

ALTINO, A MEETING POINT BETWEEN THE RIVERS AND THE LAGOON: MATERIALS AND BUILDING TECHNIQUES OF A CITY BUILT ON WATER

Altino, punto de encuentro entre los ríos y la laguna: Materiales y técnicas de construcción de una ciudad construida sobre el agua

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ABSTRACT Altino, located at the edge of the Po valley and on the northern margin of the Venetian lagoon, has been important for Venetic settlement from the 8th century B.C. The town, already a marketplace from the 2nd century B.C., became an important port during the Roman time. From the 6th and 7th centuries, the area of Altino was starting to be abandoned. From a literature review focused on the city of Altino, it is possible to realize that only few studies focused on the architectural aspects of the buildings. Due to the remaining structural evidence belonging to the buildings, found often at a foundation or under foundation level, these have not been studied from an architectural technique point of view. Because these structures are now buried, through the study of excavation reports it is possible to analyse them. How deep was the knowledge of the constructors about the characteristics of their environment? How did they solve the problem of the marsh area where Altino was settled? The particular geomorphological context where the city of Altino was founded made the Roman constructors take crucial decisions as to resettle the prior urban center, excavating channels to reclaim the land. This implied the constructions of roads, Annia and Claudia Augusta, being enclosed by artificial canals, which departed from the city to reach other main centers of the region, like Padova, Concordia, Oderzo, and Aquileia. The characteristics of the soil necessitated the use of the “under-foundation” which involved preparation of the soil to make it adequate to construct a building on it without any risk of collapsing. The materials used to set the soil are stilts, horizontal planks, embedded-amphorae structures, levels of gravel and clay. The study of the material used for the construction, both stone or other type (wood, gravel...), and of the building techniques, that reveal the knowledge and the expertise of the workers, let us understand the capacity

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of the artisans and the relationship between the resources of the territory itself. Altino summarised well an example of a mixture between the cognition of the environment owned by the local population and the technology capability possessed by Romans, who could adapt to settle and construct in any geomorphological context.

Keywords: Building Techniques, Materials, Soils, Constructors, Lagoon Area.

RESUMEN Altino, ubicado en el borde del Valle del Po y en el margen norte de la laguna de Venecia, fue un importante asentamiento Véneto durante el siglo VIII a.C. La ciudad, ya un mercado desde el siglo II a.C., se convirtió en un puerto importante durante la época romana. Desde los siglos VI y VII, el área de Altino empezó a quedar abandonada. Desde una revisión bibliográfica focalizada en la ciudad de Altino, es posible observar la falta de estudios sobre los aspectos arquitectónicos de los edificios. Debido al carácter residual de las evidencias estructurales correspondientes a los edificios, encontrada a menudo en el nivel de fundación o debajo de él, estas no se han estudiado desde una perspectiva arquitectónica. A pesar de la imposibilidad de la observación directa de los datos, las imágenes y las descripciones procedentes de las excavaciones lo hacen posible. ¿Cuán profundo era el conocimiento de los constructores sobre las características de su entorno?, ¿Cómo solventaron el problema de la zona pantanosa donde se encontraba Altino? El contexto geomorfológico particular donde se fundó la ciudad de Altino hizo que los constructores romanos tuvieran que tomar decisiones cruciales, tales como, por ejemplo, reasentar el centro urbano anterior a partir de la excavación de canales para recuperar parte de la tierra. Esto implicó la construcción de vías, Annia y Claudia Augusta, cercadas por canales artificiales, aquellos que partían desde la ciudad hasta alcanzar otros centros de la región como Padova, Concordia, Oderzo y Aquileia. Las características del suelo impusieron el uso de la denominada “under-foundation” (bajo los cimientos), que implicaba la preparación del suelo para adecuarlo a la construcción de un edificio sin riesgo de derrumbe. El material utilizado para establecer el suelo corresponde a soportes, tabloneros horizontales, estructuras realizadas a partir de ánforas, niveles de grava y arcilla. El estudio del material usado para la construcción, tanto en piedra como en otro tipo (madera, grava, etc.), así como de las técnicas constructivas que esconden el conocimiento y experiencia de los constructores, nos permiten entender la capacidad de los artesanos y la relación entre los recursos del propio territorio. Altino se configura como un buen ejemplo de mezcla entre el conocimiento del ambiente por parte de la población local y la capacidad tecnológica de los romanos, quienes podían adaptar sus asentamientos y construir en cualquier contexto geomorfológico.

Palabras clave: Técnicas de construcción, Materiales, Suelos, Constructores, Zona de lagunas.

INTRODUCTION

‘Item si in paludibus moenia constituta erunt, quae paludes secundum mare fuerint, spectabuntque ad septentrionem aut inter septentrionem et orientem, eaeque paludes excelsiores fuerint quam litus marinum, ratione videbuntur esse constituta’

‘So also, if in marshes walls are laid out, and these marshes are along the sea, and they look towards the north or between the north and east, and these marshes are higher than the sea-coast, they will seem to be reasonably laid out’

(Vitr.DeArch.1.4.11).

Marshes positioned along the coast, looking towards the north or between the north and east, and located at a higher level than the coast, could be reasonably used for building walls. These characteristics are part of one of Vitruvius' precepts on the environmental aspects that had to be present in the area where cities could be founded. These precepts refer to geomorphological features of some zones of the north-west Adriatic coastline, that the author cites as examples of cities characterised by "*incredibilem salubritatem*" (Vitr.DeArch.1.4.12). The cities of Ravenna, Altino and Aquileia are mentioned as successful models of human urbanism in areas with harsh environmental conditions caused by the presence of fens and marshes (Strabo.Geo.5.1.7; Pl.Eld.Nat.Hist.3.119; Vitr.DeArch.1.4.11-12). However, the physical characteristics of a territory alone do not determine success in urban planning. In fact, human action plays a crucial role, dealing with the elements of the existing environment and defining adequate strategies necessities of life. These characteristics are present in the occurrence of the ancient cities of the so-called *Venetorum angulus* (Liv.5.33; 9-10): Padova, Este, Oderzo, Concordia, Eraclea and Altino, the case study here presented. These Venetic settlements had horseshoe-shaped pattern, located on a ridge within a river bend, between the lagoonal shoreline and the ground water-table. Within the settlement watercourses were common, some of them of anthropic origin, as the canal crossing the western zone in Concordia, or the Sioncello canal in Altino. These watercourses seem to determinate the organization within the Venetic settlements themselves and later maintained during the Roman period, which would explain the different orientation of internal road system when compared with the surrounded Roman centuriated field-system (Di Filippo, 1994:198). The relationship that the Venetic settlements had with the element of water is more than ever evident. Venetic populations found a way to control the marshes and contain floods and overflows, through the use of sub-foundation such as piles and embankments (Strazulla, 1989:21-22, note 119); and the dig of *fossae* along the Venetic coastal strip (Bosio, 1967:42-44; Alfieri, 1981:3-6; Peretto, 1986:31-52)¹.

During the last century, a large number of researches has been conducted in these ancient cities in order to delineate the characteristics of their urban plans and of the environment where they were founded. Different methodologies have been applied to reach the objectives, from delimited excavation and aerial photographic and satellite image interpretation, to geophysics methodology and high resolution DEMs, including coring. Through excavation it has been observed that Concordia was founded on a ridge roughly 10 m over the surrounding lowlands (Croce, 1991:79-80); from the analysis of elevation points it has been observed that the settlement of Oderzo is on a main ridge with an elevation of 14.30-15.00 m a.s.l. on the north-west and on two secondary ridges with an elevation of 13.00-13.50

1. The *fossae* include the so-named *fossae Philistinae*, probably dug by order of Philistus, sent to conquer Adria by Dionysius the First of Siracusa in 387 B.C. In addition, other hydraulic works can be included, operated by Etruscan to connect Spina to Adria through the Po's mouth. (Bosio, 1967:42,44).

m a.s.l. on the south and north-east (Busana 1995:40-41). Through aerial photo interpretation and ancient maps of the area it has been possible to detect the city of Eraclea, with its streets and watercourses (Tozzi and Harari, 1984:27); Recently, the use of high resolution DEMs based on different datasets (CTR, CTR-n, CTC maps and LiDAR) has allowed the detection of a ‘mound’ of anthropogenic deposits with a maximum thickness of 7 m and an area extension of about 1 km² underneath the city of Padova (Ferrarese *et al.*, 2006:293, 295; Mozzi *et al.*, 2011b:16). In this context, wider research has been conducted on the city of Altino, taking advantage of the fact that after its abandonment by the population between the A.D. 6th and 7th centuries no successive overlaid phases of occupation occurred. However, agricultural activities have heavily damaged the ancient structures that are still buried underneath the fields. In 2007 a Remote Sensing survey, led by a team of researchers from Department of Geography at the University of Padova, produced a digital image that gave back the urban plan of the buried city of Altino, including the watercourses that flowed across the city. The success of the study, largely based on multispectral aerial photography together with geophysics analysis (Geo-Radar), was due to a period of drought that increased the aridity of the soil (Ninfo *et al.*, 2009:577-582; Mozzi *et al.*, 2011a:199-203; Mozzi *et al.*, 2012:15-38) (fig. 1). Field surveys and aerial photographs had also confirmed the highland morphology of the area of Altino, with a maximum elevation of 3,5 m a.s.l, whereas the surrounding areas have an elevation of around – 1 m a.s.l. , although modern studies have collected new data². In fact, a few depth excavations, altimetric analysis and the study of sampling of deep sedimentary sequences have demonstrated that a “mound” constitutes the highland morphology of this area³. Anthropogenic units that are originated from human activities which lasted from Protohistory to Late Antiquity make up the mound⁴. This has been an extraordinary discovery that reveals how anthropogenic activities have affected the proto-urban and urban transformation of the settlement of Altino since its primitive origin. Since that time the settlement was restricted to the north by the bend of a canal that occupied a paleo-river and on the east by a canal or a river running from north to south, which joined the S. Maria waterway. The largest east-west canal crossed the city centre. This canal was probably dug, deepening the bed of an ancient river basin. The river system

2. Previously, Tombolani, in his study of the city, identified these ridges with the zones named Campo Rialto, Ghiacciaia and Pastoria. Moreover, a previous settling was probably placed under Claudia Augusta road, as evidenced by regular tracks visible from aerial photographs. (Tombolani, 1984:831).

3. The elaboration of a Digital Terrain Model (DTM) based on elevation points of the CTR clearly shows the highland morphology of the area of Altino. The department of Geography of the University of Padova, together with Soprintendenza per i beni archeologici del Veneto and Regione Veneto, has carried out some coring in the area of Altino. (Mozzi *et al.*, 2011:15-16).

4. Until the 1990s, it was believed that Altino was founded in the 7th century B.C., but recent discoveries backdated the existence of the proto-urban centre to the 8th century B.C. (Gambacurta, 2011:55). The highest urban development of Altino was achieved between the 2nd and the 1st century B.C.



Fig. 1.—Digitally enhanced false-color composite image (NIR, red and green spectral bands) of the center of Altino (Realvista 2007, Telespazio S.p. A., Rome, Italy) (from Ninfo *et al.*, 2009:fig. 1).
Figure in color in the electronic versión.

also constituted artificial waterways made by the first inhabitants and permitted a fluvial connection with the main hydrographical system of the region (Sile, Zero and S. Maria) (Ninfo *et al.*, 2009:577; Mozzi *et al.*, 2011b:15-16).

