peutingeriana.de/index.html

Sečovlje saltpans:

https://www.kpss.si/en/the-park

https://pomorskimuzej.si/en/the-museum-of-salt-making

https://www.soline.si/en

Strunjan saltpans:

https://parkstrunjan.si/en/experience/saltpans/

Pag saltpans:

https://solana-pag.hr/?lang=en

http://pag-gradzdravlja.eu/realizirani-projekti/ljecilisni-centar-lokunja.html

Nin saltpans:

https://www.solananin.hr/en/home/

Ston saltpans:

https://www.solanaston.hr/en/

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Abstract

SALT EXPLOITATION AND TRADE IN THE EASTERN ADRIATIC IN CLASSICAL ANTIQUITY

Keywords: salt, saltpans, Eastern Adriatic, *Histria*, *Dalmatia*, Classical Antiquity

This work summarizes the available data and provides new information on salt production and trade on the eastern Adriatic coast in Classical Antiquity. In Roman times this comprised the Istrian Peninsula, most of which was part of the *Regio X. Venetia et Histria*, and the northern coastline of the province of *Dalmatia*. Along the eastern Adriatic coast most salt was produced in artificially built solar evaporation saltpans. Due to their extremely perishable nature and because they are located in the tidal zone or at very shallow depths, saltpans are one of the less studied marine exploitation constructions. Yet on the eastern Adriatic and namely the Croatian shore, due to the still low anthropization of large parts of the coast, many archaeological remains of historical saltpans survive to the present day. This makes the Croatian coast a privileged location for studying the history of salt production in the Mediterranean. Since the relative sea level in this part of the Adriatic has risen over the past 2,000 years, most remains of antique coastal structures, including saltpans, are nowadays partially submerged and located at the maximal depth of -1.5 m below relative sea level.

The present study offers new perspectives and contributions to the history of salt and ancient salt-making techniques that originate from personal archaeological field research carried out independently and in cooperation with different institutions, both on land and underwater. It includes a methodology to identify archaeological sites of ancient saltpans and illustrates the recurrent artifacts that are present on these sites. It also shows the main differences between the Roman and medieval saltpan structures, as well as the continuity of exploitation of the same salt production sites during different chronological periods, an example of which is Makirina Cove in Šibenik-Knin County, where salt was produced at least from Late Antiquity through the Middle Ages.

Sažetak

PROIZVODNJA I TRGOVINA SOLJU NA ISTOČNOM JADRANU U ANTICI

Ključne riječi: sol, solane, istočni Jadran, *Histria, Dalmatia,* antika

Ovaj rad želi doprinijeti gospodarskoj povijesti istočnojadranskog područja u antici, s time da pokušava nadopuniti poznavanje proizvodnje i trgovine solju, koja je u svim narednim povijesnim razdobljima imala golemu važnost. Proizvodnjom i trgovinom solju u srednjem i novovjekovnom razdoblju na istočnom Jadranu bavili su se brojni eminentni znanstvenici: Zlatko Herkov (1971), Jean-Claude Hocquet (1978-1979 i drugi), Tomislav Raukar (1970; 1977; 1981), Ante Usmiani (1984), Ivan Erceg (1977; 1981), Josip Kolanović (1995), Šime Peričić (2001; 2005), Serđo Dokoza (2015), Bruno Brakus (2019) i drugi. Međutim, vrlo malo se zna o eksploataciji soli u antici. Jedini istraživač koji je pokušao proučiti povijest soli na ovim prostorima u antici je Marin Zaninović (1991). S obzirom da je proizvodnja soli bila jedan od najvažnijih izvora prihoda ovog kraja u kasnijim povijesnim razdobljima, vrlo je moguće da je imala primarnu važnost već u antici, ako ne i ranije. Razumno je pretpostaviti da je u mnogim slučajevima postojao kontinuitet eksploatacije solnih resursa od antike do srednjeg vijeka. To je razvidno na nekoliko lokaliteta solana, gdje se mogu primijetiti barem dvije kronološke faze (vidi Pogl. 3 i 4). Radi povijesne važnosti soli na ovim prostorima, nedostatak podataka o antičkom solarstvu spriječava nas da uobličimo širu sliku o gospodarstvu cijele antičke Istre i Dalmacije.

Rad sažima dostupne podatke o proizvodnji soli na istočnojadranskoj obali u antičko doba, predstavljajući nove poglede i hipoteze, koji proizlaze iz osobnih opservacija tijekom terenskih istraživanja provedenih samostalno i u suradnji s institucijama, kako na kopnu tako i pod morem. Terenska istraživanja djelomično su uključena u projekt “Solane kao antropogena krajobrazna intervencija – novi multidisciplinarni pristup proučavanju promjena razine mora”, kojeg su 2018. započeli Hrvatski geološki institut (HGI) i Sveučilište u Haifi, u suradnji sa

Sveučilištem u Zadru, Zagrebu i Padovi, koji sada uključuje i doprinose znanstvenika iz drugih međunarodnih institucija (Bechor *et al.* 2020; 2023; Bechor *et al.*, predano). Rad predstavlja metodologiju identifikacije arheoloških nalazišta solana, te ilustrira tipične artefakte prisutne u površinskim i kulturnim slojevima. Prikazuje i glavne razlike između rimskih i srednjovjekovnih struktura solana, kao i kontinuitet eksploatacije istih lokacija za proizvodnju soli tijekom različitih kronoloških razdoblja.

