

Puteoli and the *ripa puteolana*: archaeological and geological insights into a submerged Roman waterfront

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Abstract

The submerged Roman districts of the *ripa puteolana* present along almost 2 km of coastline between the center of the port of *Puteoli* (now Pozzuoli, Italy) and the *Portus Julius* constitute an underwater archaeological area of extraordinary importance. The headquarters of merchants and *peregrini* from every corner of the Mediterranean in the *vicus Lartidianus*, and the endless rows of *horrea* (warehouses) at the service of the fleets of Rome in the *vicus Annianus* have been only scarcely explored in the past, due to the heavy and impactful presence of the industries that formost of the twentieth century characterized the west coast of modern Pozzuoli. With the project “Tra terra e mare. Studi e ricerche nelle aree costiere dei Campi Flegrei/Between land and sea. Studies and research in the coastal areas of the Phlegraean Fields”, born in 2021 from an agreement between the SABAP for the metropolitan area of Naples and the University of Campania Luigi Vanvitelli – with the collaboration, for the submerged areas, of the Scuola Superiore Meridionale, a systematic documentation program for the *ripa puteolana* has finally been launched. The underwater research conducted in 2021, 2022 and 2023 led to the reconstruction of the entire ancient waterfront, on the basis of an aerial photogrammetric survey calibrated with direct dives, to the identification of submerged *horrea*, *granaria* (granaries) and quays in the *vicus Lartidianus* and *vicus Annianus*, to the localization of a previously unknown peninsula, home to administrative premises of the harbour, and above all to the discovery of a submerged temple of the Nabataeans in *Puteoli*, unique outside of Nabataea. Together with these archaeological results, the collaboration established with the INGV enabled the collection of important new data on the relative sea level change in the bradyseismic area of *Puteoli* during the period between the 1st and 4th centuries AD, when an impressive effort was made to rebuild the breakwaters in response to the relative increase in sea level.

Keywords: Puteoli; Bradyseism; Roman era; Ripa Puteolana; Geoarchaeology

1. Introduction: The project “Between land and sea”

The Campi Flegrei caldera has been characterized by intense volcanic activity, dominated by three main phases with at least seventy explosive eruptions and minor effusive events. These have shaped the current morphology of the area, which is defined by a series of volcanic cones of different shapes and sizes, as well as extensive flat areas both along the coast and inland.

In Pozzuoli there is a coastal plain composed of marine and transitional sediments interbedded with abundant traces of human activity, and an inland flat area, the marine terrace of La Starza, which has been uplifted by at least 50 meters over the past 5,000 years and is bordered to the south by a steep cliff that is active only in the Rione Terra sector (Di Vito et al., 1999).

Geoarchaeological evidence shows that the area has been affected by significant ground-deformation phenomena, active since the formation of the caldera and later associated with the main eruptive phases. Urbanization of the area has been ongoing since the Greek period, and numerous traces can be found in almost every sector of the caldera, including the area now occupied by the Gulf of Pozzuoli.

The study focused on the sector located downslope of the marine terrace cliff (Fig. 1), in the western coastal zone of the municipality of Pozzuoli.



Figure 1. The Phlegraean Fields caldera and the area under study at *ripa puteolana* (red box).

The *ripa puteolana* today represents an archaeological context of extraordinary interest and immense potential. Until now it has been scarcely documented, largely due to the presence – extending down to the shoreline – of factories and industrial buildings, most of them now abandoned. At present, the area lies submerged as a result of the bradyseism that has affected the entire Phlegraean region.

Within the space between the commercial harbor of Pozzuoli and the *Portus Julius*, the *ripa* preserves an uninterrupted series of structures extending for approximately 2 km, partially conserved. In particular, the sector of the sea in front of the former Pirelli plant and the SOFER shipyard has yielded numerous archaeological remains and finds, which led to the subsequent identification of the *vici Lartidianus and Annianus* (Camodeca, 1994; Camodeca, 2018; Stefanile et al., 2023; Stefanile et al., 2024; Tardugno et al., 2025).

Although the coastal strip has undergone intense urban development, which continued without interruption until recently, underneath the sea an extraordinary archaeological record has been preserved. This evidence pertains to an area of great significance, from both historical-archaeological and geomorphological-environmental perspectives, closely linked to volcanic and bradyseismic activity.

Our understanding of the topography of *Puteoli* must clearly include the submerged area, which is in fact an integral part of that above ground, in addition to the volcanological features of the locality, all of which characterized the ancient landscape of the Phlegraean area. In fact, the *ripa puteolana* represents a portion of a much more complex system extending around the entire gulf, which – especially in the Augustan period – emerges as one of the most significant examples of urban organization and the development of architectural features typical of a major commercial and harbor zone, reflecting the prestige of a cosmopolitan city overlooking the Mediterranean.

In this regard, with the aim of promoting research and enhancing the coastal area of *Puteoli*, at the end of 2021 the project “Between land and sea. Studies and research in the coastal areas of the Phlegraean Fields” was launched, thanks to a cooperation agreement between the Soprintendenza Archeologia Belle Arti e Paesaggio for the metropolitan area of Naples and the University of Campania Luigi Vanvitelli, with the coordination of the Scuola Superiore Meridionale for the underwater component. The project involves the mapping of the entire submerged area with the aid of drones, and the documentation of all the submerged structures, recorded with GIS support and cataloged according to constructional and functional characteristics.

2. Methodology: investigating *Puteoli* and the *ripa puteolana*

2.1 Historical data

2.1.1 *Puteoli* port of Rome

When, after the military conquests of the 2nd century BC, Rome's dominion extended well beyond the geographical boundaries of the Italian Peninsula and the Mediterranean became *Mare Nostrum*, *Puteoli* quickly became a strategic facility of primary importance. Feeding the city of Rome required the establishment of a secure commercial network, and for this purpose – along with the definitive pacification of the maritime space, the creation of ports suitable for the management, storage, and redistribution of massive cargoes. *Puteoli*, the ancient Greek colony of *Dicearchia* in the heart of the Phlegraean Fields and located at the most sheltered point of the Gulf of Naples, was exceptionally well suited to the development of a gigantic port area; the original landing place at the base of the Rione Terra acropolis was rapidly expanded for this purpose. Already in the Augustan era the docks had begun to develop westward, and within a few generations the commercial port ended up covering a coastal strip over 2 km long. The first pier, extending from the base of the Rione Terra fortress, was monumentalized and transformed into a gigantic structure over 300 meters long, built on massive concrete *pilae*, surmounted by arches and monuments: this was the so-called ‘Caligula pier’, more likely dating to the Neronian era, which became a symbol for the entire city. Its jetty offered shelter to ships of all sizes and drafts, protecting from the southern winds – the only ones capable of agitating the bay – a long series of coastal structures that continued well beyond the area of the emporium. Behind the Rione Terra, to the southeast and toward *Neapolis*, over sixty concrete *pilae* measuring at least 3 × 3 meters were laid in the sea, in double rows, lining the entire coast and protecting the villas and the base of the acropolis. Beyond the emporium to the west, the strip of land that stretched (perhaps between lagoons and coastal ponds) up to the Lake Lucrino and *Portus Julius*, built by Agrippa in 37 BC to enable Octavian to achieve a quick victory against pirates, became the port's expansion space. It attracted entire communities of merchants, *peregrini* from the four corners of the empire, who set up their trading bases and meeting places there: the *ripa puteolana* took the form of a long waterfront dotted with warehouses and storage areas; *vici Lartidianus* and *vici Annianus*, separated by a peninsula and two small docks, became the connection between the original port and the *Portus Julius*. The latter, demilitarized after the victory over the pirates – and certainly after the creation of the military

base of *Misenum* – became the most peripheral sector of the entire commercial port of Pozzuoli, in direct contact with the zone occupied by villas and the imperial *palatium*, the beautiful *Baiae*, beyond Punta dell’Epitaffio. Goods of all kinds circulated for centuries in the *horrea* of the harbor, which was long Rome’s largest commercial port. Even after the opening of the ports of Claudius and Trajan at the mouth of the Tiber, *Puteoli* maintained its role and importance, becoming part of an even more complex port system. Small and precious goods were also stocked in the *portus puteolanus*, but above all immense quantities of grain from Egypt and North Africa. These colossal cargoes were unloaded every year by the so-called *naves alexandrinae*, exploiting a clever spatial organization and sophisticated logistics, which provided well-ventilated and humidity-free storage rooms even close to the waves, places for the necessary checks and for fiscal and customs operations, and targeted routes for re-embarkation and redistribution. The *praefectura annonae*, which for centuries was one of the keys to Rome’s very survival, began its work in Alexandria, and undoubtedly accomplished much in *Puteoli*. It is therefore not surprising that the majority of pilgrims gravitating around the port of *Puteoli* – attested by literary, epigraphic, and archaeological sources – came from Egypt and the East, which organized its trade channels with Rome around the *classis Alexandrina*. From the Tyrians to the Berytenses, and the Nabataeans of the Arabian Peninsula, many merchants were present on this shore area, praying to their distant gods, and gathering in the *tabernae*, where they carved nostalgic graffiti in memory of their homelands. *Puteoli, litora mundi hospita* welcomed the entire world to its shores, and like every great port, became a vibrant mix of different languages and peoples, and a multifaceted and cosmopolitan symbol of Rome’s universal greatness.