The research carried out over the past century in the ancient city of Altino has revealed the knowledge on the environmental and geomorphological context of the proto-urban centre and has given a clear picture of the Roman city buried under the fields. However, the field study on the city of Altino has not considered the relation between the environmental context and the building techniques used and constructive capabilities applied to make this type of environment suitable for

living. This paper aims to fill the gap concerning the tight connection between the geomorphology context and the building techniques used to control this, apparently, harsh environment. This result will be achieved by a deep analysis of the excavation reports concerning the structures found and by a study of the recent research made on the territory of Altino and on the lagoon of Venice in the last century.

GEOMORPHOLOGY AND ENVIRONMENTAL CONTEXT

The reconstruction of the ancient environmental context in which the city of Altino settled, and more generally, the areas surrounding the lagoon, is problematic. In fact, from the Renaissance period the diversion of Brenta, Piave, Bacchiglione, Sile, and Livenza to stop the silting up of the lagoon heavily increased the natural subsidence, and the intensive exploitation of the groundwater-fed river system by the factories, caused serious landform sunken of the area (Gatto and Carbognin, 1981:381-386; Brambati *et al.*, 2003:264). In addition, in the 20th century, the reclamation of land for cultivation purposes obtained by pumping station and the network of ditches, caused heavy changes to the environment of the study area (Fontana *et al.*, 2017:2). In the last three decades many studies have been carried out on the formation of the Po Plain, of alluvial megafans, the processes of formation and transformation of the lagoon of Venice, its geomorphology and on the change of sea level during the millennial (Ammerman, 1996; McClennen *et al.*, 1997; Ammerman *et al.*, 1999; Gatto and Carbognin, 1981; Tortora *et al.*, 2001; Marchetti, 2002; Mozzi *et al.*, 2003; Brambati *et al.*, 2003; Serandrei-Barbero *et al.*, 2004; Mandricardo *et al.*, 2007; Tosi *et al.*, 2007; Fontana *et al.*, 2008; Rizzetto *et al.*, 2009; Fontana *et al.*, 2017; Mandricardo *et al.*, 2021).

The Venetian-Friulan plain

Altino is in the Venetian-Friulan plain (northern Italy) and various rivers surrounding it: on the north Sile, west Zero and south-south/east S.Maria. On the east side, swamps (Cona, Dese, Ca' Deriva), a valley (Perini), mudflats and sandbars separate the city from the lagoon. The Venetian-Friulan plain is on the east of the Po plain and embraces the hinterland of the lagoon of Venice, including Altino. It extends from the Karst Mountain Fringe (close to the Slovenian border) to the Berici and Euganei hills. It constitutes part of the foreland basin of the Southern Alps and it is subjected to southward tilting of the Apennine. This plain is formed from debris of Alpine rivers: Isonzo, Tagliamento, Piave, and Brenta that embrace an area of 12000 km². During the Quaternary, these rivers created several large and flat conoid-shaped that are called alluvial 'mega-fan' due to their fan-shaped morphologies and large dimensions (Fontana *et al.*, 2008:73-74) (fig. 2). Altino is in the Brenta megafan, consisting of laterally and vertically juxtaposed

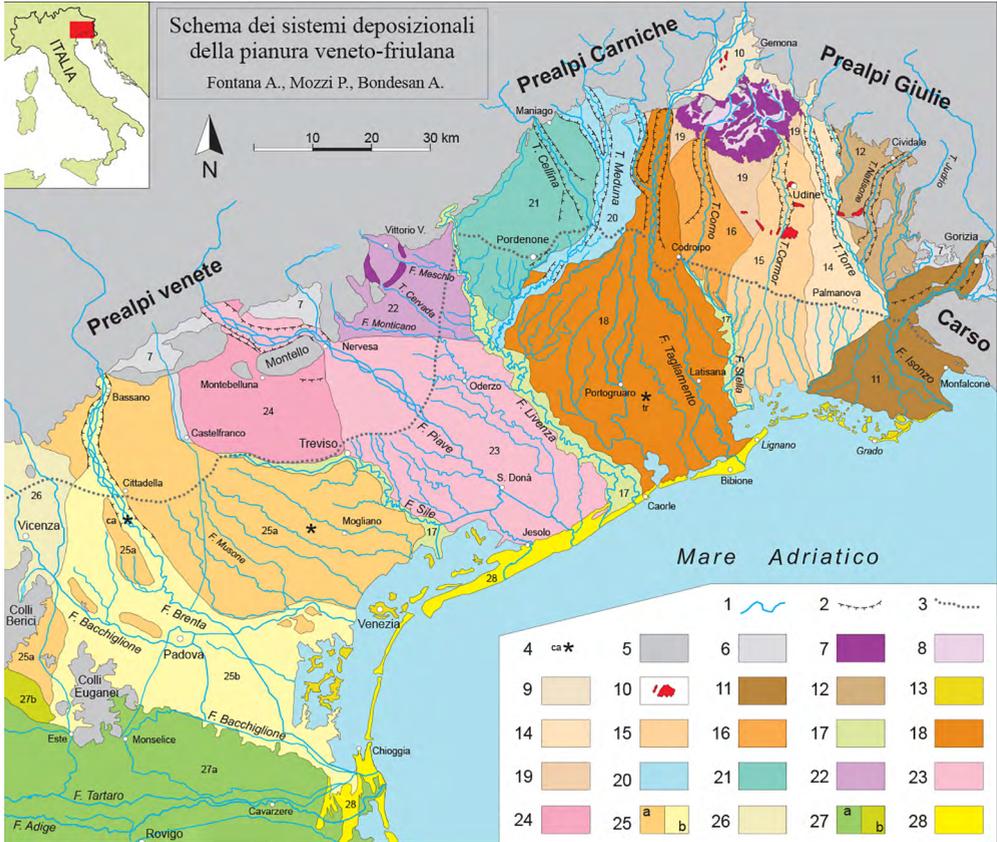


Fig. 2.—Map of the depositional systems of the Veneto-Friuli plain. Simplified legend: 13) lagoon islands; 17) systems of the main resurgence rivers (Stella, Livenza and Sile); 23) megafan of the Piave di Nervesa; 24) megafan of the Piave di Montebelluna; 25) Brenta system: (a) Pleistocene sector (Bassano megafan), (b) Holocene plain with contributions from the Bacchiglione; 26) Astico conoid; 27) Adige system: (a) Holocene plain with contributions from the Po, (b) Pleistocene plain; 28) coastal and deltaic systems (from Tosi, 2007:fig. 13). Figure in color in the electronic version.

sedimentary bodies extending across different ages, from the Upper Pleistocene to the present. This megafan has a topographic gradient of 6-4‰ in the Alpines area, which decreases to less than 1‰ after the spring belt. The area where Altino arises is the ‘low plain’ composed of silt and clay. The lithological transition between the ‘high plain’ (in the piedmont area) and the ‘low plain’ thrusts the rise of groundwater table to the surface, which creates the ‘springs belt’, extending from the east to the west with a downstream width of 3-15 km. In the ‘low plain’, the groundwater table and groundwater-fed river systems are generally between 1.5 and 3 m in depth (from the surface) (Fontana *et al.*, 2008:73-74, 76-77, 79). Mean annual rainfall is accumulated during autumn season and a high concentration of it can cause extreme flood events in the plain itself.

The Brenta megafan shows a well-recognizable and preserved LGM portion, called the ‘Bassano megafan’. This deposit represents the main aggradation phase of this megafan between 22000 and 14500 ¹⁴C B.P when the sea level was 120 m deeper than the actual one (Tosi *et al.*, 2007:30). The surface of the LGM deposition is composed of sandy alluvial ridges divided by a wide silty-clay flood basin. The layers related to the paleo-riverbed are thick < 2-3 m and have fine silty sands, separated by clay and silty sediments. This succession of deposits has been interpreted as an avulsion process⁵. In between these deposits there are thin peat or organic layers that are the product of fens formed by the rising of the groundwater table that kept soils or depressed areas waterlogged (16000 and 14500 years B.P). Between this time and the Early Holocene Brenta megafan was cut by an erosional scarp caused by river downcutting that led to the deactivation of the megafan itself (Marchetti, 2001:365). The concentration of flows in defined areas stopped river activity in vast sectors of the megafan, including the area nearby Altino. Between 14500 and 8000 years BP, soil formation prevailed, confirmed by Mesolithic sites along the lagoon shore (Mozzi *et al.*, 2003:195, 208). The pedogenesis process created a new soil known as ‘caranto’ with a thickness between a few centimetres in the inner margin of the lagoon and about 2 m towards the sea. It is composed of clayey silt and silty clay with massive consistency due to lengthy aerial exposition has light grey colour with ochre mottles and contains carbonate concretions (Mozzi *et al.*, 2003:207-208; Tosi *et al.*, 2007:23-24; Fontana *et al.*, 2008:83-84). This paleo-soil, probably formed in a time slice of 8000 to 12000 years, marks the transition to the marine-lagoonal Holocene⁶. Palynological investigations demonstrate that the main arboreal angiosperm existed on the plain, typical of alluvial forests (Marchetti, 2002:367). At the end of the Subboreal period, at about 5.000 years BP, it started the formation of fluvial ridges that are still visible. These fluvial ridges are 2-5 m higher than the surrounding plain and 500-2000 m wider than the Pleistocene ones. Riverbeds assumed meander shape in the lower tract caused by avulsion (Fontana *et al.*, 2008: 85). In the 2nd millennium B.C., the stretch of the Sile river near Altino flowed in an erosional scarp wide hundreds of metres and 7-8 m of deep in respect to the surrounding plain. Because of the proximity of the Dese and Zero rivers to Sile, it is possible to make a comparison. The first settlement in Altino developed on low river terraces consisting of strips of LGM plain carved by small valleys a few metres deep, on which the ‘caranto’ is still partially preserved. The plain elevation was the same of the surrounding areas, contemporary including between 0 and -1 m a.s.l. From this level succeeding, anthropic deposition lay on with a

5. ‘Avulsion is the process whereby a river diverts its flow out of an established channel into a new permanent path on the adjacent floodplain’ (Lanzoni, 2022:95-96).

6. Samples taken in Ca’ Tron, an area on the northern lagoon shore, demonstrate that the apex of marine transgression on the Late Pleistocene alluvial plain is dated in post-Roman times. This new data let us estimate an addition of 4.000 years of pedogenesis on the time-slice of 4.000 to 8.000 years for soil formation on this alluvial plain. Therefore, the total amount would result in 12.000 years. (Mozzi *et al.*, 2003:207).

maximum thickness between 3 and 4 m., forming the ‘mound’ of Altino (Mozzi *et al.*, 2011b:16) (fig. 3). As the sea level rose, the rivers deposited sediment into these valleys between the 2nd and 1st millennia B.C. It was completed by the Roman period in the case of Sile, as the samples taken in Ca’ Tron show. In addition, the presence of the via Annia on a ridge, visible from aerial photos, confirms that the process of formation of fluvial ridges in the area ceased by the Roman Age and that the ridge was not more object of successive sedimentation (Mozzi *et al.*, 2011b:13). Since 2nd century B.C. an intense deforestation due to the conversion of forest into cultivated land with relative centuriation generated an intense areal erosion of the soils. The evidence of this phenomenon is the presence of truncated argillaceous horizons (B_t horizon) on which the topsoil horizon (A horizon) has developed. Sometimes this argillaceous horizon (B_t horizon) is completely removed and the topsoil horizon (A horizon) overlies the substratum layer (C horizon) (Mozzi *et al.*, 2003:196). During the Roman time lots of watercourses crossed the area between Musone, Sile and Piave rivers, promoting the productiveness of the terrains and the growth of cultivation. However, if Piave and Sile riverbanks were not dammed, the terrains alongside them could have been easily turned into fens and swamps due to their flood. This is proved by the evidence of conversion of wasteland of the area and also by the tracks of dams found along paleo-riverbanks in this region (see *infra*; Lacchini, 1972-1973). The state of abandon after the fall of Roman Empire and the degeneration of climate caused the reforestation of the plain but also the formation of marshes. Alluvial deposits due to the reverse of direction of their flow to the present course buried Annia road and numerous Roman sites. Their stratigraphic and topographic positions testify that the formation of ridge started after Roman period. In the stratigraphy of all megafans of the Venetian-Friulan plain an important period of floods is evident during Early Middle Age (A.D 4th-5th to 10th century). This interval corresponds to a period of high rainfall recorded in the historic chronicles and coincides also with the collapse of the field and drainage systems settled during the Roman period (Marchetti, 2002:367; Fontana *et al.*, 2008:86).