S obzirom na još uvijek nisku razinu utjecaja antropogenog faktora na području hrvatskog priobalja, mnogi kopneni i podvodni arheološki ostaci povijesnih solana opstali su do danas, što hrvatsko priobalje čini izuzetnim mjestom za proučavanje povijesti proizvodnje soli u cijelom Sredozemlju. Stoga je fokus ovog rada eksploatacija soli. Podaci koji bi mogli upućivati na trgovinu solju na istočnom Jadranu u antici toliko su oskudni da nam dopuštaju samo osnovne pretpostavke i potragu za analogijama u kasnijim razdobljima, kada se ta pitanja mogu djelomično rasvijetliti uz pomoć arhivskih dokumenata.

Duž istočnog Jadrana i mediteranske obale većina soli proizvedena je u umjetno izgrađenim solanama. Sol je po mnogočemu značajna za sva ljudska i životinjska bića – bila je neophodan sastojak za očuvanje namirnica te je omogućavala njihov prijevoz i trgovinu. Unatoč važnosti soli u svakodnevnom životu, solane su jedan od slabije proučavanih priobalnih proizvodnih objekata. Razlog je gradnja neizdržljivim materijalima: solane su većinom izgrađene od blata, u manjoj mjeri od kamena i drva, a potrebno ih je stalno održavati kako bi odoljele vremenskim nepogodama te snazi udara valova.

Učestalija su arheološka nalazišta radionica za preradu ribe u Sredozemlju (Lagóstena *et al.* 2005; Botte 2009; Marzano 2013; Botte, Leitch 2014; Trakadas 2015), koja su koristila velike količine soli i bila u izravnoj vezi sa solanama. Poveznice među solanama, radionicama za soljenje i preradu ribe te ribolovnim lokacijama trebalo bi u budućnosti dodatno istražiti. Rimske radionice soljenja i prerade ribe u antičkoj Istri i Dalmaciji još uvijek su nepoznate, ali postupno se pojavljuju novi dokazi, paralelno s napretkom keramoloških istraživanja lokalno proizvedenih amfora za soljenje ribe.

Ostaci solana uz hrvatsku obalu jedinstveni su u Sredozemlju. Građene su u plitkim i muljevitim uvalama, smještenim najčešće na zapadnoj istarskoj obali, na sjevernojadranskim otocima Krku, Rabu i Pagu, na obali i otocima sjevernog dijela Dalmacije, u Kaštelanskom zaljevu, te u južnoj Dalmaciji na poluotoku Pelješcu. Arhivski dokumenti svjedoče o postojanju solana još od ranog srednjeg vijeka. Tijekom visokog i kasnog srednjeg vijeka grad Zadar je posjedovao mnogo solana, smještenih na kopnu i na brojnim otocima njegovog arhipelaga (Raukar 1977; Hocquet 1978: 83-85; Grgin 1996; Dokoza 2015), dok su šibenske solane građene u uvalama i jezerima južno od grada (Kolanović 1995: 190-227; Brakus 2019). U istom su razdoblju, s nastavkom korištenja u novom vijeku, gradovi srednje i južne Dalmacije – Trogir, Split i Dubrovnik – proizvodili sol u susjednim močvarnim obalnim područjima (Hocquet 1978: 85-87). Sol se znatno manje proizvodila na otocima srednje i južne Dalmacije, kojima nedostaju tereni pogodni za eksploataciju soli. U rimsko je doba Zadar bio kolonija Iader, dok je Šibenik, kojeg su osnovali Hrvati u srednjem vijeku, vjerojatno bio uključen u područje antičke Scardone, današnjeg Skradina. Trogir, Split i Dubrovnik i njihova područja bili su dio *ager*-a antičkih kolonija Salone, Narone i Epidauruma. Stari su Rimljani bili poznati po tome što su izvlačili maksimalnu iskoristivost iz raspoloživih prirodnih resursa: za specifičnu poljoprivrednu i pomorsku eksploataciju, među koje spada i proizvodnja soli, birali su posebna prigodna područja. O kontinuitetu iskorištavanja istih uvala za proizvodnju soli od antike do srednjeg vijeka na temelju toponimije već su upozorili brojni stručnjaci (Skok 1950; Zaninović 1991; Matijašić 1998; Šimunović 2005), kao i na njihovo postojanje na istim lokacijama kroz stoljeća (Zaninović 1991; Auriemma 2016). Jedan od najznačajnijih primjera iskorištavanja morskih resursa od antike do novoga vijeka su Fizine na slovenskoj obali, između Pirana i Portoroža, gdje se uz skladišta soli iz 19. stoljeća nalazi rimsko naselje i ribnjak (Gaspari *et al*. 2007; Auriemma 2016). Studija slučaja uvale Makirina kod Tisna (Šibensko-kninska županija) pokazuje da se kombiniranim arhivskim, kartografskim, toponomastičkim, arheološkim i geoarheološkim istraživanjima može dokazati kontinuitet proizvodnje soli na istoj lokaciji od antike do srednjeg vijeka te kasnije.