2.2 Archaeological data

2.2.1 The suburb of the colony

Puteoli is located in a central position within the Phlegraean Fields and has a complex urban fabric.

The first documented settlement was on the fortress of the Rione Terra, seat of the *Colonia civium Romanorum* founded in 194 BC. Beginning in the Augustan period, urban expansion affected wide sectors of the *suburbium*, through a planning process strongly conditioned by the morphology of the territory (Sommella, 1978; Amalfitano et al., 1990; Gialanella, 1993a; De Caro 2002; De Caro and Gialanella, 2002; Gialanella, 2014; Cavalieri Manasse and Gialanella, 2016; Cavalieri Manasse and Gialanella, 2020). In this sense, even today the topography, together with the volcanic nature of the area, continues to influence the district’s urban planning (Gialanella and Sampaolo, 1980-1981; Amalfitano et al., 1990; Gialanella, 1993a; Gialanella, 1993b; Gialanella, 2008; Camodeca, 2018).

The suburban area of *Puteoli* is characterized by an alternation of slopes and terraces. At the heart of the *suburbium* lay one of the major intersections of urban and extra-urban routes of the Roman period, corresponding to the present-day Quadrivio dell’Annunziata: here converged the *via Puteolis-Capuum*, together with the more ancient median axis across the city, connected to the large baths complexes and amphitheaters, and finally the *via Domitiana* (Gialanella, 1993a) (Fig. 2).

Written sources report that from the late 2nd and early 1st century BC, this area and the entire sector between the harbor and the upper part of the city experienced significant building development (Sommella, 1978; Gialanella, 1993a) (*Lex parieti faciendo* of 105 BC). In the nineteenth century this sector was identified with the *regio vici Vestoriani et Calpurniani*, named after two late Republican families. Numerous buildings connected with the storage of goods, such as *horrea* and warehouses, are located here, reflecting the commercial vocation of the area (Gialanella and Sampaolo, 1980-1981; Camodeca, 1993; Camodeca, 2018).

In the Republican period, numerous residential buildings must have been scattered throughout the area, such as the villas whose remains are still visible today, situated on the ridges and at times sloping down towards the sea (Fulvio, 1890; Dubois, 1907). The most famous was that of Cicero, the *horti Cluviani*, which the orator inherited from *Cluvius* (Gialanella and Sampaolo, 1980-1981; Camodeca, 2002). Increased construction is then documented in especially the second half of the 1st century AD; the *via Domitiana* was opened in 95 AD (Gialanella and Sampaolo, 1980-1981; Gialanella, 1993a).



Figure 2. Area of the Quadrivio dell'Annunziata in the Archaeological Map of *Puteoli* (from Gialanella, 1993b, IX).

2.2.2 *Vicus Lartidianus*

The location of the *vicus Lartidianus* along the *ripa puteolana* is mainly due to the discovery of a statue base dedicated to Emperor Hadrian, recovered from the stretch of sea between the Armstrong shipyard (now the disused SOFER) and the Pirelli factory (now Prysmian). The base, found in 1889 about 25 meters from the coast in front of the former SOFER, bears a dedication to Emperor Hadrian from 121 AD by the *inquilini vici Lartidiani* (Camodeca, 2018).

The numerous submerged structures in this stretch of sea were already known to antiquarians in the 18th and 19th centuries. Vertical aerial photographs were used by Giuseppe Camodeca in the late 1980s and early 1990s to draw up a 1:2000 scale plan of the entire area from the port of *Puteoli* to the *Portus Julius*. Verified in some places by underwater surveys, conducted in conditions of visibility that were decidedly less favorable than today, this is an essential base map for any study of the *ripa puteolana* (Camodeca, 1994). These initial studies have been followed in recent years by new underwater surveys in the eastern sector of the *vicus Lartidianus* (Lombardo, 2023).

Building on these previous studies, since 2021, topographic mapping, cataloguing, and archaeological documentation activities have been developed as part of the new project “Between land and sea” (Stefanile, 2023).

Based on the current state of research, two main orientations can be discerned in the organization of the *vicus Lartidianus*, one to the east and one to the west. We may (preliminarily) presume that these were dictated by adaptation to the coastline profile, in relation to the dynamics of wind processes and marine deposition/erosion – i.e. depending on the direction of the main winds throughout the year and, consequently, the force of the waves hitting the shore.

The area of the *vicus Lartidianus* can be divided into six main sectors (Fig. 3).

The north-eastern sector, referred to in the project as sector S1, corresponding to the small inlet west of the Cantieri Maglietta shipyard, is characterized by the presence of an east-west colonnade – and, in particular, a paved road.

To the south lies sector S2, where a second colonnade can be seen, consisting of ten marble columns alternating with brick columns, while further west there is a sequence of rooms measuring approximately 5 × 25 meters, which are currently interpreted as warehouses. Of particular interest between these rooms and the colonnade is the presence of a narrow room about 4.4 meters wide, unpaved and flanked to the west by a 1.90-meter-wide quay with two flights of stairs and a slipway facing south, perhaps interpretable as a channel for mooring small boats for unloading goods into the rectangular rooms present on both sides (Lombardo, 2023).

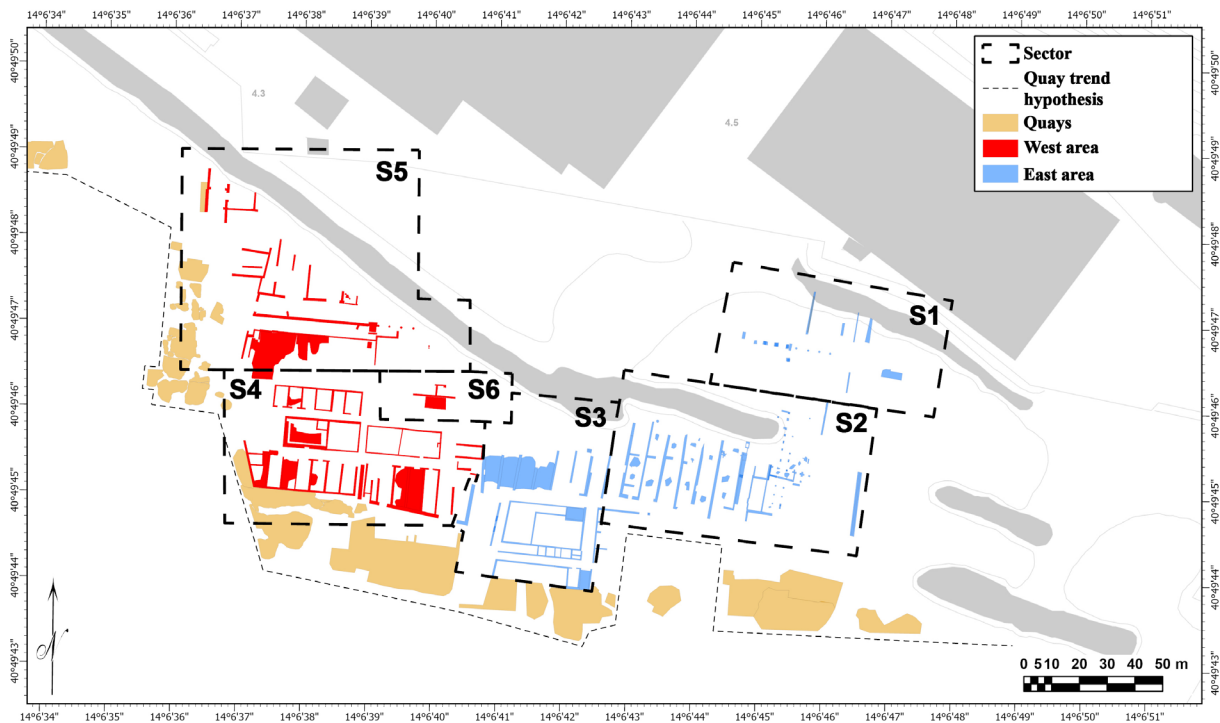


Figure 3. *Vicus Lartidianus*: division into investigation sectors (elaboration by M. Silani).

Continuing westward, sector S3 seems to form a sort of connection between the western and eastern portions of the topography of *vicus Lartidianus*. Characterized by a sequence of buildings that cannot be interpreted with certainty at the current stage of research, in the absence of underwater surveys, it is nevertheless possible to distinguish two different complexes divided by a strip about 4 meters wide, perhaps an internal street, in the photos taken with a UAV (*Unmanned Aerial Vehicle*). The complex to the north seems to feature a series of long, narrow rooms that can be interpreted as warehouses, while to the south there is a complex with a different layout, centered on a large rectangular hall onto which several small rooms face southwards.