The lagoon and the variation of coast shore-line

The presence of submerged structures within the lagoon indicates that the position of ancient coastal strips was not the same as that which we can see nowadays and that a larger emerged area characterized the landscape in Antiquity (Mandricardo *et al.*, 2007:205; Dorigo, 1983; Canal, 1998). In the modern Palude di Cona and Palude Centrega some buildings and infrastructures had been discovered and they are interpreted as part of the “sea harbour” of Altino. In addition, during the last excavation in Torcello, evidence of a Roman settling (a roman villa) then abandoned during Late Antiquity, was found (Mandricardo *et al.*, 2021:9).

The lagoon of Venice started to set about 7000-6000 years B.P. , when the distal portion of Bassano megafan was inundated and consequently the pedogenesis

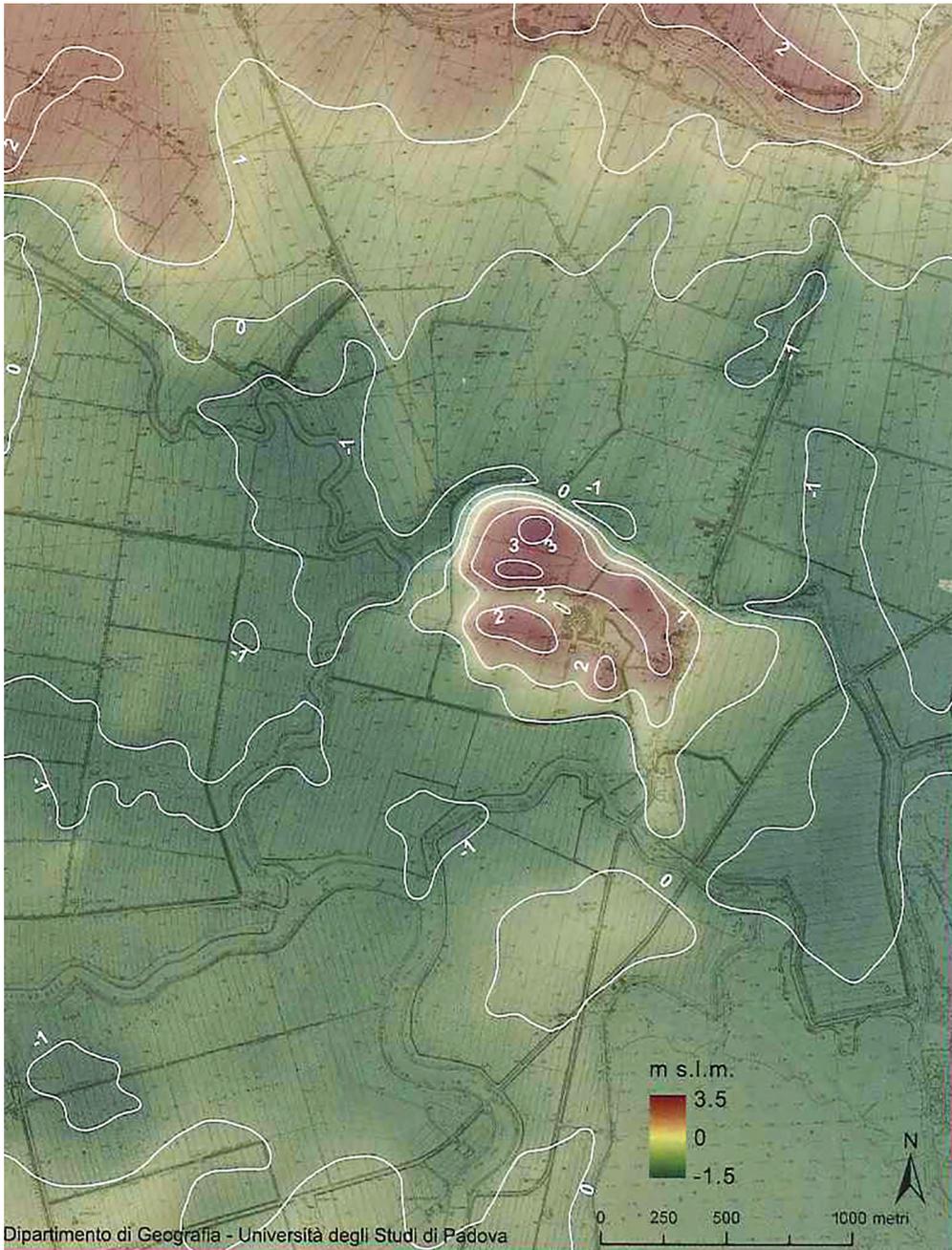


Fig. 3.—DTM of the archaeological site of Altino and the surrounding plain (from Mozzi *et al.*, 2011:fig. 3).

process was ceased. Between 5700 and 4000 years B.P., there was the maximum extension of immersed land by the Holocene marine transgression (Fontana *et al.*, 2008:74). Littorals together with lagoon-barrier were formed, enclosing the lagoon and concentrating tidal flow into tidal channels that have evolved with inlets and barriers (Madricardo *et al.*, 2021:6; McClennan *et al.*, 1997:749). Throughout the peak of marine transgression, the coastline of this area was within the contemporary lagoon (Tosi *et al.*, 2007:25-26). Late Holocene layers are made of organic or peaty sediments in the lagoon environment whereas in alluvial units the peat constitutes the infill material of the remaining watercourse. In this period, buried soils are common and their stage of development can give the period of stability of the surface on which they formed (Fontana *et al.*, 2008:85).

In this period lighter oscillations of marine sea level are indicated by secondary transgressive and regressive depositional events. The origin of these events has to be related to climate changes that could affect the processes of supply and of accumulation of sediments, together with eustatic phenomenon⁷. The most evident example is the position of the ancient sandbank on the Holocene upper layers, on which Roman human settlements have been found. Above this, anthropogenic unit is laid on sandbank deposits (Tosi *et al.*, 2007:27). Roman structures were found within the area of the lagoon at a depth of 2-3 m from the bottom m.s.l. In most cases this evidence is cut by existing canals or are in shallow water (less than 1 m depth) (Madricardo *et al.*, 2007:206). The peak of a stable phase of relative sea level took place in Roman time, when an intensification of sediment supply to the coast brought to deltaic and shallow-marine outward growth of the shoreline (Madricardo *et al.*, 2021:6). In the central sector of the lagoon of Venice the first lagoonal deposits are directly in contact above the Caranto paleo-soil at a depth of 1-3 m below m.s.l. These lagoonal deposits have a maximum thickness of 10 m in correspondence with the Cavallino littoral, getting thinner towards the inland and disappearing nearby Altino and Marco Polo airport, where the maximum lagoon ingression occurred in the Middle Ages (Mozzi *et al.*, 2011b:15). By pollen analysis the formation of salt marsh areas in the higher part of tidal flats was evidenced, whereas other zones were transformed into open lagoonal environments that were characterized by the supply of fluvial sediments and water. The appearance of grains of hygro-hydrophytes proves the formation of waterlogged environments. These types of plants substituted the arboreal plants (in specific oak woods) that spread during the Holocene period. Before then, during the Glacial period, Pine forests and

7. A paleo-channel found in the Palude of S. Caterina (lagoon of Venice) evidenced the modification of stratigraphy when paleo-channels, together with lagoonal canals, cut into lagoonal sediments and underlying alluvial sediments. Silty laminated sand and sandy silt deposits filled in the paleo-canal. Micromorphological analysis evidenced within these deposits the presence of thin horizontal layers (with sandy sediments, fragments of lagoonal mollusc and vegetal remains) formed by the different forces of the tidal phases. The content of *Collema granosum* in 20% of the total Foraminifera that is in these layers indicates a regular freshwater supply. The shells found in the bottom layers of the fill-in of the paleo-canal date it at least 4500 years B.P. (Madricardo *et al.*, 2007: 211-212).

other microthermic plants were diffused (Mozzi *et al.*, 2003:196). The interaction between tidal phenomena and fluvial activity created a metastable condition that could change in space and time. The first sedimentary process has a thickness of less than 1 m. Taking into consideration the contemporary average height tide of 0.3 m above sea level of the lagoon of Venice, in Antiquity the mean sea level was respectively 2.3 and 1.1 m below the modern one (Mozzi *et al.*, 2003:208). The shoreline position has changed over the millennial depending on climate condition: for instance, during warm periods the coastline moved to the inshore whereas in climatic crisis it was migrating to the offshore. For the area of the lagoon of Venice the reconstruction of the position of the coastline during Late Holocene was arduous, because of the consolidation of the sediments that caused a significant scatter of the relative sea level (RSL) points⁸. Due to considerable transformation occurred in the last two millennia it is hard to catch which could have been the local trend of RSL during ancient time. In the northern part of the lagoon a paleo-beach ridge, dated to Roman Age (2.100-1.800 years B.P.), had been identified on the place of the modern Treporti channel. Over this ridge a buried alignment of lithic material (interpreted as a road) was set, lengthening for about 3 km along the channel. The presence of this road is probably due to the existence of two channels: one collected the water of the Sile and Piave rivers from the land to the sea; the other one had salty water, lengthening from Torcello to Treporti⁹. This paleo-beach ridge appears contemporary to the end of the RSL stabilisation period. Later, the sea level rise overflows the paleo-beach, partly destroying it. Consequently, the lagoon gradually extended upstream, submerging the LGM plain from the lowest areas. Prove of this is the diversion of Annia at the end of the 1st century B.C, as observed in Ca' Tron (Bondesan *et al.*, 2004:109-146). The coastline shifted back to S. Erasmo Island when the second transgressive phase occurred. Later in their deposition, lagoonal sediments were affected by subsidence, with an average vertical value estimated at around -0.6 mm/year (Amorosi *et al.*, 2008:41-67). That is the reason for Roman deposits between -1.5 and 2.0 m a.s.l. in several areas.

This comprehensive review of the data produced by various researchers during the last five decades attempts to reconstruct the environmental context where the first human settlers, specifically the Roman ones, were established. The geological factors that created this area, particularly during Holocene, let us understand the problems the ancient population faced in settling. Among these can be mentioned the presence of groundwater table and groundwater-fed river system between 1,5-3 m depth from the surface and flooding and tide phenomena that could quickly

8. The relative sea level (RSL) is the sea level in a given location over time. 'This is done by measuring the height of sea level as observed at any one time relative to a fixed point on land'. Different processes such as atmospheric pressure, winds, changes in the mass of ocean water, ocean currents and earth movement can influence this level (Ammerman *et al.*, 1999:305).