Ostaci solana uz istočnu obalu Jadrana danas su djelomično potopljeni zbog porasta razine mora. U Hrvatskoj se nalaze na maksimalnoj dubini od 1,5 m. Sastoje se od velikih suhozidnih pregrada, tj. nasipa, koji su zatvarali cijele ili dijelove većih plitkih uvala, opremljenih odgovarajućom muljevitom podlogom ravnog dna. Ta je podloga korištena za izgradnju dna slanih bazena, njihovih graničnih nasipa i kanala, koji su iskopani izravno u sedimentu. Unutar omeđenog prostora kojeg stvara pregradni zid solane nalaze se različiti paralelni ili okomiti zidovi od kojih neki predstavljaju granice kanala. Neki su kanali korišteni za dovođenje morske vode u solane i za premještanje salamure u različite odjeljke, dok su drugi odvodili kišnicu i oborinske vode iz slanih bazena natrag u more. Na različitim solanama sačuvani su otvori za zapornice koje su uvodile morsku vodu u solanu i regulirale protok vode među raznim slanim bazenima. Pojedine solane još uvijek čuvaju dobro omeđene solne bazene koji su vidljivi iz zračnih fotografija (u slučaju srednjovjekovnih solana, koje se nalaze na nižim dubinama) ili na terenu (u slučaju rimskih solana u Bijeci, a možda i u Pakoštanima). Na nekoliko lokaliteta pronađeni su ostaci drvenih pilona i dasaka, kao i slojevi žbuke u Makirini.

Iako je većina solana napuštena početkom 15. stoljeća zbog mletačkog monopola, na zračnim snimkama mogu se prepoznati ostaci, vidljivi jer se nalaze na manjim dubinama (-0,3 do -0,7 m). Solane iz antičkog doba, koje se često nalaze na istim mjestima, mogu se identificirati samo arheološkim terenskim radom. Arheološka istraživanja solana na hrvatskoj obali pokazala su da su u solanama srednjovjekovni zidovi suhozidi građeni nepravilnim vapnenačkim kamenom različitih dimenzija. U rimskim solanama mogu postajati suhozidi i zidovi vezani žbukom: u oba slučaja građeni su blokovima pravilnijih oblika koji su pažljivo slagani u različite redove.

Desetljećima su znanstvenici predlagali hipotezu o povezanosti solana i rimskih vila, ali nisu imali dovoljno elemenata koji bi to dokazali. Taj je odnos očit u uvali Makirina, lokalitetu koji je uključen u multidisciplinarni projekt "Solane kao antropogena krajobrazna intervencija". Izuzetno očuvani ostaci solane u Makirini, nalaze se neposredno ispred rimske vile (početak 1. st. - prva polovica 6. st. po Kr.). Dio solane radiokarbonski je datiran u 5. ili 6. st. po Kr.: drveni elementi korišteni u gradnji solana vjerojatno su posječeni istovremeno kada su sagrađeni ranokršćanski objekti na mjestu rimske vile iz carskog razdoblja na obali. U prilog radiokarbonskom datiranju, studijama razine mora i analizama žbuke koji su obavljeni na nalazištu, vanjski nasip drevnih solana u uvali Makirina također može se lingvistički datirati prije 7. st. po Kr. Lokalitet Makirina također dokazuje kontinuitet korištenja solane sigurno od razdoblja kasne antike do srednjeg vijeka, što potvrđuju arhivski dokumenti i arheološki ostaci na lokalitetu. Strukture vidljive na terenu omogućuju povlačenje izravnih paralela s drugim srednjovjekovnim solanama na istočnojadranskoj obali.