The topography of the western portion of the *vicus Lartidianus* is generally easier to understand and may be interpreted more reliably. In sector S4, north of the massive quay facing the sea, a sequence of seven rooms measuring on average 4-4.5 × 12-15 meters is clearly visible, separated by a narrow passage 2.8 meters wide from six other rooms with areas of approximately 50 square meters, which can be interpreted as *horrea* with northward access along an internal road 3.3 meters wide. Underwater surveys have made it possible to document, for the moment, at least two phases in the life of these warehouses, recognizable by the raising of the floor levels. In some rooms, gaps in the flooring reveal the relationship between the last phase floor of these buildings visible today and the perimeter walls, where two construction phases with different types of *opus reticulatum* can be identified. The floor is laid over a substantial deposit of medium-sized tuff chips (Fig. 4).

Immediately north of these warehouses are two large rectangular rooms (27 × 11 meters), both divided into two areas. Another internal road, also 3.3 meters wide, separates the two rooms from a second series of six smaller warehouses, each 32 square meters in size, visible in the first room to the west.

Further north, in sector S5, there is an important structure, Building F, already known from previous underwater research carried out in the early 1990s (Camodeca, 2001) and the site of the discovery in 1972 of numerous marble fragments, found under a *sequispedalis* floor, raised during the last phase of the complex's life (Fig. 5).

The presence of this material, which can be dated to between the late 2nd or early 3rd century AD, allows this complex to be interpreted as possible workshops of *marmorarii* and the identification of a phase of reconstruction of the building – due, according to the current interpretation, to subsidence phenomena linked to bradyseism. Behind it, underwater research has also identified and documented the large portico with piperno columns referred to by Dubois as the “portico delle Ninfe” (Dubois, 1907), already known to antiquarians in the 18th and 19th centuries (Paoli, 1768), and still clearly visible in both aerial photographs and underwater surveys. This major building in sector S5 and the portico overlook a probable street about 6 meters wide. Finally, to the north of the street there are several rooms, one of which is floored with brick tiles, with traces of lead working, possibly a *plumbaria*.



Figure 4. *Vicus Lartidianus*: floor and two phases visible in the structures of warehouses (photo by M. Silani).

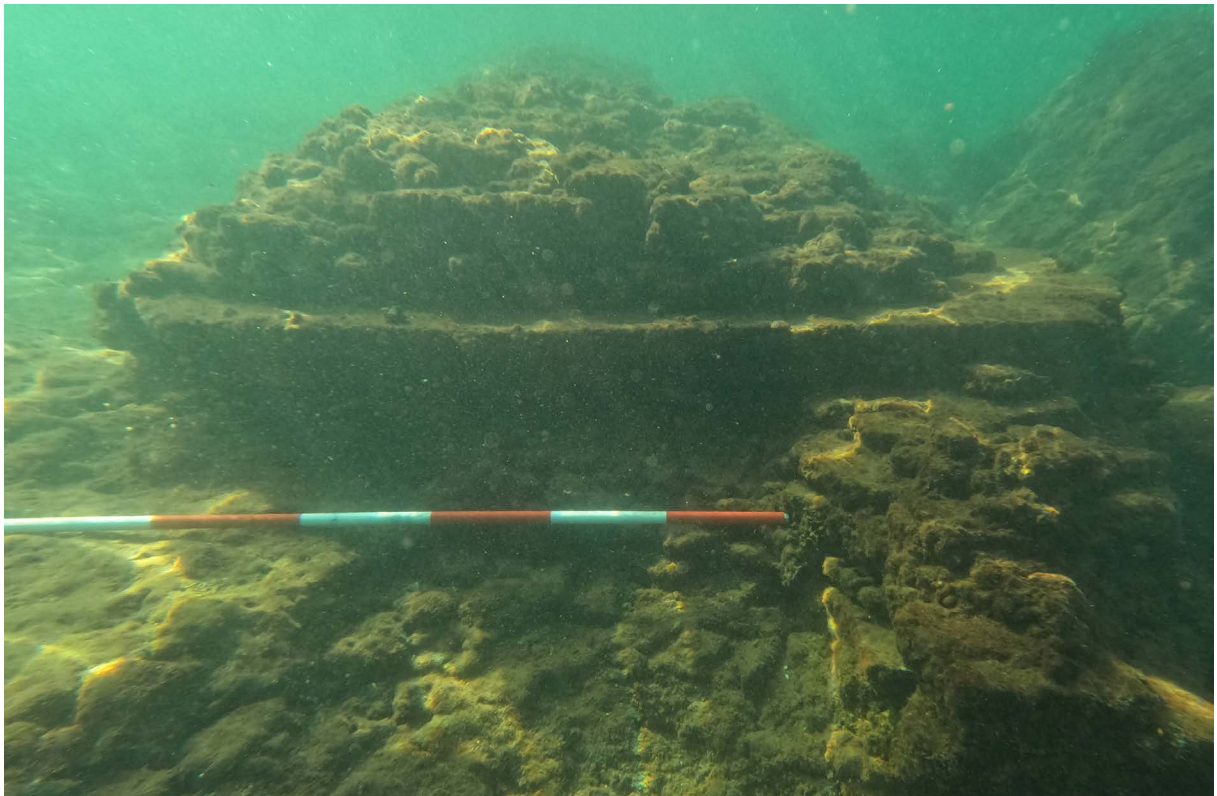


Figure 5. *Vicus Lartidianus*. Building F: the image shows the different floor levels (photo by M. Silani).

In the western area of the vicus, between the two sectors just described, there is a large space measuring at least 20×30 meters, where aerial images show no significant structures. However, underwater surveys conducted during the project “Between land and sea” have made it possible to locate in this very sector S6 an important sanctuary of the Nabataean Arabs (Stefanile, 2024), the presence of which in Pozzuoli was already known from epigraphic evidence (Camodeca, 2018). The investigations revealed a building consisting of two rooms, named A, to the east, and B, to the west. In room A, two altar bases with recesses on the surface were identified (Fig. 6); the larger one has a dedicatory inscription on the front: *Dusari sacrum*, to *Dushara/Dusares*, the main deity of the Nabataean pantheon (Lacerenza, 1988-1989).

Of particular interest is the presence in both rooms of a tough conglomerate that effectively incorporates the altar bases up to their mensa and raises the floor levels; there is a *cocciopesto* floor on top of the conglomerate in room B (Fig. 7). These floor surfaces, which belong to a new phase of use of the building – and probably of the entire area – have been preliminarily dated to the beginning of the 2nd century AD and are associated with an extensive pavement of tuff chips located behind the perimeter wall of the sanctuary.

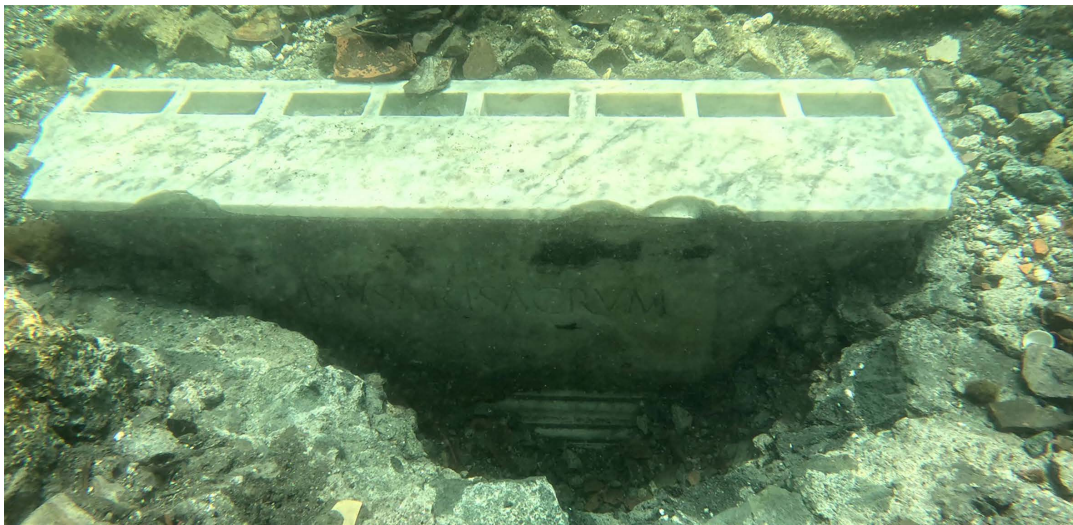


Figure 6. *Vicus Lartidianus*: the altar of *Dusares* in the Nabataean sanctuary (photo by M. Stefanile).