9. The present configuration of the lagoon is the result of modern changes, mainly due to the diversion of the rivers operated by Venetians. In fact, for many centuries, S. Erasmo Island was the littoral of the lagoon with two inlets, one to the south and one to the north (Madricardo *et al.*, 2021:6).

occur. In addition, the soil composition, formed by loose deposits consisting of alternation sandy, silty and clayey units, with frequent peaty intercalations, made the building activities challenging. This review highlights the role played by water in the context of the alluvial plain and specific the delicate balance between rivers and the sea, whose product was the lagoon. Since its occupancy, the anthropic factor has played a significant role in controlling water dynamics and, therefore, the transformation of Brenta megafan.

MATERIAL AND CONSTRUCTION ANALYSIS OF THE BUILDING PROCESSES

As most of the buildings of the ancient city of Altino are buried, the data concerning the material and building techniques have been gathered from the edited works of the excavation during the last century¹⁰. The data collected have been ordered in summary tables divided for the type of building process operated during the construction: preparation of soil (see suppl. table 1 in the electronic version), foundation (see suppl. table 2 in the electronic version); and for the type of structure: drain/sewer (see suppl. table 3 in the electronic version), basin/cistern/reservoir (see suppl. table 4 in the electronic version), well (see suppl. table 5 in the electronic version)¹¹. All the tables are divided into seven main categories relating to the area where the evidence is located, to the record specifically analyzed in the other categories of the table. The following three categories (morphology and set up, material, assemblage, and dimension) analyze deeply the parts that constitute the single type of building process or the type of structure. These four categories are additionally divided into different items that change in relation to the type of building process or type of structure in order to examine them with regard to their specific typology and use. The seventh and last category is the chronology, not always possible to determine, but useful for linking the single construction technique to a period of time and observing the period of use of this practice. Each record has a number that indicates the building and the structure of the building itself that can be a foundation or preparation of soil, or a drain, for instance; or

10. In March 2021, the Museo e Parco archeologico nazionale di Altino, in collaboration with the Soprintendenza ABAP per il comune di Venezia e Laguna, and P. E.T.R.A società cooperativa, started a new season of excavation in the Augustan district of the city still in progress. During this excavation, a sewer with side walls in bricks was found under the street of the quarter.

11. The tables are part of a general cataloging of Roman typology technique in the Cisalpine region, within the framework of the 'ArcheoEd project' (University of Padova) and 'ACoR' ('Atlas des techniques de la Construction Romaine') and are based on an already consolidated approach. The formulation of the tables presented in this article has been simplified for layout reasons. However, some items (e.g. connection with conduits, trunk cross-section, shaft) have been added by the writer, to have a complete perception of the structure itself. Because of the lack of information related to the state of preservation of the structures itself, the elevation and roofs tables are not here presented. (All this tables are attached to the digital version on the journal's platform).

the single structure when it was found isolated. E.g. N. 41.4 = N is for number; 41 indicates the building; 4 indicates the structure that is part of the building itself (this number is progressively given). When there is only the first number it is a single isolated structure (fig. 4)¹².

The preparation of soil

The building processes present in Altino have a remarkable presence in the techniques used to prepare soils. These techniques include digging canals or ditches, selected or casual sediment backfills, wooden structures (in specific piling), embedded-amphorae structures, and stone and burnt brick fragment deposits. The digging of artificial canals was the most impact anthropic action that had affected the city of Altino since the Roman Period.

The excavation of the Sioncello canal during the first half of the 1st century B.C. completed the ring of waterways that enclosed the city centre, connecting the Sile river with Canale S. Maria. The effect of the finalized watercourse ring was the creation of a circuit directly connected with the lagoon system; this was decisive for fulfilling the hygienic and environmental requirements, permitting periodic ingression and outflow of the tides (Cresci, 2011:99). For what concerns the other watercourses, some of which had an artificial origin, we do not have extensive knowledge, except for their existence proved by the remains of quays or wood reinforcement placed along their banks and by modern research. Indeed, the digital image obtained by the Remote Sensing survey gave back the urban plain of the buried city, including the watercourses that flowed crossing the city. The southern canal looks to mark the city's southern boundary, and because of its linear shape, it seems to be of artificial origin. Remains of a bridge and a quay have been found along this southern canal. This canal joined with Zero river and another north-south watercourse that, in turn, was linked with the Sioncello canal. Another east-west waterway of relevant dimension connected with Zero river and the north-south watercourse crossed the city centre. Later, in A.D. second half of the 1st century, three ditches were dug in Località Fornace, which had been the holly area of the city since the 6th century B.C. These ditches belong to the seventh phase of the sanctuary (A.D. second half of 1st -6th century) and occurred with the creation of a drainage system and redefinition of the spaces. Together with this, some

12. The building and structure number of Altino here presented starts from 41 because this collection of data is part of a larger catalogue that includes all the structural roman evidence found in the province of Venice. Within this list each building or structure has its own data sheet. This catalogue is part of the writer's BA thesis, which was included in the ArcheoEd project (Gottardo, 2013-2014). In this article new evidence regarding the embedded-amphorae structures have been added to the previous catalogue. As these records had already their own number, it has been decided to keep them: e.g. n. 10 refer to the data sheet in Tirelli, Toniolo, 1998: 87-106. When the name 'Museum' appears is not referred to the contemporary Museum but to the previous one, now known as 'Altino Lab'.

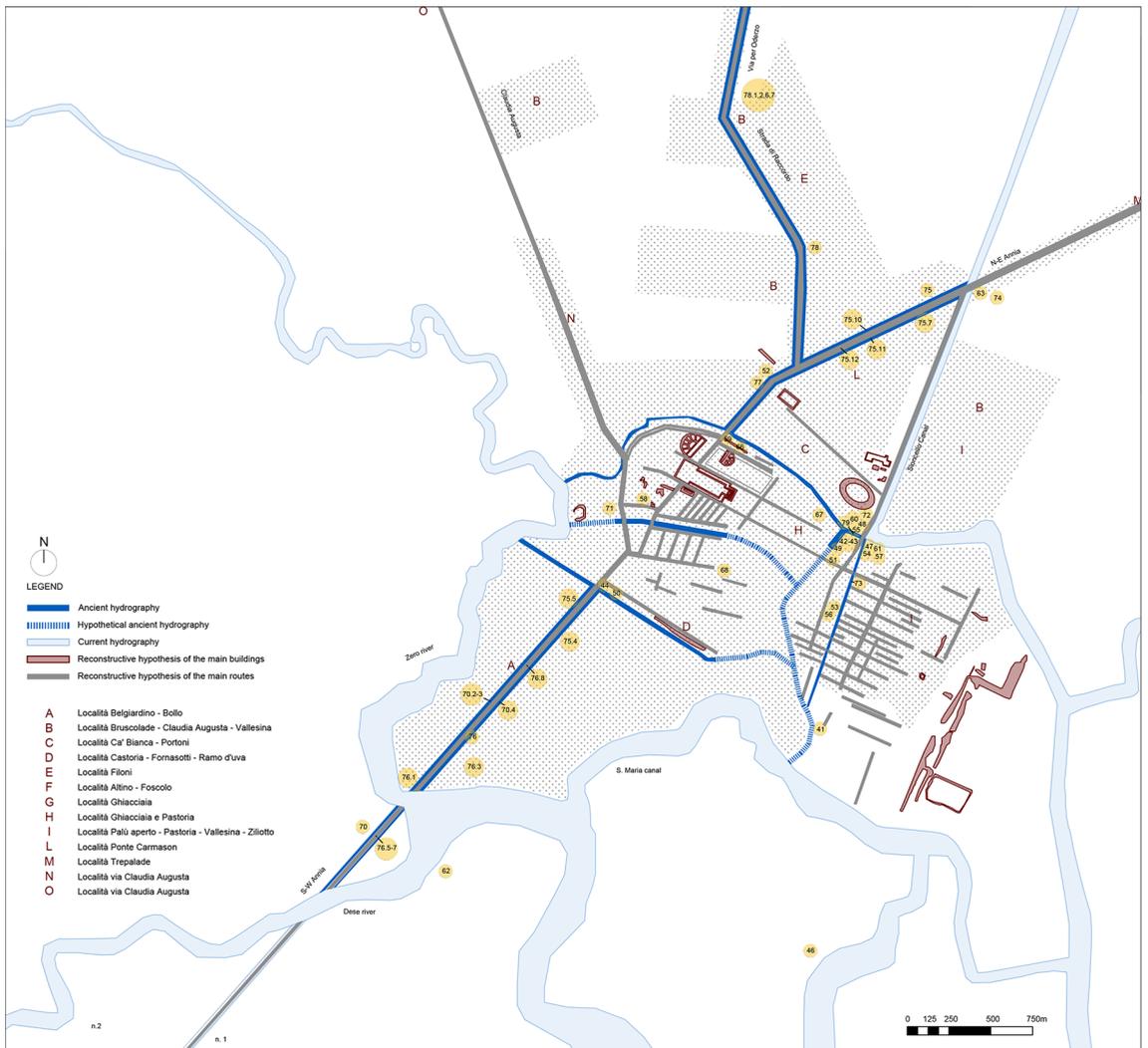


Fig. 4.—Map with location of the archaeological buildings and structures found in the town of Altino. The following structures are not present into the map: N. 69; N. 45; N. 80; N. 82, n. 10, N. 84; N. 86; N. 91; N. 93; N. 81; N. 83; N. 85; N. 88; N. 89; N.90; N. 92, due to their location in the lagoon area. (Map edited from Tirelli, 2011). Figure in color in the electronic version.

structures were built that led to the dismissal of the previous ones. The width of two of these ditches varies from 1,10 m to 1,50 m, with a depth of 0,40 m, whereas the northern is 3 m wide and 0,80-1 m deep. The southern ditch also marked the boundary between the holly area and the surrounding. The northern ditch had been interpreted as a temenos due to discovering a wall running aside it (Cipriano and Tirelli, 2009:64-67; Cresci, 2009:129-136; Capuis, *et al.*, 2009:40-59; Bianchin, 2009:23-38). These ditches presumably joined the north-south paleo-river across the urban centre. However, not only the city centre was affected by the presence

of artificial canals, as the existence of ditches dug together with the construction of roads demonstrated in the suburban area. The southern-western tract, as well as the northern-western tract of Annia road, had respectively two ditches running parallel to the road. It had been possible to recognise two phases of the northern ditch that run along the southern-western tract of Annia, which are related to the two phases of the road itself. Whereas during the first phase, dated to 153 B.C., the ditch appears to be an extensive infrastructure with a width of 7-10 m, during its second phase (*post quem* A.D. 1st century), narrowed in dimension with a width of 4,60 m.