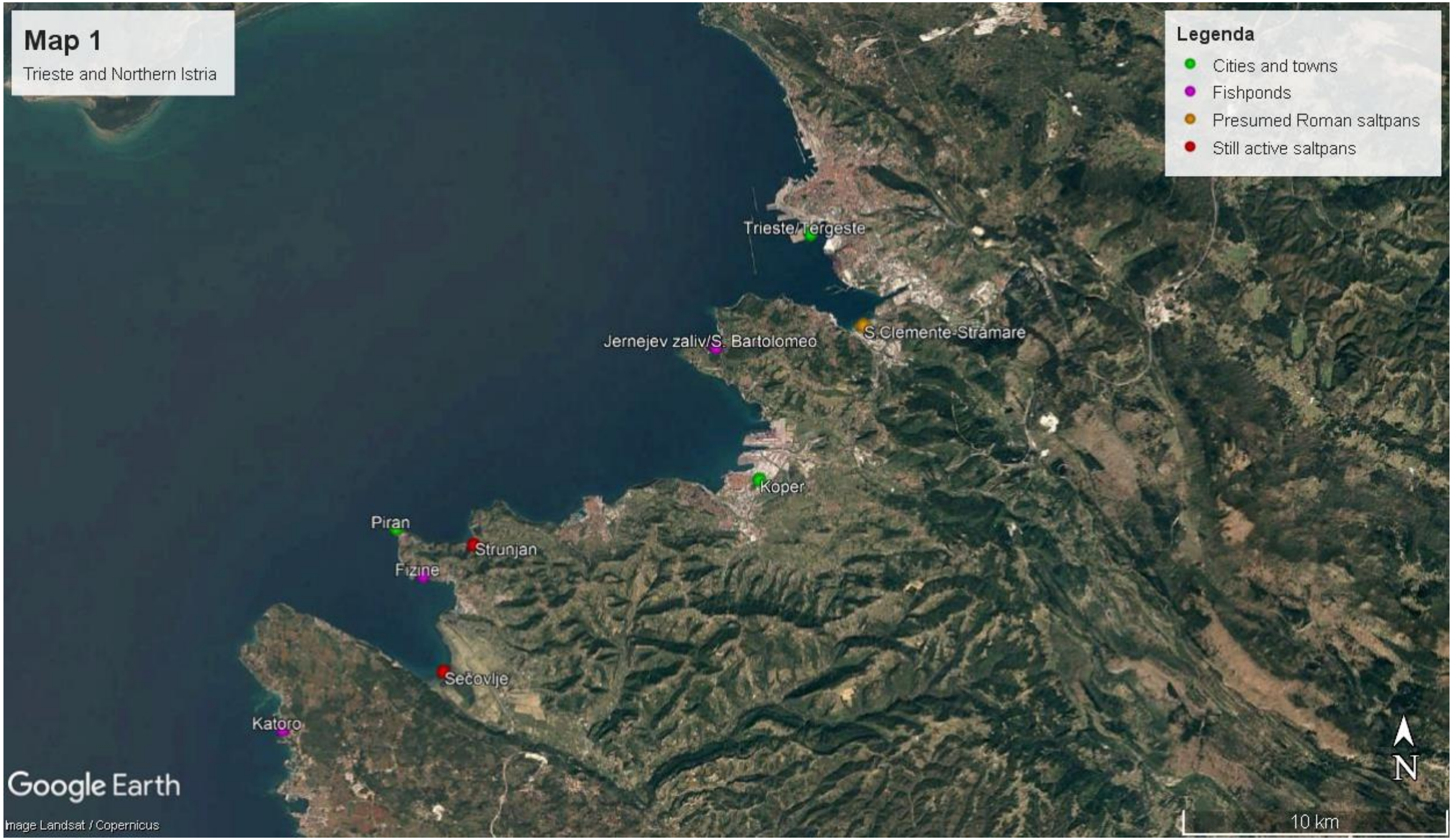
Drugo postignuće arheoloških istraživanja, uključenih u gore navedenom projektu, je spoznaja da su solane na otoku Lavsi u Kornatskom arhipelagu rezultat jedinstvenog plana koji je izgrađen vjerojatno tijekom druge polovice 14. stoljeća, kao što to sugeriraju arhivski dokumenti i studije razine mora. Datiranje ovih solana u rimsko doba, koje je prvi predložio D. Vrsalović 1979. godine, i danas se nalazi u brojnim znanstvenim i stručnim publikacijama. Iako obližnje koncentracije rimske keramike pokazuju posjećenost uvale Lavsa u ranijim razdobljima, možemo samo pretpostaviti da se u rimsko doba sol proizvodila na otoku na istom mjestu kasnosrednjovjekovne solane.

Daljnja arheološka istraživanja u uvali Makirina i na drugim lokacijama od interesa, zajedno sa spoznajama iz trenutačnih iskapanja ostataka solane u uvali Bijeca u Istri, sigurno će pridonijeti nove, zanimljive elemente za razumijevanje drevnih tehnika proizvodnje soli u Jadranskom moru i Sredozemlju.