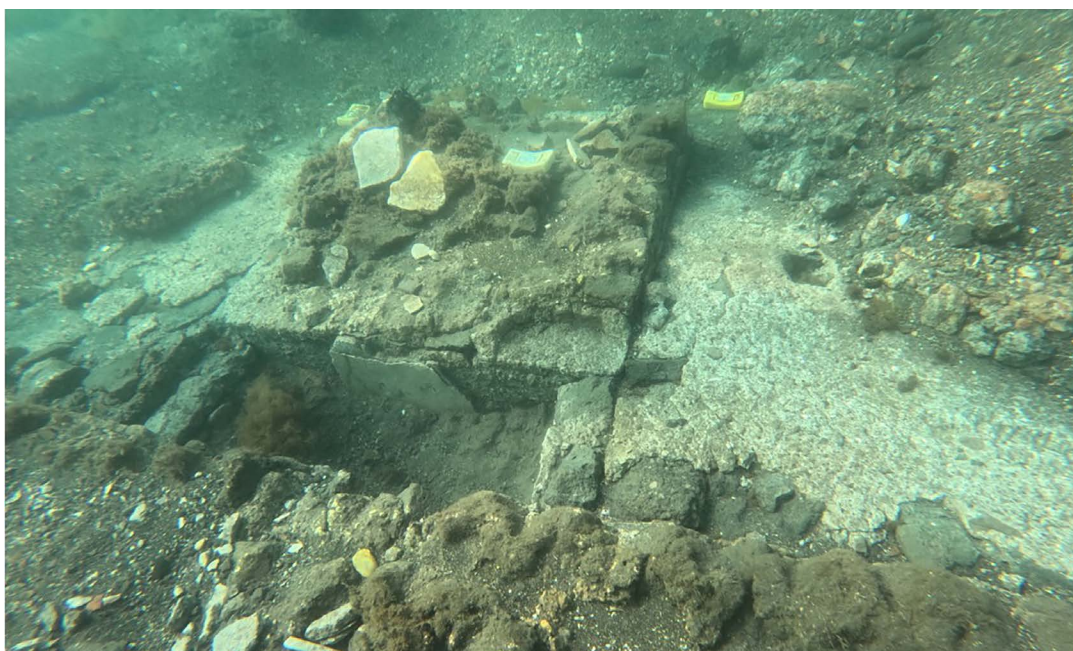


Figure 7. *Vicus Lartidianus*: *cocciopesto* floor in the second phase of use of the Nabataean sanctuary (photo by M. Stefanile).

2.2.3 Penisola Mediana

The most surprising area that was discovered during the surveys is the central space between the two *vici*, consisting of a peninsula, 40 meters from the eastern edge of the *horrea* in the *vicus Annianus* and 165 meters from the western edge of the buildings in the *vicus Lartidianus*: this zone extends approximately 50 meters seaward from the ancient coastline and forms two small artificial bays – monumentalized, on the eastern side, by massive concrete docks, and on the western side by a long front of brick arches, found collapsed on the sandy seabed.

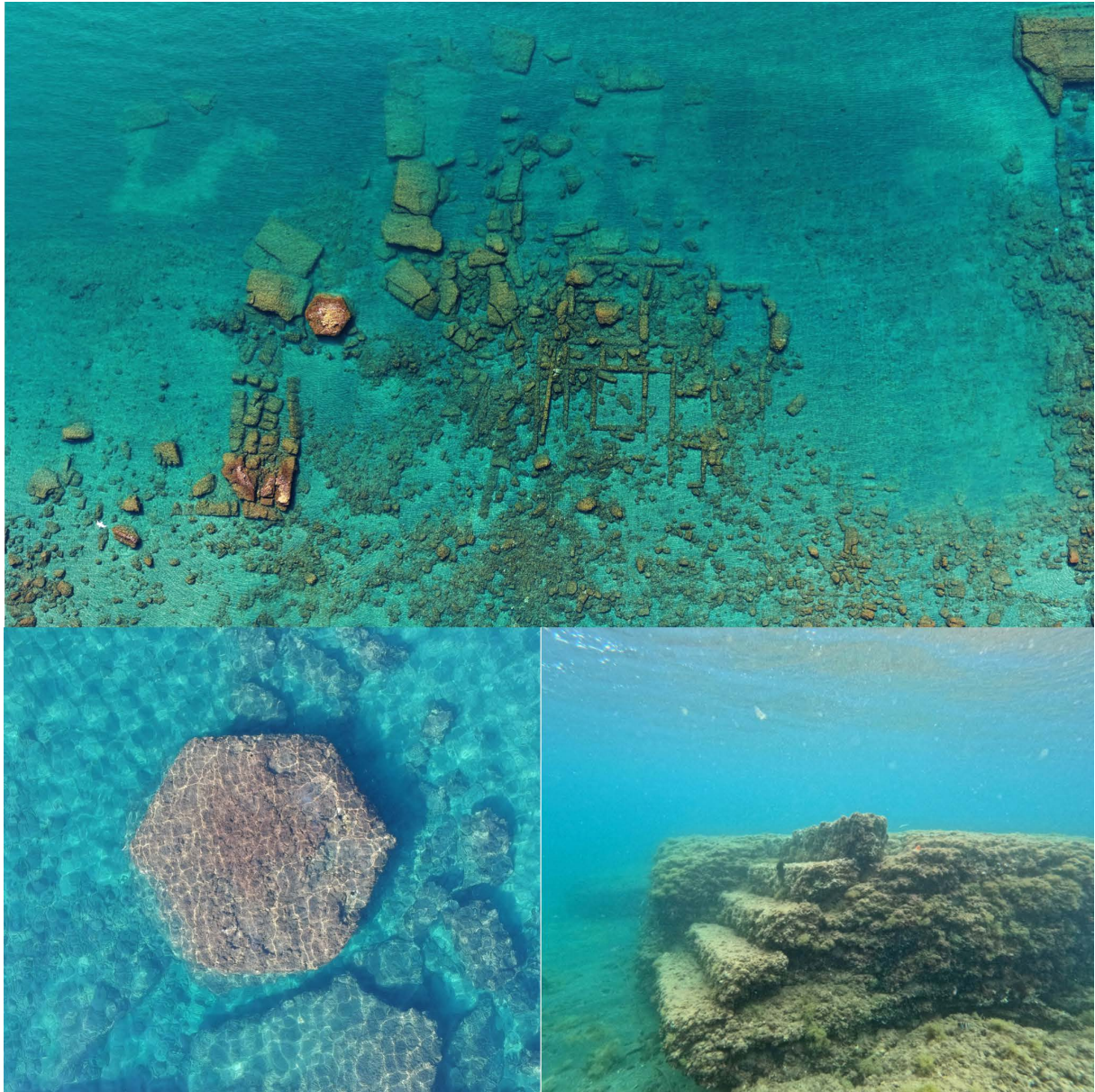


Figure 8. *Ripa puteolana, Penisola Mediana*. The composite image shows the remains of stairs at the quay for mooring boats, the layout of buildings visible from aerial photographs, and the submerged remains of an hexagonal structure (photo M. Stefanile).

The entire peninsula, the layout of which is completely invisible in the aerial photographs used in the Camodeca plan (Camodeca, 1994), was clearly occupied by a structure that has been badly damaged by storm surges but still displays its ancient splendor (with white and colored marble elements, collapsed *sectilia* still with their supporting clamps, nails and bronze elements scattered over a vast area, collected in the corners and on ledges of the walls) (Fig. 8). In the

eastern part of the sector, two large columns and two twisted columns are still lying on the seabed, only half-covered by sediment, and seem to be associated with a curious concrete pile of perfectly hexagonal shape (side 3.60 m), perhaps used as the base of a signal monument, at the entrance to the eastern dock, immediately adjacent to a large dock structure where 5 steps of an access staircase are still clearly visible. The available data suggest that the central peninsula probably housed an important building, linked to the port's administration itself. Perhaps it had to be visited it by convoys or those carrying cargoes upon arrival. Access was via the steps by the hexagonal monument, after temporary mooring at the largest of the smooth-shafted columns, which appears to show clear signs of anchoring ropes. This physical location for the registration of food cargoes allows us to reopen, with new data, the debate on the presence of a *procurator annonae* in *Puteoli*, and to re-evaluate the relationship between *Puteoli* and the *portus annonae* par excellence, Trajan's port at the mouth of the Tiber. While the idea of *Puteoli*'s rapid decline following the inauguration of the large Ostian ports had long been dismissed, today it can be confidently argued that, even after the opening of Trajan's port, *Puteoli* maintained a role of primary importance, within an expanded *Puteoli-Portus* port system in which Rome's two major commercial ports coexisted for centuries, without competition but with convergent efforts to create a common network.

2.2.4 *Vicus Annianus*

Enormous rectangular granaries, 27 meters long and almost 8 meters wide, arranged neatly behind the quayside of the *Vicus Annianus*, appear today to be the only physical spaces capable of storing the huge grain loads of the fleet from Alexandria. Underwater surveys have revealed the presence of massive walls capable of resisting the thrust of tons of grain, and the use of raised floors to protect the goods from humidity and pests, and – in one fortunate case – also the existence of wood and nails, apparently used to build mezzanines and shelving that would have permitted the exploitation of warehouse space even at height.



Figure 9. *Vicus Annianus*, aerial image of part of the area occupied by granaries (photo M. Stefanile).