Despite this, the southern ditch that runs along the same tract of Annia looks to have only one phase dated back to 153 B.C. and was more extensive than the northern one, with a width of the upper part of 10-13¹³. For what concerns the northern and southern ditches running aside the northern-eastern tract of Annia road, they appear not to be characterised by different phases. They have the same width of 3,50 m in the upper part, whereas the bottom has a width of 1,50 m. The enormous ditch excavated parallel to a road was the one running aside the ‘Strada di raccordo’ with a width of 15 m. A significant road planning that connected the city centre with the surrounding modelled the northern suburban area of Altino: the northern-eastern tract of Annia was leaving Altino in the direction of Iulia Concordia; the ‘Strada di Raccordo’ was connecting the Annia Road with the ‘Via per Opitergium’; the ‘Via per Opitergium’, as the name anticipates, was driving to Opitergium; the Claudia Augusta road was part of a strategic transalpine communication system (Cipriano, 2011:152; Tirelli, 2011:115). This system of road-ditch is common in northern Italy, where episodes of river flooding and the lagoon tidal cycle often occur. These natural phenomena not only endangered the existence of the towns but also agricultural fields and roads, especially when their course intersected with one of the river networks with large rivers. In this case, *terrei-aggeres* with ditches were built, consisting of a large amount of land used as a fill-in to raise the road surface by many meters, often consisting of levels of selected soil with a trapezoidal cross-section¹⁴. This is the technique used to create all the roads departing from and arriving at the city centre of Altino since the Iron Age. The first example of this type of which we have evidence is the proto-road backdated to Iron Age, whose track is remarked later on by Annia road. The southern-western tract of this road is composed of a stratified composition of gravel with sandy loam, a width of 2,20 m, but it does not seem to be associated with ditches. Above it, the Annia road stretches with a width of 12 m, composed of homogeneous layers of sand that have aside layers of organic mud, successively cut by the ditches of the following phase. These organic mud layers probably indicate episodes of flooding that occurred in the last period that would have caused the decision to raise the

13. The phases here mentioned concerning only the Annia, and not the proto-road that lies under it, dated to Iron Age (Tirelli and Cafiero, 2004:171; Ghedini *et al.*, 2002).

14. Another example is the road system exiting from the city centre in the Padova area (Bonetto and Busana, 1998: 88-93; Bonetto, 2000:151-158).

road surface further. At this stage, dated to 153 B.C., the definitive Annia road was built, enlarged with 19,80 m. It was composed of stratified layers of backfill sediments derived from further digging of the ditches, on the top of it a gravel layer with thick of 0,20 m. The first half of the 1st century B.C. is dated the 'Strada di Raccordo', whose backfill is constituted of sediments and was large 17 m. At the same time, the use of sediment was also applied for different types of aims as the levelling off the ground in case of sloped terrain, as it is possible to see under the Landing Gate where the backfill is composed of heterogeneous sediments with a basal organic layer, above which was a layer of brick flakes and on the top a layer of sterile clay (Tirelli, 1999:16; Cipriano, 1999:36-37; Bonetto, 2009:202); Moreover, the sediments were used for areal ground consolidation, which implied the use of selected sediments placed in different layers.

This last ground consolidation can be mainly observed in the area of the necropolis settled aside Oderzo road (or 'Via per *Opitergium*'), where there is areal backfill made of compact, plastic brown-dark grey clay with tracks of piles and clayey sand (Tirelli, 1988:112). Also, in the southern bath area under a prestigious building, there were backfills dated to the Age of Augustus (first phase of the building) and the Early Imperial Age (second phase). Here there are horizontal layers backfilled above ground composed of sand, clastic clay, and yellow clay (Gropo, 2010:65-67). The backfilling was also applied to deactivate waterways due to upcoming urban necessities. This action constituted a marking point between a period during which the Roman urban plan adapted to the previous urban scheme and the following time when the continuous growth of the city and the related necessities of space and a more direct connection with the suburban area made to change the original urban plan. The stretching of Sioncello canal, passing across the city centre, was backfilled at the beginning of the Age of Augustus (Tombolani, 1987:311, 319; Tirelli, 2001:295; Cresci, 2011:99).

Later, in A.D. end of the 1st century, the part of the watercourse flowing in front of the Landing-Gate was also filled. Layers of claim, loam, animal bones, marine fauna and pieces of coal, together with fragments of common and tableware ceramic and *amphora*, constitute this watercourse's backfilling. (Gambacurta, 1992:70-78; Tirelli, 2003:32-45; Bonetto *et al.*, 2020:192-193). The first deposits of this fill-in can be related to a progressive partial obstruction possible due to scarcity of maintenance of the waterway itself; the successive layers are composed of selected materials due to an intention to dismiss the watercourse. However, the fill-in of Sioncello canal results from a unique action due to the spread of the residential district. Apart from these extensive interventions, a more punctual use of this method has been identified to support the foundation only, known as a multi-layered soil sub-foundation. This particular arrangement of sub-foundation constituted of alternating layers of selected material, was laid at the base of the foundation in sub-horizontal, sometimes irregular, courses and centimetric thickness. This technique has been identified in correspondence to the southern wall of the prestigious building found in the southern area of the bath, where there are layers of clay and tiles disposed in alternate order. This structure belongs to the second

phase of the building, dating to the Early Imperial Age; afterwards, the structure found in the correspondence of the southern foundation of the cavaedium of the Landing Gate dated to the first half of the 1st century B.C. Here there is a stratified disposition of material composed of big fragments of sandstone, tiled burnt bricks, clay, burned loam, and then by alternating layers of clay and burned loam that also contained vegetable remains cinder and coal inclusions (Cipriano, 1999:37; Tirelli, 1999:17). The alternation of clay, with layers of fragments or whole burnt bricks, had the double function of draining and retaining water, stabilizing the soil and protecting the structures from the capillary rising of water¹⁵. Three rows of piles disposed of in a half-circle fixed in the earth reinforced the multi-layer soil sub-foundation (Tirelli, 1999:16; Cipriano, 1999:36-37; Bonetto, 2009:202).

The use of wooden structures is indeed one of the most widespread techniques employed in Altino, together with the embedded-amphorae structures. The wooden structures used in the city could be mainly of four types: simple squared or round piles fixed into the earth, simple squared or round piles fixed into the earth with a layer of bricks or stones above them, the assemblage of header planks jointed with piles, and the assemblage of planks placed on the piles to form a laying surface. The simple squared and round piles fixed into the earth have been found mainly in areas near watercourses (ditches, canals, or rivers), meant to support ponderous buildings and where the soil did not have load-bearing capacity. Evidence of this use has been found: below the foundation of quays along the waterways, beneath a foundation of the bath, below the sewer in Località Ca' Bianca, and under the foundation of massive monuments or corrals in the necropolis disposed aside the Northern-eastern Annia road (fig. 5), including Le Brustolade, and along the Southern-western Annia road. Another example is the piling of Building 5/D found in the lagoon area close to Lido del Cavallino¹⁶. The piles found in Altino until now do not have the tip reinforced with the metal covering as it was not necessary when it was not possible to reach the solid soil. In this case, the piles are called 'hanging pilling' because the wood cannot reach the underneath solid ground and are placed at a short distance between them with the additional purpose of preventing slipping and sliding in the incoherent alluvium soils (Antico, 2011:109)¹⁷.

15. A comparison can be made with the multi-layered sub-foundations evidenced in Aquileia, although in this case, there are gravel or sand layers instead of the use of layers of burnt bricks. However, they accomplished the same function (Bonetto and Previato, 2012:233.).

16. Although the lagoon area close to Lido del Cavallino is not concretely part of the city of Altino, it has been decided to include the structures found in this area as part of the city itself. Here has been identified the city so-called 'Porto a mare' ('Sea harbour'), from where a 9 m wide road that seems to follow the alignment of the centuration of Altino was found in the area of the Scanello canal at a depth of 3 m. Several buildings connected internally by minor paths have been identified in this area through underwater surveys and cores. The data that have emerged show the existence of an area rich in commercial traffic along roads or 'ditches' connecting the 'Porto a mare' with the city of Altino (Canal, 1998:57-72).

17. However, Vitruvius advised that when it is impossible to reach a solid soil layer because the terrain is composed of up to its most profound layer of marshland and loose soil, the area must be



Fig. 5.—Preparation of the soil: piles underneath a huge monument along the north ditch of Annia (from Scarfi, 1985).

Once the piles were fixed into the earth, layers of burnt bricks or stones could have been laid above the head piles to create a stable foundation surface. This is the case of piling (Tirelli, 1999:16; Cipriano, 1999:36-37; Bonetto, 2009:202) in the area of *cavaedium* of the Landing Gate, of the one underneath the warehouse in Località Portoni (Tombolani, 1986:71-100; Tombolani, 1987:324-331; Tirelli, 1993:29-40; Pujatti, 1997:115-129; Tirelli, 2001:295-316), and of the piles found in Località Fornasotti (Tombolani, 1986:71-100; Tombolani, 1987:324-331; Tirelli, 1993:29-40; Pujatti, 1997:115-129; Tirelli, 2001:295-316). Another variety of the wooden structure assemblage is the disposition of header planks jointed with piles to create a barrier to protect the structure from water's effects. This type of assemblage is typical of buildings constructed along a watercourse or a ditch. For instance, in the bridge (Tombolani, 1984:283-284; Cipriano, 1999:36; Gambacurta, 1992:72) of the Landing Gate, in the bridge found in Località Fornasotti (Tombolani, 1985:73-75; Tombolani, 1987:330-331; Tirelli, 2001:307; Tirelli, 2003:38), in the quay located in the northern-western area of the Museum, in the necropolis of Località Le Brustolade (Tirelli, 1984:281) and the one aside from the 'Strada di Raccordo' (Tirelli, 1985:48) (figs. 6, 7 and 8), and in the lagoon area close to Lido del Cavallino¹⁸. The last type of wooden structure used in the city is the assemblage of planks placed on the piles to form a laying surface, similar to the timber frame on which the foundation could be constructed. Only one case of this type of assemblage has been found in Altino, under a drain (Gambacurta, 2003:88) in Località Fornasotti — Capannone del Latte. For what concerns the species tree used for the wooden structures, they have not been determined in most circumstances. Eight of the ten examples recognized have been identified as *Robur* oak, a wood with good mechanical strength and high toughness, resistance to humidity and salt, as well as to weathering and atmospheric agents. Only one case proves the use of *Carpinus Betulus*, usually used as excellent firewood, and although its hardness and tear resistance, it is susceptible to humidity. The last example is the evidence of oak, whose species has not been better specified.

The embedded-amphorae structures have been the other widespread techniques employed in Altino¹⁹. As the use of wooden structures, the technique of embedded-amphorae structures is also intended to make solid terrain by tamping it down. The records discovered in Altino can be grouped into six main types within which other assortments have been evidenced: amphorae placed in a vertical position with the rim fixed into the earth; amphorae placed in a vertical position with the foot fixed

emptied. Then a dense piling of burnt willow, olive, or oak must be created with the help of machines, and the interstices must be filled with charcoal (Vitr. De Arch. 3.4.2.).

18. In the description of the assemblage of the wooden structures found in the building 2/D and structure 1/B not clear if the planks belong to the type of assemblage just described or to the type of assemblage of planks placed on the piles to form a laying surface, or if it is a mixed assemblage between the two types.

19. The writer has decided to name this type of amphorae evidence using the lexicon proposed by Antico Gallina. For an in-depth look at the terminology topic, see Antico Gallina (2011:180-183).



Fig. 6.—Wooden assemblage for ditch bank reinforcement along the ‘Strada di Raccordo’ (from Tirelli, 1985).



Fig. 7.—Other view of the wooden assemblage for ditch bank reinforcement along the ‘Strada di Raccordo’ (from Tirelli, 1985).