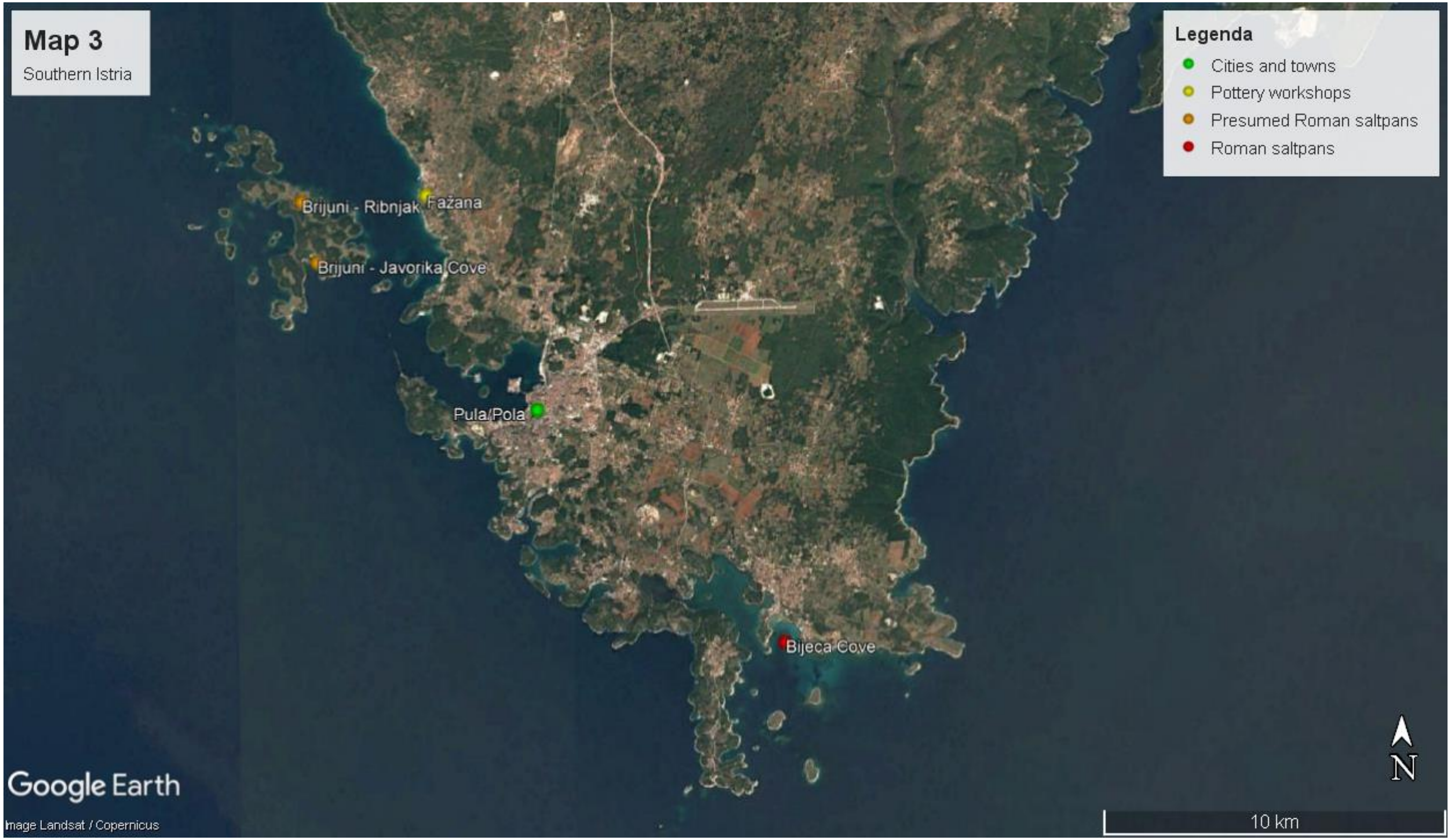
Author's biography

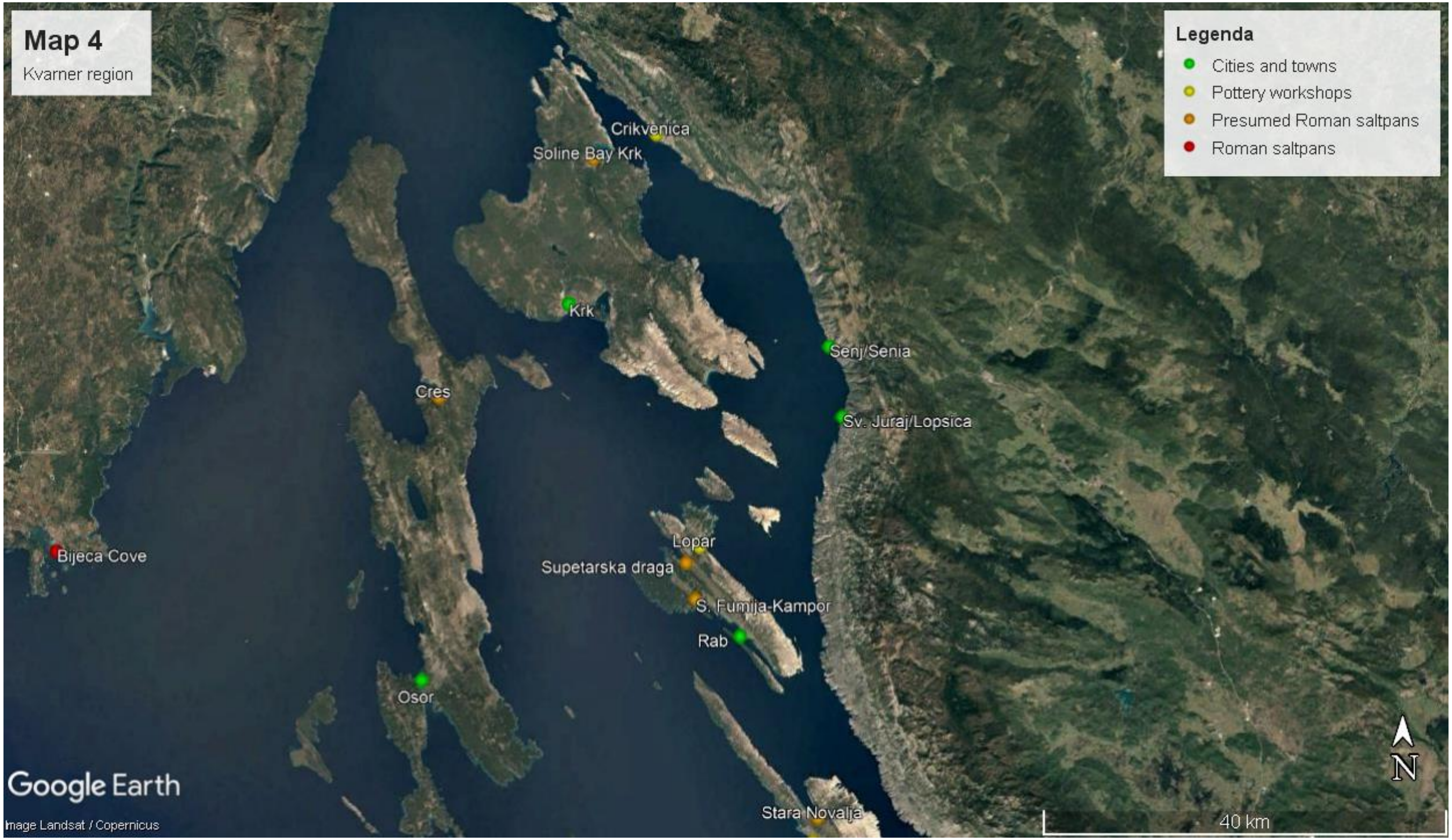
Maja Grisonic was born in Osijek, Croatia and grew in Trieste, Italy, where she attended schools with Slovenian teaching language. During her high school years she lived one year as an exchange student in Minnesota, USA. She studied archaeology at the Universities of Trieste and Pisa, but her joint love towards the country where she was born and underwater archaeology brought her back to Croatia, where she joined numerous underwater archaeological excavations organized by the Department of Archaeology of the University of Zadar. After graduating at the University of Pisa in 2015, she started the PhD in Zadar. She participated at several international conferences, where she presented the preliminary results of her research and published a number of articles in national and international journals and conference proceedings. During her PhD she benefited of numerous short-term scholarships: the French Embassy in Croatia - Campus France scholarship for professional education and training at the Centre Camille Jullian, MMSH, Aix-en-Provence (2016), several Erasmus + Traineeship scholarships at the CCJ-MMSH (2018), the Maison Archéologie & Ethnologie René-Ginouvès in Paris Nanterre (2018) and the University Paul-Valéry Montpellier 3 (2019). She was awarded with three one-month scholarships by the École française de Rome (2018, 2019, 2022) for pursuing research on salt production and trade in antiquity. She currently lives and works in France.