The sources available to us on this topic are many and varied, and extraordinary evidence also comes from the surroundings of Pompeii, from the *triclinia* building in the *Murecine* area and from the exceptional private archive of the *Sulpicii* discovered there. The wax tablets transferred by the last of the *Sulpicii*, Pozzuoli bankers, to the *Pompeii* area shortly before the 79 AD eruption contain evidence of loans of large sums to private entrepreneurs willing to go heavily into debt to enter the most lucrative business available in the port of *Puteoli*: the purchase of surplus Egyptian grain stocks, sold at low cost by the state upon the arrival of the Alexandrian fleet, and their subsequent resale months later, at fabulous profits. This activity was mentioned by Cicero as a possible source of enrichment, but it was costly, due to the need to invest much capital – both in purchasing the grain and renting granaries able to store it for months until it was marketed. Once again, archaeology offers confirmation, and underwater research offers the incredible opportunity to recognize these facilities and contexts. The granaries of the *vicus Annianus* also had a long life, and their end coincided with that of ancient *Puteoli* itself: in the late 4th century AD, the granaries were likely still in use, well protected by a quayside that shows clear signs of progressive elevation. Faced with rising sea levels due to bradyseism, it evidently seemed more convenient to transform the quayside into a retaining wall, leaving the granaries in their original position, even though they were now sunken below sea level. This operation was already known from epigraphic sources, if we consider pertinent to this intervention the inscriptions dating to 394-395 AD which refer to the reconstruction of the bank on the left and right sides of the slaughterhouse, *iactis molibus propter incursione ingruentium Procellarum* (Stefanile, 2023; 2025).

2.3 Geoarchaeological data

2.3.1 Bradyseism and archaeological data

Along the northern stretch of the gulf coastline developed the so-called *Emporium*, the great harbor district of *Puteoli*, still active in the 3rd-4th centuries AD, as attested by the well-known glass flasks depicting the Pozzuoli shoreline, bounded on the seaward side by quays with porticoes (Ostrow, 1989; Bejarano Osorio, 2002; Popkin, 2018; Cassibry, 2021; Gianfrotta, 2022).

The principal building of the *Emporium* is the *Macellum* (Fig. 3), brought to light in the mid-18th and early 19th centuries. It is one of the largest known in the Roman world, dateable to between the late 1st and 2nd centuries AD, and reorganized in the Severan period, to which the central *tholos* with its massive columns belongs. These columns have long been regarded as the measure and symbol of Phlegraean bradyseism (Parascandola, 1947; Amalfitano et al., 1990; Lirer et al., 2010; Gianfrotta, 2020) (Fig. 10).

During phases of descending bradyseism, the columns, submerged in water, were affected by the presence of lithophagous mollusks within a band between 2.6 m and 5.7 m above the floor level. Radiometric analyses carried out on the shells testify to the dynamics of the phenomenon beginning from the late 4th century AD, when the monument sank together with the coastal strip, leading also to the decline of the city's commercial harbor.

Geoarchaeological cores have made it possible to better understand the morphology of the area occupied by the *Macellum* and its surroundings, and to define more precisely the evolution of bradyseismic phenomena, already active in the Republican period and probably influencing urban expansion, impacting the various phases of the city's development (Amato and Gialanella, 2013).

Beneath the current ground surface, a first level has been identified, plausibly corresponding to concrete poured into wooden formworks in the water, dating to the Augustan period. On top of this level a pavement in *cocciopesto* was laid, at about –3.5 m a.s.l., interpreted as the first surface of use. Stratigraphic sequences then revealed the presence of structures resting on this floor, relating to the raising of the quay and dating to the Flavian period.

In late Flavian times, traces of groundwater emergence are evident, with deposition of silts on the quays and raising of the floors, though without abandonment of the site. In the Severan period, the entire structure was reorganized, as attested by a lead pipe (*fistula plumbea*) bearing the name of Septimius Severus and by the construction of the central *tholos* (Amato and Gialanella, 2013).

Study of written sources and analysis of lithophagous mollusk traces on the columns have allowed the identification of a phase of negative bradyseism during Late Antiquity, with a relative rise in sea level up to +7/+8 m, resulting in the abandonment and submersion of the lower city.

Signs of bradyseismic activity are also known at the *Rione Terra*, though difficult to interpret. In 1538, the seismic-volcanic phase culminated in the eruption of Monte Nuovo, which caused extensive damage. Subsequently,

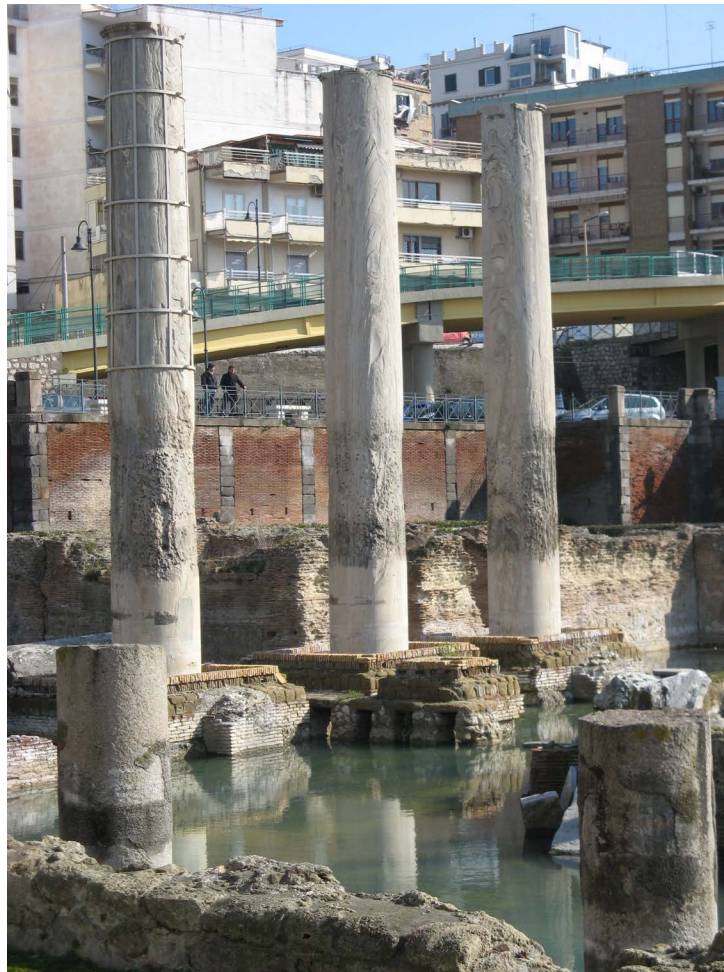


Figure 10. The main building of the *Emporium*, the *Macellum*. Its columns have long been considered the measure and symbol of Phlegraean bradyseism (photo by M. L. Tardugno).

Viceroy Don Pedro of Toledo tried to stimulate the town's rebirth by massive demolition of earlier structures to bring inhabitants back. For the first time the remains of the ancient settlement suffered major damage: rubble was poured into their ground floors, and Roman structures became the platform upon which the 17th-century city was built, forming part of the foundations of mansions for the nobility (Gialanella et al., 2022; Tardugno and Proietti, 2025).

In this context, however, identifying and defining chronologically the traces left by seismic events over time proves very complex, since the state of preservation of many structures is attributable not only to natural phenomena but also to the readaption of spaces in the modern age.

Nevertheless, interesting data come from the northern front of the tuffaceous promontory, where several Roman rooms of rectangular plan, covered with barrel vaults, belong to an Augustan system functioning as substructures on the slope. These seven rooms, generically referred to as "cryptoporticoes", were arranged in series along the northern terraces, oriented N/S and accessible from the northern side; they date to about the 1st century AD (Crimaco and Gialanella, 2003) (Fig. 11).

A careful examination of pottery finds and obliteration layers has allowed the identification, beneath more recent strata, of a marshy level dating to the 8th-9th centuries AD, deposited during the ground subsidence due to bradyseism, which led to the submersion of the structure up to the springing of the vault. This demonstrates how this sector of the acropolis, frequented since the 1st century BC, was invaded by the sea during the Early Medieval period.

Beneath the most recent trodden surface, excavation revealed a Renaissance layer, under which lay a stratum of marine sand rich in mollusk remains, with numerous heavily abraded potsherds with rounded broken edges. Moreover, at certain points in the masonry, up to the springing of the vault, seashells were found which yielded radiocarbon (C14) dates between AD 600 and 750. The mollusks lived on the western wall of the cryptoportico and would have lost their habitat following ground uplift and marine regression (Crimaco and Gialanella, 2003).