Fig. 8.—Detail of the piling (from Tirelli, 1985).

into the terrain; amphorae placed in a vertical position with both rim or foot fixed into the earth; amphorae placed in a horizontal position; amphorae placed in a horizontal and vertical position, and amphorae placed in an oblique position. The intent of the technique of amphorae placed in a vertical position with the rim fixed into the earth was to gain a structure capable of withstanding loads from above, acting like a dome. The bottom part operated on the diametrical arrangement of the arched structures that intersected at the highest point in correspondence with the foot, withstanding loads from above. However, when the entire amphora was used, it had lower bearing capacity because the support would have been reduced to a single circular crown, and it would not have been easy to compact the terrain between the neck and shoulder of the amphora. In this case, the lower mechanical resistance of the mouth compared to the tip could be compensated by the fact that part of the vertical load was absorbed by friction, where there was sufficiently compact soil between the bodies of the containers (Frassine, 2013:95). This embedded-amphorae structure could be areal or linear extended as the amphorae

structures found in Località Fornasotti (*Archeologia Veneta* 1991:56), in Località Palù Verto (Tirelli and Toniolo, 1998:105), and the necropolis along the southern-western Annia road. Within this type, four particular assortments have been noticed: two of them have been employed together with *Robur* oak planks jointed to piles or only piles (*Archeologia Veneta* 1991:41, 64.) fixed into terrain between the amphorae. Further, in one case, the amphorae were filled in with sediments, ceramic fragments, bricks, and loom weight; above this structure a layer of ceramic fragments, pebbles, and marble fragments. In both cases, the embedded-amphorae structures are in the areas along the Southern-western Annia and its ditches. Another particular assortment has been evidenced in the necropolis of northern-western Annia (*Archeologia Veneta* 1991:75) where there are two alignments of amphorae, one over the other. The last assortment noticed in this type is the case in Località Fornasotti (*Archeologia Veneta* 1991:56) where the amphorae are fixed into yellow clay. The application of clay would have been instrumental in increasing the bearing capacity of soil in geotechnical reclamation when there could be a loss caused by the presence of an underground water system. The second type of embedded-amphorae structure, placed in a vertical position with the foot fixed into the terrain, supplied the distribution of the forces on the ground. In this case, the material cast from above could easily fill the space between the necks and be compacted. However, to make the system work properly, the rim had to be closed to avoid the fill-in of amphorae and the nullification of the soil lightening effect²⁰. Despite this, the examples found in Altino have shown different solutions with the open rim as in the cases located in the lagoon area close to Lido del Cavallino (Canal, 1998:63, 66), in the necropolis in Località Le Brustolade, and Località Fornasotti. In this last case, the amphorae had sawed rim and foot, and a layer of terrain 0,50 m thick was lying above them. Another example evidenced was sawed amphorae with fill-in composed of mortar with terracotta fragments, contained into a squared wooden structure made of header planks jointed to the piles in the necropolis along the Northern-Eastern Annia road. An example of amphorae joined with mortar, with fill-in composed of sediments and sand, was found in Località Fornasotti. The use of these selected materials has to be interpreted as a reinforcement of the amphora dome when the strain of the arched structures was no longer sufficient to support the load of the structure built above them. A peculiar case is the one found in Val Pagliaga (Tirelli and Toniolo, 1998:105) where all the amphorae had one hole in the shoulders. The hole acted as venting point to prevent the air inside the body from going under pressure (Frassine, 2013:97-98). Amphorae placed in a vertical position with both rim and foot fixed into the earth constituted the third type of embedded-amphorae structures, which has been evidenced only in the necropolis of the Northern-Eastern Annia (Tirelli, 1999:10). This example has linear extension and shows a successive addition of embedded-amphorae structures disposed at a

20. For 'soil lightening effect' is meant the replacement of the soil place with more substantial material, such as amphorae, to restore the initial stress conditions when the construction process is completed (Frassine, 2013:96).

right angle and placed in a vertical position with the rims fixed into the terrain. This change of disposition and homogeneity in the position of the amphorae can be seen as the awareness that the previous assemblage did not work correctly. In addition, the spaces between the amphorae were filled in with ceramic fragments, whose function has to be related to the ventilation for the 'salubrity' of the structure supported. The fourth type of embedded-amphorae structure is the amphorae placed in a horizontal position into the terrain that could have a linear or areal extension. The amphorae so disposed were creating a structure of continuous, parallel arches in the upper and lower part, formed by the walls of the amphorae (Frassine, 2013:96). In this way, the embedded amphorae had good resistance to stresses and high bearing capacity, like the case found in the necropolis of Northern-eastern Annia. In order to strengthen the bearing capacity of these containers, in one example found in the necropolis of the Southern-western Annia road, it has been evidenced that some of the sawed amphorae contained small ones (Marcello, 1956:85). Only one example (Tirelli, 1983:351) in the necropolis of Località Le Brustolade proves the assortment of rows of eight amphorae, one connected to the previous and the next one by a foot-rim joint. In this case, the amphorae constituted a sort of conduit that attracted the water table moving it away thanks to its slope (Frassine, 2013:97-98). The fifth type of embedded-amphorae structure shows both uses of amphorae in vertical and horizontal positions. As explained, in both cases, the forces acting on the amphorae structure are solved by compressive stresses, thereby eliminating tensile stresses and absorbing friction with the terrain. In two assortments here evidenced, the amphorae are sawed: in one case, the foot is sawed, and in the other one, the neck is sawed (fig. 9). If it is the neck to be sawed when the amphorae are in the vertical position with the rim fixed into the earth, it resulted in a secure annular support surface that improved the bearing capacity of the structure itself (Frassine, 2013:95). In the necropolis of Northern-eastern Annia road, amphorae in a horizontal position along the perimeter, contained in the inner part of the structure amphorae in a vertical position with the rim fixed into the earth. Ceramic fragments filled in the interstices. In the necropolis Le Brustolade, an example of the amphorae placed vertically in the inner part of the structure, and the ones in horizontal position had the rim towards the ditch. In both cases, the disposition of amphorae in a horizontal position along the perimeter of the embedded-amphorae structure seems to be a work of containment of the amphorae positioned vertically. This function is clear in the last case where the amphorae in horizontal position are located along the ditch bank, a delicate point where structural failure could easily occur. The last type of embedded-amphorae structure technique identified in Altino is the one placed in an oblique position, with the rim fixed into the terrain²¹. In two of the four cases has been possible to determine the inclination of the amphorae, estimated at 70°. In this typology, the sections of

21. Only one case found in the necropolis along the Northern-eastern Annia road has not been specified if the rim is or is not fixed into the terrain (Tirelli and Toniolo, 1998:94-96).



Fig. 9.—Example of embedded-amphorae structure (from Tirelli and Toniolo, 1998).

the artefacts will be ellipses that would receive the loads in the upper part, while the lower one would transmit the strain into the ground. Thus the amphorae placed in an oblique position create elliptical arches that are more resistant than the horizontal ones (Frassine, 2013:96-97). In most cases, this technique has employed Dressel 6 B, followed by Dressel 6 A, Lamboglia 2, Dressel 1 C, flat-bottomed wine amphorae, and in three cases, the type of amphora has not been identified. Among all these classes of amphorae only Dressel 1 C, employed in one case, has an oblong body that tends to be more spindle-like. In contrast, the others are shorter, with an ovoid or elliptical body in profile. The body's width in Dressel 1 C is 0,28-0,29 m, and the wideness of the other amphorae body ranges between a minimum of 0,34 in Dressel 6 B and 6 A to a maximum of 0,42 m in Lamboglia 2. These different features between the classes of amphorae determined the most prevalent use of one class instead of another. A bigger width of the amphorae could span a larger space and have more resistance to loads thanks to the creation of a more stable circular crown formed by the body of the amphora that transferred the compressive stresses to the terrain. The last technique used to prepare the soil recorded in Altino was depositing stone and burnt brick fragments that were set into a trench or areal digging or as bank reinforcement in correspondence of ditches

or waterways. Examples of the first case are in the necropolis of Northern-eastern Annia, and seven in Località Le Brustolade, where there is a structure with courses of bricks. Six deposits of a structure are composed of bricks, tiles, and amphora fragments; in one deposit of a structure have been recorded courses of sandstone blocks. The process of excavating a trench or an areal digging in which were set the material just mentioned had the intent to modify a defective natural environment condition by inserting more compact and durable material that could also give ventilation to the supporting structures. Despite this, different purposes had the terracotta deposits disposed along the ditch banks that were associated with the installation of the wooden structures found in the necropolis Le Brustolade (Tirelli, 1983:350-352) (fig. 10). The examples recorded here show the use of header planks linked to piles or only piles disposed of along with ditch banks and behind them the terracotta deposits. In this case, artificial banks were created to protect the areas near the ditches and the road from bank erosion and frequent flooding.

Foundation

Among the building processes operated during the construction, the second main conserved in Altino is the foundation. According to the majority of the records found, burnt brick is the preferred material for foundation, employed in fragments, entire, and with other materials. The foundation's plan in burnt brick could be equally simple linear, irregular linear, or a platform. It has been noticed the preponderant employment of *sesquipedales* padano in the foundation, the most common brick in the northern regions²². *Bipedalis* was only used to a limited extent because it was an expensive material. It is attested only in the first chronological phase of the domus Fornasotti (fig. 11), where it was used with *sesquipedales* placed in horizontal courses and joined by row clay. However, during the second phase of the domus it is possible to observe different material employment in the foundations, with the use of *sesquipedales* with tiles, or only *sesquipedales* (Pujatti, 1997:115-129; Pujatti, 2005:161-172). The employment in horizontal courses of tiled *sesquipedales* with tile whose flaps are facing upwards, recall the 'compressed tile fragment technique' (Type 2), where the flaps are the facings of the structure. It was an economical technique because it employed reused material (Bacchetta, 2003:49). The *sesquipedales* are used in fragments, entire, and associated with parts of terracotta cornix layed in horizontal courses only in the foundations of the two big corrals in the necropolis Le Brustolade (Tirelli, 1984:281; Tirelli, 1985:37; Cao and Causin 2006:239-263). The use of *sesquipedales* in the foundation does not seem related to a particular type of building; we can observe it in civil and holly

22. Considering that the *sesquipedales* used in the Domus Fornasotti belong to the type of *sesquipedales* padano because of their dimension, it is possible to assume that also the others found in the foundations in Altino were *sesquipedales* padano, although no specified.



Fig. 10.—Embedded-amphorae structures and backfill contained by wooden structure along the ditch (from Tirelli, 1985).



Fig. 11.—Detail of the wall structures of the building of Località Fornasotti (from Zaccaria, 2001).

buildings, as well as in private constructions (Tirelli, 2001:485, 481) and burial contexts. There is a single exciting case of using unburnt brick combined with burnt brick fragments for the foundation of a plinth of the sanctuary in Località Fornace. Brick fragments were mixed with non-hydraulic mortar or hydraulic mortar, as in the case of the foundations of the bath, to obtain the concrete, and eventually with the addition of stone flakes as in the foundation of a circular tomb. The evidence of reused material such as tile and pottery fragments is quite frequent. Specifically, tile fragments were used for the preparatory layers of the floor, often alternated with a layer of a mixture of lime mortar, gravel, and stone fragments, with a layer of purified mortar, or with a layer of a mixture of white mortar with stone fragments. The use of stone is also observed, although less frequently than burnt bricks. The high transport fees from the quarry to the construction site caused an increase in the cost of the building itself. Therefore a limited large-scale use of stone is observed, reserving it for urban contexts and the construction of buildings of great importance, preferring instead brick, which was much cheaper and easier to make²³. In fact from the records found in Altino it is observed the use of stone in: foundations of civil buildings such as quays and a warehouse, or of other buildings of the harbours (Canal, 1998:55-56, 59, 72); for some of the foundations of the Landing Gate, for bridges, for corrals or monuments in the necropolis (Scarfi, 1985:130-132), and other building not better recognized in their intended use. Among the identified stones employed in foundations, Sandstone is the most commonly used type of rock, employed between the Late Republican period and the Late Imperial period²⁴. Sandstone is a sedimentary rock of 50% sand mixed with minerals such as quartz, feldspar, mica, chlorite, etc. Depending on the type of sandstone, it may be more or less suitable for exposure to weather conditions; it is compact and resistant. Other characteristics are abrasiveness and good compressive strength. The sandstone employed in the city was usually used in the form of finished or unfinished blocks or ashlar and arranged in regular or irregular horizontal courses, as in the Landing Gate, in the bridge of Località Fornasotti, in a quay, and in the warehouse. Another type of rock identified in Altino is the Aurisina limestone, employed in parallelepiped blocks arranged in horizontal courses joined with lead clamps for the foundation of a corral in the necropolis of Oderzo road (Tirelli, 1988:111-112; Cao and Causin 2006:239-263). Aurisina limestone has a high calcium carbonate content of up to 99,50 %. In all its varieties, it has an excellent petrographic, chemical, mineralogical, and physical-mechanical characteristic, such as resistance to wear and impact. The use of a not better-specified type of limestone is proved only in one building, dated between the end of 1st century B.C to A.D. 4th century. The Trachyte is the other stone material used for the construction of the foundation, employed as finished blocks in a massive monument in the necropolis of the

23. This assumption involves the sites located in the northern Italy in general, as they are set on the plain, far from the quarries (Bacchetta, 2003:83).