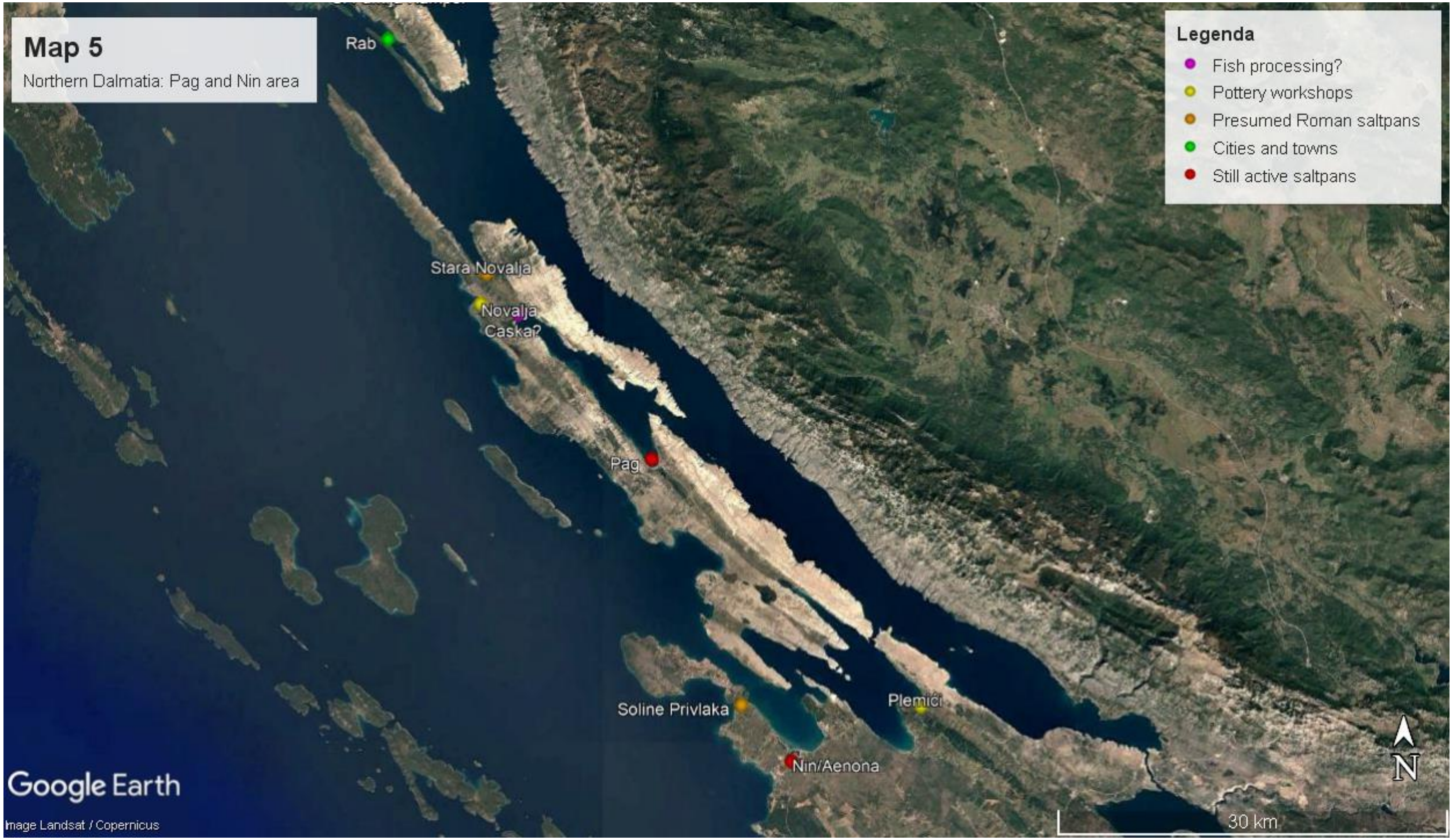
MAPS

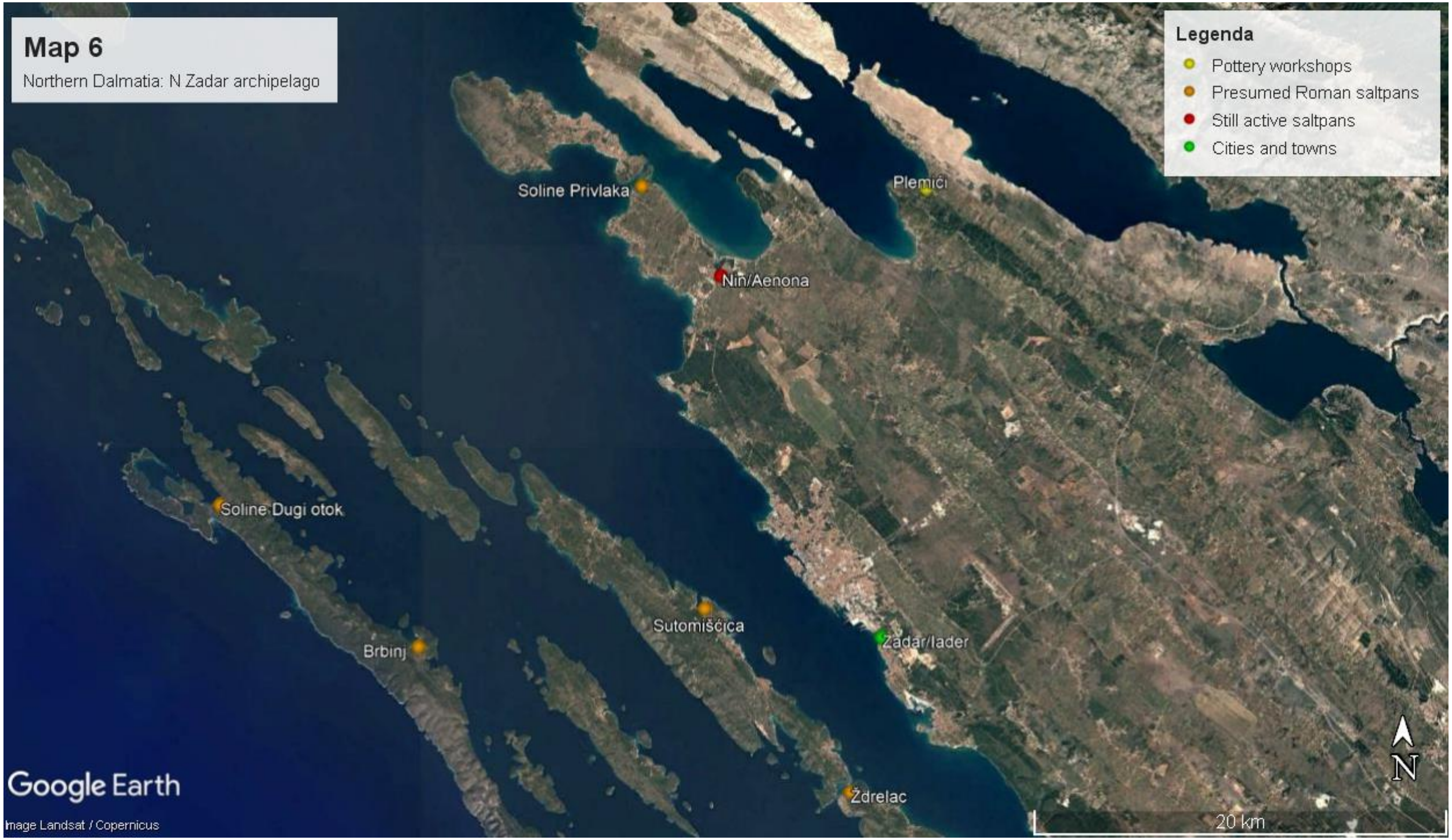

Map 1
Trieste and Northern Istria
Legenda
Cities and towns
Fishponds
Presumed Roman saltpans
Still active saltpans
Trieste/Tergeste
S.Clemente-Stramare
Jernejev zaliv/S. Bartolomeo
Koper
Piran
Strunjan
Fizine
Sečovlje
Katoro
N
10 km
Google Earth
Image Landsat / Copernicus