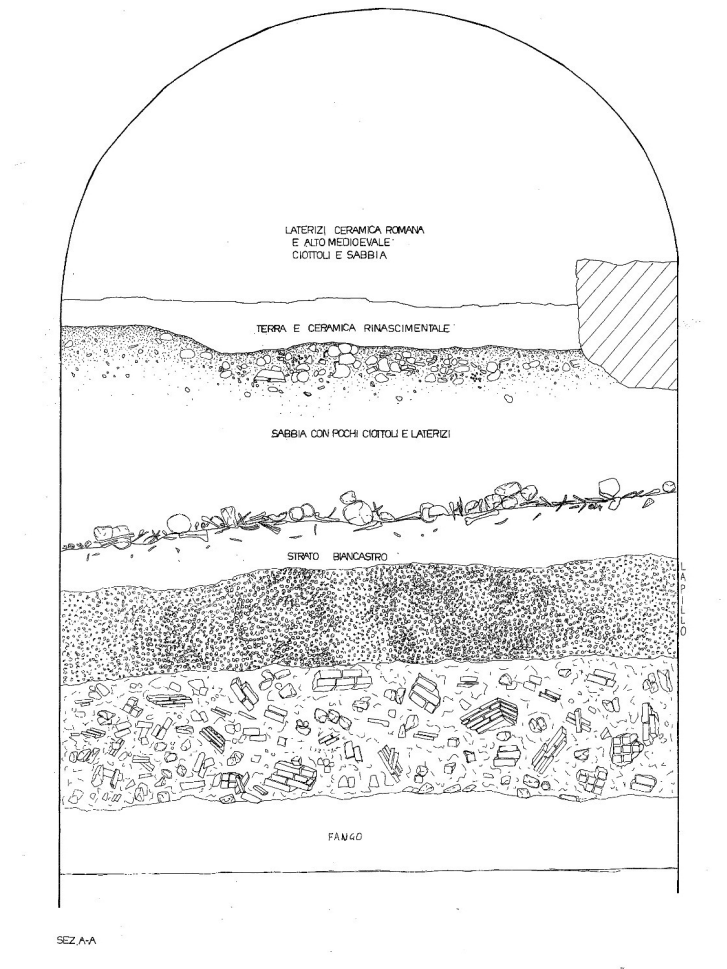


Figure 11. Rione Terra. Northern sector. Section of one of the rooms of the so-called *Cryptoporticus*, in which is clearly visible a marshy layer dating to the 8th-9th century AD, caused by bradyseism, which led to the submersion of the structure up to the vault (from Crimaco and Gialanella, 2003).

2.3.2 Bradyseism and the *ripa puteolana*

No specific data can be attributed with certainty to the effects of bradyseism along the *ripa puteolana*. The available information is deduced from interpretation of archaeological data described in sections 2.2.2 and 2.2.4. Preliminary findings attribute the raising of the floor level of Building F (see 2.2.2, Fig. 3), interpreted as a *marmorarii* workshop, to the effects of bradyseism. Beneath the *sesquipedalis* floor (–1.246 m a.s.l.), fragments and scraps from marble production dating from the late 2nd to early 3rd century AD (see 2.2.2) suggest that the intervention was due to bradyseism problems.

The same explanation could be put forward for the reconstruction of the floors inside the *horrea* in the southern sector of the *vicus Lartidianus* (see 2.2.2, Fig. 2, –2.114 m a.s.l.), although reasons related to problems of humidity and insulation of the floors for better preservation of goods could also explain these changes in elevation.

The raising of the floor levels seems to be the most plausible sign of bradyseism (see 2.3.2., 3.1), but we are well aware that the reasons behind these changes in the buildings on the *ripa* may be linked to different causes, first and foremost the decommissioning or simple change of use of a building. This second scenario would seem to be linked to the documented transformation of the Nabataean sanctuary in the *vicus Lartidianus* at the beginning of the 1st century AD, with the construction of a cement conglomerate sealing the rooms of the sanctuary (see 2.2.2, –3.067 m a.s.l.).

Also significant are the indicators attributable to changes in the average sea level present in the *vicus Annianus*. The series of progressive renovations identified in the quays, unfortunately not currently datable with precision, documents a gradual rise in sea level, possibly the effect of descending bradyseism (see 2.2.4).

Finally, significant data for defining the morphology of the Puteolan shore come from geological surveys conducted north of the *vicus Annianus* (Gialanella, 2023), where excavation tests and geoarchaeological surveys have revealed the occurrence of a post-Roman submersion of the area, occupied by a lake environment perhaps already in the Republican period, which expanded during the Imperial era and was submerged due to negative bradyseism in late Imperial times (Gialanella, 2023, Fig. 17).

3. Results: Proposed reconstruction of the *Puteoli* waterfront

3.1 The topography of suburb

Due to the city's topographical configuration, urban planning developed along parallel terraces, with streets following the contour lines and with slopes connecting the lower city and the *emporium*, through stepped junctions or steep arteries (Gialanella, 1993a). Some of these can be identified at the Vallone Mandria, where a secondary branch connected to the harbor is documented, and at the Vallone Cordiglia, which is crossed by a road that, starting from the *via Domitiana*, linked the *vicus Lartidianus* with the harbor district (Camodeca, 1994; Gialanella, 1993b; Camodeca, 2018). It is near the latter that a portion of paved road was identified, connecting the *ripa* with the upper terraces (Gialanella, 1993b; Camodeca, 2018).

Precisely in this area, in the lower part of the town, in a zone that in antiquity was bounded to the east by the sector of the *ripa Hortensiana* and the modern harbor, excavations carried out in the 1990s revealed structures belonging to a building complex, most probably a bath house. Several phases of this complex have been identified, dating from the Augustan period to the 4th century AD (Ceraudo et al., 2001; Crimaco and Gialanella, 2003; Gialanella, 2023). The most interesting evidence, however, concerns the numerous renovation works documented around the end of the 1st century AD, which may be related to bradyseismic activity, since substantial deposits were laid down, upon which walls and pillars were built. In the same area, geoarchaeological surveys have been conducted in recent years, prior to the construction of new harbor facilities near the site of the former Armstrong pier. These surveys yielded very interesting, though still partial, data at a junction point between the submerged and the exposed parts of the ancient city, precisely where the stretch of paved road was found that connected the *ripa* with the *via Domitiana*, crossing the Vallone Cordiglia mentioned above (Gialanella, 1993a).

The cores taken revealed the seabed levels dating to the early Imperial and Flavian periods. At about –3.50 m a.s.l., partially submerged masonry structures were intercepted, extending inland into the coastal zone behind, which were aligned with the road crossing the higher Vallone Cordiglia. At present, it is difficult to define their exact function due to the absence of systematic excavation. Many sediments recovered from the cores can in fact be attributed to washouts from the overlying Vallone (Gialanella, 2023). Nevertheless, given their position, they may have been connected either with road systems or harbor activities.

Behind the *ripa*, in a dry-land area, a sector pertaining to the *vicus Lartidianus* has been investigated in recent years. Some structures in *opus reticulatum* were identified, datable in their earliest phase to the Augustan period; they faced onto a street and consisted of various rooms whose function remains uncertain (Gialanella, 2023).

The entire complex shows traces that can plausibly be attributed to the early phases of descending bradyseism: they are in fact covered by sandy deposits and, for this reason, during the Flavian era they were renovated and integrated, also by raising the floors by about 0.2 m and by adding steps to the access stairways.

Between the 2nd and 3rd centuries AD, the building was abandoned and obliterated by a silty deposit, upon which, at a later stage, a new paved road was constructed, raising the original levels by 0.40 m. In this phase, the floor levels of the rooms were also raised, reaching an elevation of 2.70 m a.s.l. In the 4th century AD, the entire area was abandoned due to the intensification of descending bradyseismic phases, which became very significant, as documented also by literary and epigraphic sources (Camodeca, 2018; Gianfrotta, 2020; Stefanile et al., 2023).

3.2 The topography of the *ripa puteolana*

Survey and research carried out since 2021 has yielded notable progress in our knowledge of the topography of the ancient *ripa puteolana* (Fig. 12). As mentioned above, the already excellent topographic basis of the Camodeca map (Camodeca, 1994) has been widely updated, offering a new viewpoint and a new perspective on a long sector of

the ancient waterfront. The *ripa puteolana* was not only an appendix to the port of *Puteoli*: it was a long series of structures, well organized and planned by the Roman authorities in order to offer logistic efficiency and adequate spaces for a trade model based on lengthy maritime networks, large redistribution hubs and extensive areas for the conservation of cargoes, with the aim of providing food and supplies to a big city and its empire, throughout the year.

From an archaeological perspective, the complex overlay of older and newer construction elements in a densely occupied area requires correct documentation and careful interpretation: a series of layers laid down during the construction phases makes topographical interpretation more complicated, especially in a port that functioned and maintained its various sectors for over four centuries. At the same time, despite the evident reuse of areas and buildings, one can still perceive the coherence of the planning, the care taken in identifying the road axes (particularly in the *vicus Lartidianus*), the tendency towards zoning with functional purposes, and the consistency of the orientations of walls and buildings.