24. The earliest example is the foundation of a quay in the eastern area of the Museum, and the latest evidence is the foundation of the warehouse in Località Portoni.

Northern-eastern Annia road (Scarfi, 1985:130), as flakes together with sandstone flakes in the warehouse, and as flakes together with burnt brick fragments and mortar in the bath. Trachyte is a durable stone with mechanical properties comparable to the best granites: resistant to wear, compression, water, and salt, and is not slippery. This last characteristic makes it suitable, especially for road paving (Previato, 2010-2011:105-107). Evidence of the reuse of stone material in A.D. 4th-5th century are two foundations where polygonal blocks previously used for the crown of the road are arranged without course.

Hydraulic drains: conduits, basins and wells

Among the types of structures found in Altino, drains and sewers are the most attested. In all the cases where the material has been described, they are made of burnt bricks, with the broader use of *sesquipedales*, employed mainly as bottom and covering material (Pujatti, 1997:119-120). The use of *sesquipedales* as walls and covering material is visible in the drains found in Località Ghiacciaia (Bressan *et al.*, 2018:243), in the bath (Cipriano, 2010:124-125), and in a sewer found in the eastern urban area (Bressan *et al.*, 2018:245). The single example in which the structure is made entirely of *sesquipedales* is the sewer discovered under the *kardo* (fig. 12). This was a massive infrastructural work collecting all the discharges of the north-east area of the town, built in the Age of Augustus- A.D. 2nd century. The use of half *sesquipedales* as covering material has been noticed in the drains of five quays in the northern-western area of the Museum. Unusual examples are the drains of a quay in the northern-western area of the Museum, where wooden planks are used as bottom material, dated to the end of 1st century B.C.- A.D. half of 1st century. Another remarkable example is the drain found in Capannone del Latte. The walls are in tiles fragments with their flaps facing upwards, containing a fill-in of burnt brick fragments; here, the tiles were also used as bottom material. In four cases, the covering of these hydraulic supplies has survived, evidencing the use of vaulted covering, curved covering, and flat covering in the four drains that were linked to the main sewer. The more ancient drains found in Altino have been discovered in Località Fornace dated to the first half of the 7th century B.C., that show loam and pile holes tracks.

Basins and one pool are the second types of structures recorded in Altino: basins were found within the workshop site, in the domus of Località Fornasotti where the textile fabric was processed²⁵, in the *pars rustica* of the suburban villa (fig. 13); one hydraulic structure has been discovered in connection to the main sewer found under the *kardo*. The last structure was a pool in the bath located in the urban centre. Concerning material nature, only the bath pool has marble and

25. This hypothesis is supported by the presence of several basins of a different dimensions, the finding of loom weights and the organisation of the rooms (Zaccaria, 2001:75).



Fig. 12.—Sewer found in Località Ca' Bianca (from Tombolani, 1985).



Fig. 13.—Northern basin of the suburban villa (from Cipriano, 1998).

limestone squared slabs as bottom and walls coating. The material coating was crucial to keep impermeable bottom and walls from water, although it is not often preserved. The material coating could be made of clayey loam, hydraulic mortar, or *cocciopesto* that could also be used as the material of the construction itself. In the majority of the basins, the walls are constructed with bricks (Cipriano, 1998:127, 137; Pujatti, 2005:166-167), and only in one case the tiles are employed.

In Altino have been discovered four wells: three (Cipriano and Tirelli, 2009:61-63; Tirelli, 2000:50; Tirelli, 2003:42) are in the sanctuary of Località Fornace (Bonomi and Malacrino, 2009: 229-246; Bonomi and Malacrino, 2011:71-80) and one is in the suburban villa (Calomino, 2012). The most ancient one is dated to the first half of 7th century B.C. and belongs to a pre-sanctuary phase of the area of Località Fornace, whereas the most recent ones are dated to A.D. 1st-2nd century. In two cases, the evidence of a shaft has been identified: the first shaft has a squared shape, and the second one has a subcircular shape. This indicates how the well was constructed: the presence of the shaft reveals that the trunk casing was built in a giant pit, whereas its absence shows that the trunk casing was built against loose soil. All four wells have a circular plain, probably because a circular shape could offer more excellent resistance to the thrust of the surrounding terrain (Vigoni 2011:21-22). In all the examples, at the base of the well, there is a wooden structure that could be a wooden-lined box covered by small wooden slats or made of planks or four wooden beams arranged together. The only exception is the well found in the suburban villa, which has not been completely excavated. The presence of these structures, often made of wood because it is more resistant to contact with water, was crucial to support the load of the trunk casing material when the soil reached by the excavation of the well was not stable. At the same time, these wooden structures and the functional equipment material could work as a filtering system. For functional equipment materials are meant those materials, such as purified sand, gravel, and other draining soil, positioned at the bottom of the well shaft to act as a filtering system and isolating material (Vigoni, 2011:24-26). These layers of sediments could reach a thickness of 1 m, as in the example of the sand layer of the southern well. The trunk casing material arranged on the wooden structure was made of small wood slats in the well dated to the first half of the 7th century B.C, whereas the wells dated to the Roman period were composed of bricks. The demand for the trunk casing material for wells had led to the elaboration of a new burnt brick form: the arch-shaped brick, called 'pozzale'. Its use can be seen in two wells dated to the Roman period and, in one case, arranged without mortar between the courses. Only in one case has been found the head casing material, composed of a puteal. The diameter of the well head varied between a maximum of 1 m to a minimum of 0,60 m; only in one case is reported the base diameter of 0,50 m. The southern well is the deepest, with 3,40 m.

INTERACTION BETWEEN ARCHITECTURAL DECISION AND GEOMORPHOLOGICAL CONTEXT

This interaction between the geomorphological context and the architectural decision is not to be looked through only in the Roman period, as its origin has to be dated back to the first settlements in this region. The proof is that the ridges beneath the city of Altino are of anthropogenic origin and started to form in the Prehistoric period (fig. 14). The digging of canals started in the Roman period with the creation of the Sioncello canal, a series of ditches aside from the roads in the suburban area and of ditches in a defined area such as in Località Fornace, constituted the most impact human activity occurred in this region during ancient time. Water control in an area surrounded by watercourses and a groundwater-fed system was vital. Successive episodes of groundwater rising occurred since LGM, and the organic mud layers (in Annia road stratigraphy) prove frequent flooding episodes. In addition, the gradual extension of the lagoon upstream from the 1st century B.C. constituted a considerable challenge for the population. Although the dig of artificial canals since Protohistory time can seem controversial in an area already rich in watercourses, in reality, they worked not only to control river floods and the ingression and outflow of tides coming from the lagoon but also to lower the level of the groundwater table²⁶. The continuous draining and flowing of water in the canal induced a curve of depression in the surface of the groundwater table (cone of depression), which became gradually greater the closer it was to the ditch. This depression depended on the permeability and the type of sediment within which the channel is built, as well as on its depth, width and quantity of water drained (Frassine, 2013:78). Consequently, the formation of fens and marshes area was avoided, fulfilling the environmental requirements for living²⁷. These canals could be dug in a natural depression or a pre-existing riverbed, as seems to be the case with the east-west canal that crossed the city centre. They also constituted agricultural canalization works and were used for trade navigation, as evidenced by the presence of piers along the riverbanks.

The city lies on an alluvial plain, on the last surface of LGM, composed of sand, silty sand, and clay sediments, with the groundwater-fed river system flowing between 1,5-3 m depth from the surface. Within these layers, peat and organic layers proved episodes of the waterlogged area during the past. The sand is predominantly fine and silty with a coefficient k (permeability coefficient) between 10^{-4} m/s for fine sand and 10^{-7} m/s for silty sands (Tosi *et al.*, 2007:120). Loose soils, peat soils, marshy soils, etc... are defined as ‘bad soil’, which has no load-bearing capacity without consolidation measures (Giuliani, 2006:164). This soil characteristics well explain the reason for the widespread of techniques for the preparation of soil in

26. For the canals dug in Protohistory, see the ‘Introduction’ section.

27. In contrast, ‘Those places, however, which have stagnant marshes, and lack flowing outlets, whether rivers or by dykes, like the Pomptine marshes, by standing become foul and send forth heavy and pestilent moisture’ (Vitr.DeArch.1.4.12).

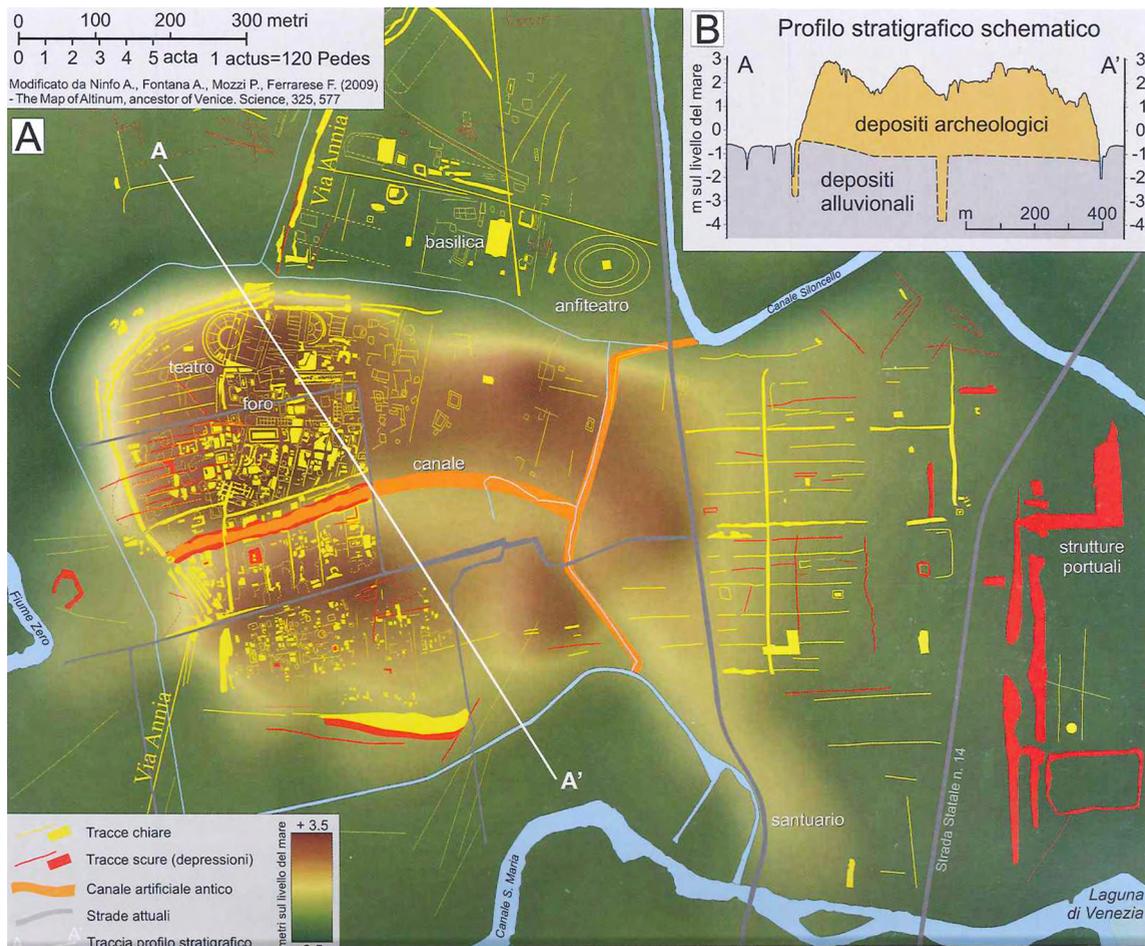


Fig. 14.—A) Plan of the Roman city of Altino from Remote Sensing, overlapped the DTM; B) Schematic stratigraphic profile of the archaeological ‘mound’ of Altino (from Mozzi *et al.*, 2011b:fig. 4).
Figure in color in the electronic versión.