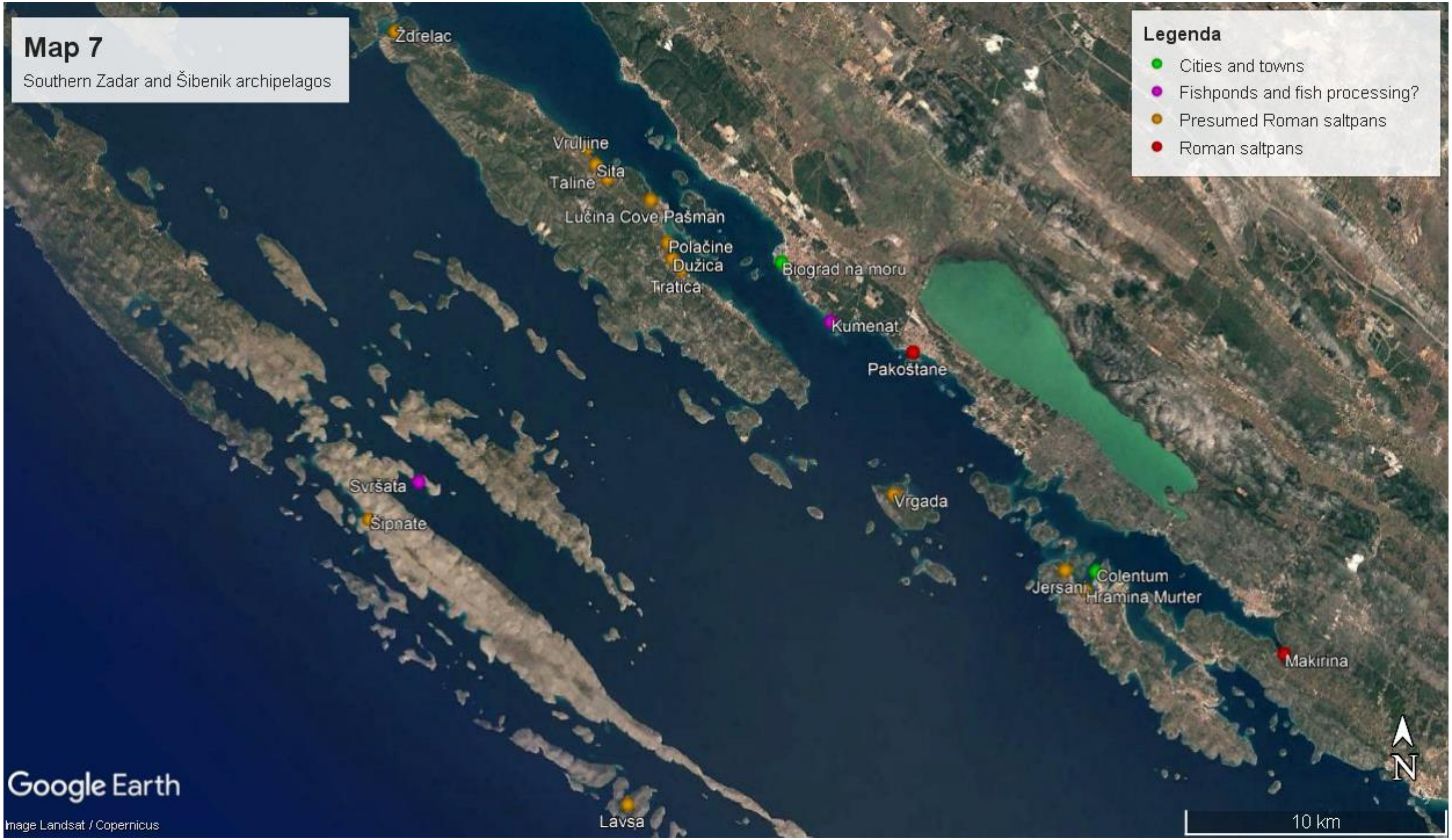

Map 2
Central-western Istria
Legenda
Cities and towns
Fishponds and fish processing?
Pottery workshops
Presumed Roman saltpans
Kupanja
Velike Soline Črvar
Loron
Červar-Porat
Male Soline
Busuja
Fratrija purple dye workshop
Poreč/Parentium
N
4 km
Google Earth
Image © 2022 CNES / Airbus


Map 3
Southern Istria
Legenda
Cities and towns
Pottery workshops
Presumed Roman saltpans
Roman saltpans
Brijuni - Ribnjak
Fažana
Brijuni - Javorika Cove
Pula/Pola
Bijeca Cove
N
10 km
Google Earth
Image Landsat / Copernicus


Map 4
Kvarner region
Legenda
Cities and towns
Pottery workshops
Presumed Roman saltpans
Roman saltpans
Crikvenica
Soline Bay Krk
Krk
Senj/Senia
Sv. Juraj/Lopsica
Cres
Lopar
Supetarska draga
S. Fumija-Kampor
Rab
Osor
Bijeca Cove
Stara Novalja
N
40 km
Google Earth
Image Landsat / Copernicus


Map 5
Northern Dalmatia: Pag and Nin area
Legenda
Fish processing?
Pottery workshops
Presumed Roman saltpans
Cities and towns
Still active saltpans
Rab
Stara Novalja
Novalja
Caska?
Pag
Soline Privlaka
Plemići
Nin/Aenona
N
30 km
Google Earth
Image Landsat / Copernicus


Map 6
Northern Dalmatia: N Zadar archipelago
Legenda
Pottery workshops
Presumed Roman saltpans
Still active saltpans
Cities and towns
Soline Privlaka
Plemići
Nin/Aenona
Soline Dugi otok
Sutomišćica
Brbinj
Zadar/Iader
Ždrelac
N
20 km
Google Earth
Image Landsat / Copernicus


Map 7
Southern Zadar and Šibenik archipelagos
Legenda
Cities and towns
Fishponds and fish processing?
Presumed Roman saltpans
Roman saltpans
Ždrelac
Vruljine
Sita
Taline
Lučina Cove Pašman
Polačine
Dužica
Tratica
Biograd na moru
Kumenat
Pakoštane
Vrgada
Svršata
Šipnate
Jersan
Colentum
Hramina Murter
Makirina
Lavsa
N
10 km
Google Earth
Image Landsat / Copernicus


Map 8
Central Dalmatia: Gulf of Kaštela
Legenda
Cities and towns
Presumed Roman saltpans
Roman saltpans
Solin/Salona
Saltpans of Salona?
Split
Epetion
Pantan
Kopilice
Trogir/Tragurion
N
7 km
Google Earth
Image Landsat / Copernicus


Map 9
Central and southern Dalmatia
Legenda
Cities and towns
Still active saltpans
Fish processing?
Presumed Roman saltpans
Solin/Salona
Kopilice
Split
Epetion
Makarska
S. Klement
Vid kod Metkovića/Narona
Ston
Soline Mljet
Dubrovnik
Cavtat/Epidaurum
Herceg Novi
Kotor
Tivat
Ulcinj
N
100 km
Google Earth
Image Landsat / Copernicus