Even though the construction techniques reveal a number of rethinks and updates, the entire shoreline was occupied in accordance with a coherent concept, taking advantage of three natural peninsulas that sloped gently

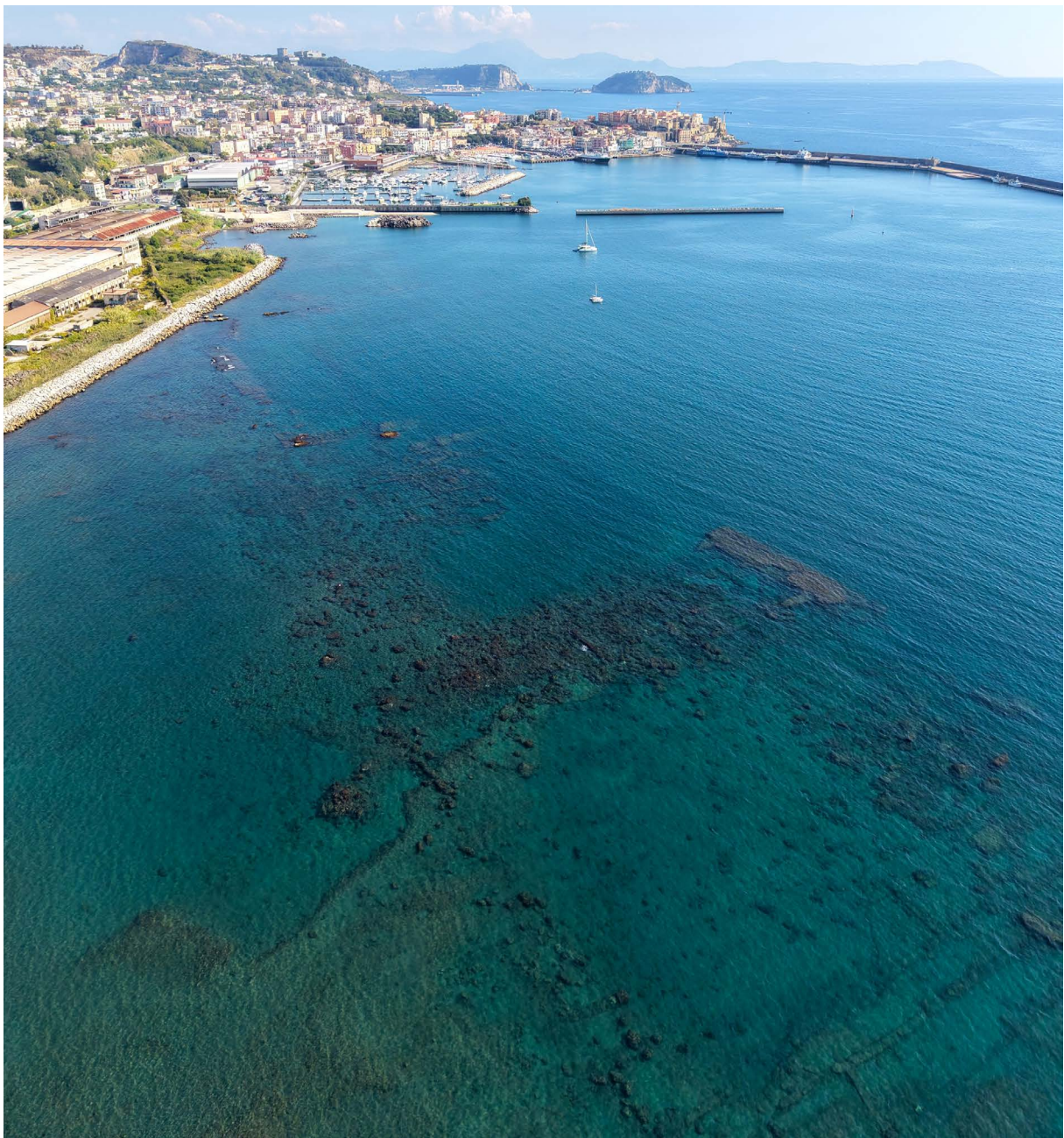


Figure 12. Aerial view of the *ripa puteolana*: in the foreground, the big horrea of the *vicus Annianus* (photo M. Stefanile).

toward the sea, interspersed with small bays ideal for temporary docking of vessels. To Roman maritime engineers, the presence of calm waters (the *sinus Puteolanus* is already a natural harbor within the larger Gulf of Naples), the abundance of *pulvis Puteolanus*, the volcanic ash capable of producing cement that would harden even in sea water and could be used to build large piers and breakwaters with minimal effort, the presence of coastal lagoons, such as at *Portus Julius* and perhaps behind the *vicus Annianus*, and the direct connection, through natural valleys, to the major land routes, must have seemed like unique opportunities for the best possible port available to Rome. In this sense, the *ripa*, more than any other location, explains the success of *Puteoli* itself.

3.3 The ancient geomorphology

Based on the data available, it is possible to make some observations that will be useful for a future detailed reconstruction of the landscape of the Puteolan coast between the Republican and Late Imperial periods.

A synoptic overview of the floor levels available in the contexts investigated so far, from the *Macellum* to the *vicus Lartidianus*, along a coastal route of 1 km, could be significant for the study of bradyseism in Roman times (Fig. 13).

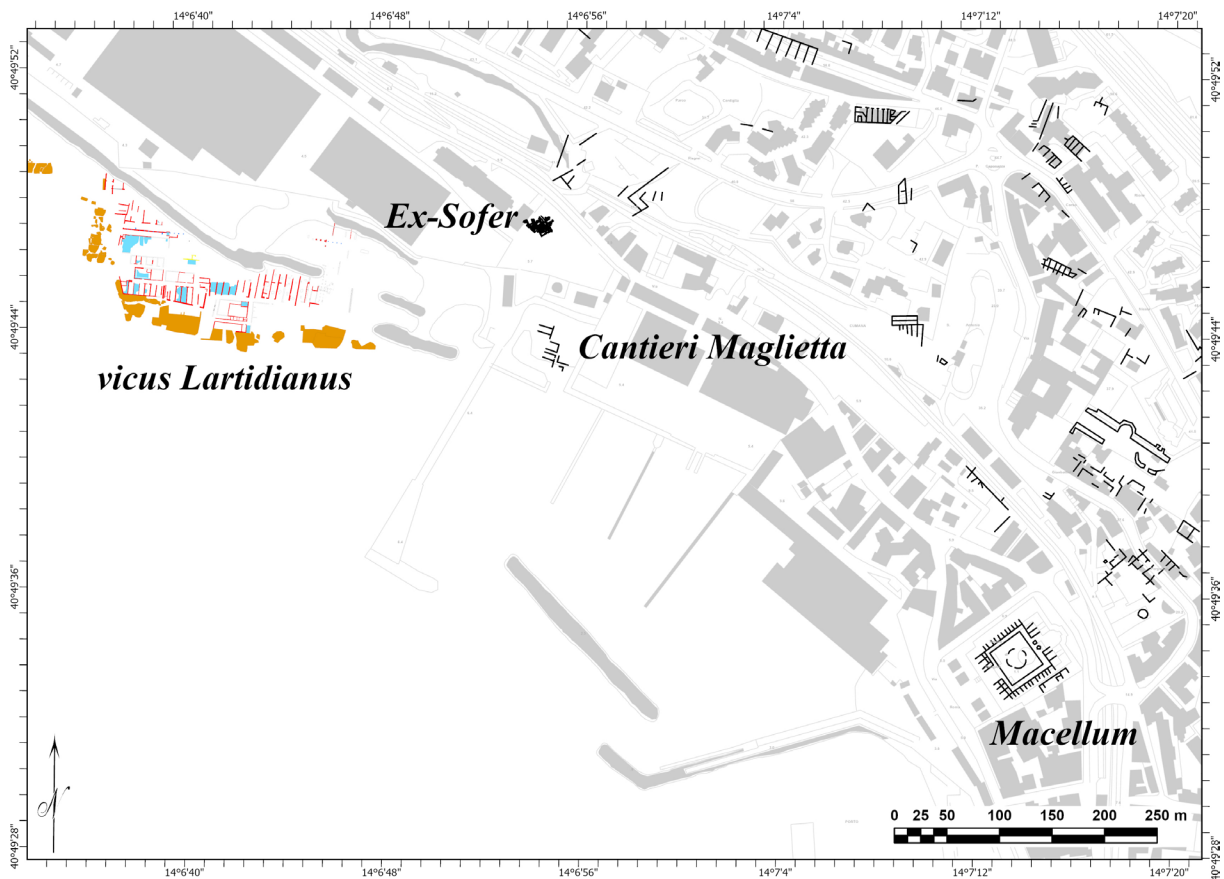


Figure 13. Indication of sites investigated with geoarchaeological surveys from the *Macellum* to the *vicus Lartidianus* (elaboration by M. Silani).

An integrated N-S section of the *vicus Lartidianus* shows a progressive rise in floor levels between the 1st and 3rd centuries AD (Fig. 14), from an elevation of -3.75 m a.s.l. to -1.25 , a rise of about 2.5 m over two centuries.