the city of Altino²⁸. Ancient builders could overcome the obstacles imposed by the natural environment by exploiting all the resources at their disposal. Because since the Holocene period, the angiosperm has been predominant in this area, and a series of inscriptions have confirmed wood trade with Alpine valleys, the use of wood for creating good soil compactness is undeniable²⁹. The criteria for the choice of tree

28. A remarkable presence of techniques for the preparation of soil can be observed mainly in the necropolis areas due to the spread of the excavations from the early '90.

29. Cfr. *infra*; Specifically, an inscription found in Feltre mentioned that the *Collegium fabrorum* of Altino dedicated a statute to a patron, C. Firmio Rufino, who belonged to Menenia tribe from Feltre. This inscription indicates the wood trade between Cadore and the lagoon surroundings: the departure point was the site of Berua, passing across Feltre, and then using Piave river as means of transport; the arrival point was Altino (Anti, 1956:19, 23).

species were primarily load-bearing capacity, the possibility of obtaining suitable pieces, and, immediately afterwards, resistance to air, water, and woodworm³⁰. The first dated employment of wood structure for the preparation of the soil was collocated in the Late Republican Age of Augustus, and it spread till the Late Imperial Period. The wood was used to make piles disposed to a regular distance or very close to each other: the space between them is usually commensurate with the load to be supported and the interval between the rows of piles. The piles were beaten with a hammer usually until ‘absolute rejection’, which occurred when the pile had reached solid ground. This structure transmits axial stresses to the ground through tip resistance and lateral friction (Antico, 2011:109). These wooden structures for land reclamation not only improve the geotechnical conditions of the soil, increasing its load-bearing capacity, but also enable the stabilization of the soil and the control of wetlands (Frassine, 2013:100-101). The use of wood structures was also functional for the reinforcement of bank canals, ditches, and water streams and to protect the structure itself from the effect of water. In this case, a fundamental modification of the banks was operated, adding fill material to compact the bank.

Even though literary sources do not mention the use of amphorae for construction, the evidence of their employment has been widely recorded in Altino and the Cisalpine area. The widespread employment of this technique started in the first three decades of the 1st century B.C. in the necropolis of the Northern-eastern Annia road. It continued till A.D. 1st-2nd century when the last example was found in the lagoon area close to Cavallino. The records found in Altino show six types of embedded-amphorae disposition, commonly placed underground digging next to or under walls, under corrals, and along watercourses, and also used together with wooden structures. When the amphorae were fixed in a water-saturated area, a hole was made in their shoulder, letting the water up to its maximum capacity. In this case, the hole acted as a venting point to prevent the air inside the amphora body from going under pressure, improving the condition of the soil³¹. Because the groundwater-fed system was close to the surface, the amphorae were in rows, one connected to the previous and the next by a foot-rim joint, constituting a conduit. This conduit leads to form a cone of depression and, consequently, the lowering of the water table, densification of the soil, and increase in its bearing capacity (Frassine, 2013:97-98). Its features, such as meagre specific weight, entire foot and very high resistance to loads, made *amphorae* suitable for their employment in construction. A broader preference for amphorae with elongated and wide bodies and pronounced taproots has been recorded (Dressel 6 B). Together with similar

30. The use of *Robur* oak, and *Carpinus Betulus* is in contrast with the use of Alder advised by Vitruvius when it comes to construct piling in direct contact with water (Vitr.DeArch.2.9.10). For an in-depth look at the use of wood and its characteristics in Roman construction see Giuliani (2006:241-246).

31. A comparison can be made with the case of the embedded-amphorae structure found in Padova, on the western side of Prato della Valle, an area that suffered from water capillary rise problems (Frassine, 2013:97, 98).

features between different classes of amphorae, the place of origin and the area of distribution of specific classes of amphorae must be considered decisive factors of their employment. Except for Dressel 1 C, produced mainly in the Tyrrhenian coastal area and commonly distributed in the western Mediterranean, the other *amphorae* classes had workshops along the Adriatic coast or the northeast region of Italy. The *amphorae* could transmit the distributed load to the soil beneath them. This geotechnical work was determined by the type of soil with which they were in contact, which also determined their arrangement: footwork or lateral friction. Their use for both geotechnical reclamation is evident, as they work as ground consolidation to support the above structure. In addition, they were used for hydraulic reclamation, for instance, ventilation systems, sometimes infiltration, isolation, or thermal stabilization. (Antico, 2011:198-199). The discriminating factor between the amphora system and the wooden structure system in the case of Altino has to be related to the structure's load to support that required wood system on one side and to the hydraulic reclamation acted by the amphorae system on the other side. A more punctual construction technique, whose function was to absorb the load of the foundation, was the 'multi-layer soil sub-foundation'. The earliest example of a multi-layer soil sub-foundation found in Altino is the one under the southern foundation of the cavaedium, dated to the first half of the 1st century B.C. Selected material laid in sub-horizontal, or irregular courses with a centimetric thickness with loose sediments of various granulometric sizes that receive the foundation plane of the building above, absorbing its load in itself (Bonetto and Previato, 2012:250-251). It differs from the foundation because it does not transmit loads of the construction above to the soil in line with the load-bearing capacity of the soil itself (Giuliani, 2006:161). The homogeneous or stratified sediments of different granulometric sizes replaced alluvial soils characterized by low load-bearing capacity, with this sub-foundation with low specific weight to not overload the weak soil. *Terrei aggeres* were used for the construction of roads since the Iron Age, but with a remarkable increase in height and width in Roman time: from a width of 2,20 m during the Iron Age to 19,80 m in 153 B.C. The creation of elevated structures allowed the protection of the transit above the road and worked as a barrier against river flooding.

Geomorphological and environmental context also influenced the nature of the material used to construct foundations. Bricks are the most widespread material employed in foundation construction due to the massive presence of its raw material in the region: clay. The easy transportation and, thus, the low-cost acquisition of the material itself is not considered secondary reasons. The bricks were made from clay mixed with water and often of sand, straw, and a small quantity of pozzolana. The positive features that favoured the spread of brick in Roman buildings were its regular and constant shape, its lower specific weight than one of the stones of equal strength, and its homogeneous and more easily controlled compression and structure (Giuliani, 2006:199). The most common type of brick used in Altino and in general in the northern area was the *sesquipedales* padano, which differ from the canonical one for the dimension: canonical *sesquipedales* 0,45 m; *sesquipe-*

dales padano 0,30 x 0,45 m (Giuliani, 2006:206). The first example of the use of *sesquipedales* in Altino dates back to the second half of the 1st century B.C. It was widespread till A.D. 1st-2nd century when it is dated the last example in the lagoon area close to Lido del Cavallino. However, examples of the employment of stone in the foundation are observed in the construction of buildings of great importance and everyday use (e.g. piers). The use of Sandstone spread from the Late Republican to the Late Imperial Period, whose basin of origin has not been identified. However, due to the geographical proximity, it is possible to assume that it was in the pre-Alps in the Belluno area³². The Aurisina limestone comes from the area of Carso triestino, in the north-east upper part of the Adriatic sea (Previato, 2010-2011:57-64). This material had to be transported to the town by sea, evidencing a stone trade between the two areas. Building material trade with the Euganean hills has been evidenced by the use of Trachyte stone that arrived through fluvial trade thanks to a series of *fossae*. The use of Trachyte has been recorded in structures from the Age of Augustus to A.D. 3rd century. The use of the other type of stones has been observed for a period ranging from the Late Republican to the Late Imperial Period. The other archaeological evidence found in Altino are drains, sewers basins, fundamental infrastructure for a city life. All the wells found in Altino deserve special attention: from the first example dated to the first half of the 7th century B.C. to the last ones found in Località Fornace dated to A.D. 1st – 2nd century. These structures summarise a *continuum* in the application of some building techniques originated in the Venetic period and maintained during the Roman Age. The wooden-lined box placed at the base of the well trunk to support the casing material and, at the same time to filter water is an example. This technique is applied in wells dated to the 7th century B.C. and A.D. 1st-2nd century. What changes here is the type of material used as trunk casing material, which no longer consists of wooden slats, but of a particular type of brick, widespread only in Northern Italy: the pozzale. This is a circular arch brick created as a specific element for wells construction; it can be seen as the most representative result produced by the spread of brickwork in northern Italy (Vigoni, 2011:30). Also, the practice of digging canals seems to have originated in the Venetic Period and broadened during the Roman age with changes in the *fossae*'s depth and width.

CONCLUSION

All the reasons here are explained, and the analysis of the presented cases shows the widespread use of techniques for soil preparation in Altino that are the

32. A potential clue to this assumption is the existence of small quarries in the area of the 'Costa Fragona' and on the side of the Rio Caglieron, from which the so-called 'dolzha stone' was extracted. The 'dolzha stone' is a sandy, molasses-type sandstone well suited for processing. Big blocks of finished molasses sandstone are employed in the foundation of the Landing Gate (N. 42.5) and in a quay (N. 47.2) in the eastern area of the Museum.

core of the interaction between environmental context and architectural capability owned by ancient builders. The concept behind this building solution was radical and utilitarian: replace loose soils characterized by no load-bearing capability with structures, such as wooden structures, embedded-amphorae structures, sediments backfill, and multi-layer sub-foundation. In addition to guaranteeing land reclamations and control of river floods, groundwater tables and lagoon tides, canals and ditches were dug. Given the lithology, the slope gradient, the thickness and the depth of the groundwater table, different techniques were applied to contrast the state of the soil. Whether all these structures were used to improve the geotechnical condition of the soil, they were acting in different functions. Wooden and embedded-amphorae structures were used to improve soil resistance to load-bearing structures by tamping them down with amphorae or piles. This action transmitted compressive stresses to the beneath soil or axial stresses to the soil by lateral friction and tip resistance (in the case of piles). The multi-layer sub-foundation absorbed the load foundation, and the sediments protected the structures from capillary rising water (as the amphorae). Therefore, with good reason, the city of Altino can be defined as a meeting point between the rivers and the lagoon where human construction activities heavily conditioned the environmental context, as well as the geomorphology of the soil brought to the development of new building techniques to contrast the weakness of the environment.

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