This data, when compared with known sites between the suburb of *Puteoli* and the *ripa puteolana*, shows a fair degree of consistency. Although there is a margin of uncertainty in the sea level values collected from published sources, in the absence of specific data-processing details, it is clear that all sites saw a rise in floor levels between the end of the 1st century AD and the 3rd century AD (Table 1). A relationship of this kind in contexts so distant from each other seems to be attributable to large-scale phenomena such as bradyseism.

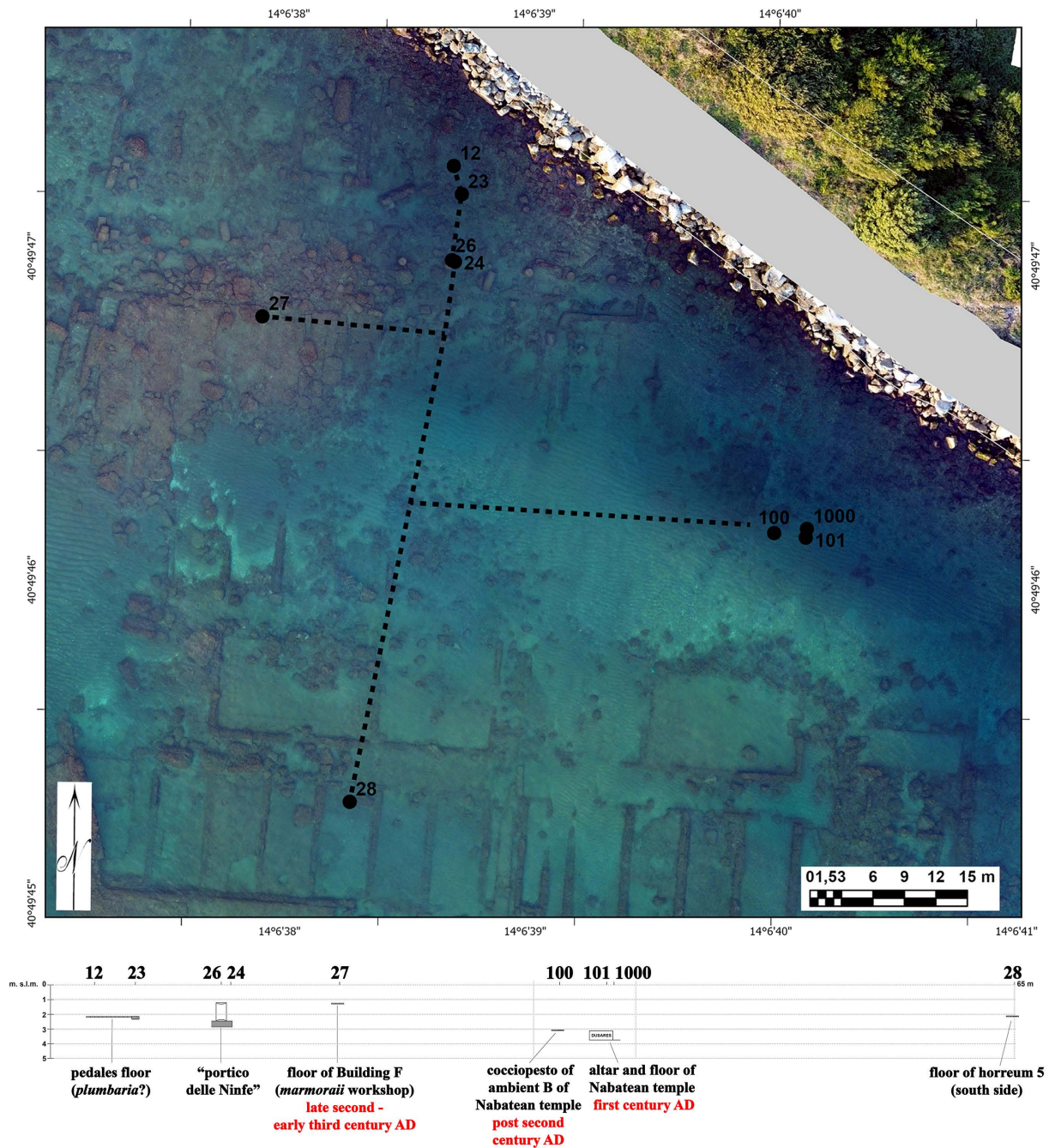


Figure 14. *Vicus Lartidianus*. Location of the floor levels of the main buildings of the *vicus Lartidianus*. N-S section and indication of the chronology of the individual floor levels (elaboration by M. Silani).

At present, it is also possible to put forward a reconstructive hypothesis for the course of the coastline between the Republican and Imperial periods. Based on the studies by Amato and Gialanella (2013), the western sector of the *ripa puteolana* can be integrated with the mapping of the quay between the *vici Lartidianus* and *Annianus* conducted during the “Between land and sea” project (Fig. 15). Thanks to data from geoarchaeological surveys conducted in the sector behind the *vicus Annianus* (see 2.3.2), it is possible to hypothesize the presence of the coastal basin of the Lucrino lake and an access channel just west of the *vicus Annianus*. This would have been a functional configuration that could have exploited the coastal geomorphology, as was done not far away in the area of the Porto Julius with the infrastructure works conducted by Agrippa (see 2.1.1).

Table 1. Altitude above sea level and chronology of floor levels of the main buildings investigated at sites along the suburb of *Puteoli* and the *ripa puteolana* (Macellum, Cantieri Maglietta, Ex-Sofer, Vicus Lartidianus) (elaboration by M. Silani).

Site	Id point/ Core number	Archeological structure	Chronology	Altitude meters a.s.l	Geoid	Survey day and tidal variation	Date	Project/Pubblication
Vicus Lartidianus	12	pedales floor (plumbaria?)	?	-2,146	EGM2008	±0.30 m	20/06/2024	Project Between land and sea
	23	threshold (plumbaria?)	?	-2,136	EGM2008	±0.30 m	20/06/2024	Project Between land and sea
	26	column of “portico delle Ninfe” (preserved section)	?	-1,165	EGM2008	±0.30 m	20/06/2024	Project Between land and sea
	24	base of “portico delle Ninfe”	?	-2,457	EGM2008	±0.30 m	20/06/2024	Project Between land and sea
	27	floor of Building F (marmorai workshop)	late 2 nd -early 3 rd century AD	-1,246	EGM2008	±0.30 m	20/06/2024	Project Between land and sea
	100	cocciopesto of ambient B of Nabatean temple	after II century AD	-3,067	EGM2008	±0.30 m	20/06/2024	Project Between land and sea
	101	altar table of Nabatean temple	1 st century AD	-3,120	EGM2008	±0.30 m	20/06/2024	Project Between land and sea
	1000	floor of ambiente A Nabatean temple	1 st century AD	-3,750	EGM2008	±0.30 m	20/06/2024	Project Between land and sea
	28	floor of horreum 5 (south side)	?	-2,114	EGM2008	±0.30 m	20/06/2024	Project Between land and sea
Macellum	S21	floor/roadway	Augustan periodo (end 1 st century BC-1 st century AD)	-3,460			2013	Amato, Gialanella 2013
	S21	floor/roadway	Flavian age (second half of the 1 st century AD)	-2,260			2013	Amato, Gialanella 2014
	S21	floor/roadway	Late Flavian-Traian age (1 st -2 nd century AD)	0,140			2013	Amato, Gialanella 2015
	S24	floor/roadway	Augustan periodo (end 1 st century BC-1 st century AD)	-3,180			2013	Amato, Gialanella 2016
	S24	floor/roadway	Flavian age (second half of the 1 st century AD)	-2,180			2013	Amato, Gialanella 2016
	S24	floor/roadway	Late Flavian-Traian age (1 st -2 nd century AD)	0,120			2013	Amato, Gialanella 2016
	S25	floor/roadway	Augustan periodo (end 1 st century BC-1 st century AD)	3,440			2013	Amato, Gialanella 2016
	S25	floor/roadway	Flavian age (second half of the 1 st century AD)	2,990			2013	Amato, Gialanella 2016
	S25	floor/roadway	Late Flavian-Traian age (1 st -2 nd century AD)	0,110			2013	Amato, Gialanella 2016
Cantieri Maglietta	sector 1	cocciopesto floor	mid-1 st century BC	-2,600			1991	Ceraudo, Gialanella, Pellandra 2001
	sector 1	bipedales, sesquipedales floor	Late Imperial age	-0,900			1991	Ceraudo, Gialanella, Pellandra 2001
Ex-Sofer	central sector	road	Augustan age?	2,670			?	Gialanella 2023
	central sector	paved road	second half 2 nd century AD-3 rd century AD	2,970			?	Gialanella 2023
	north sector	room B	Augustan age?	2,030			?	Gialanella 2023
	north sector	room B	Flavian age	2,500			?	Gialanella 2023
	north sector	room B	second half 2 nd century AD-3 rd century AD	2,700			?	Gialanella 2023

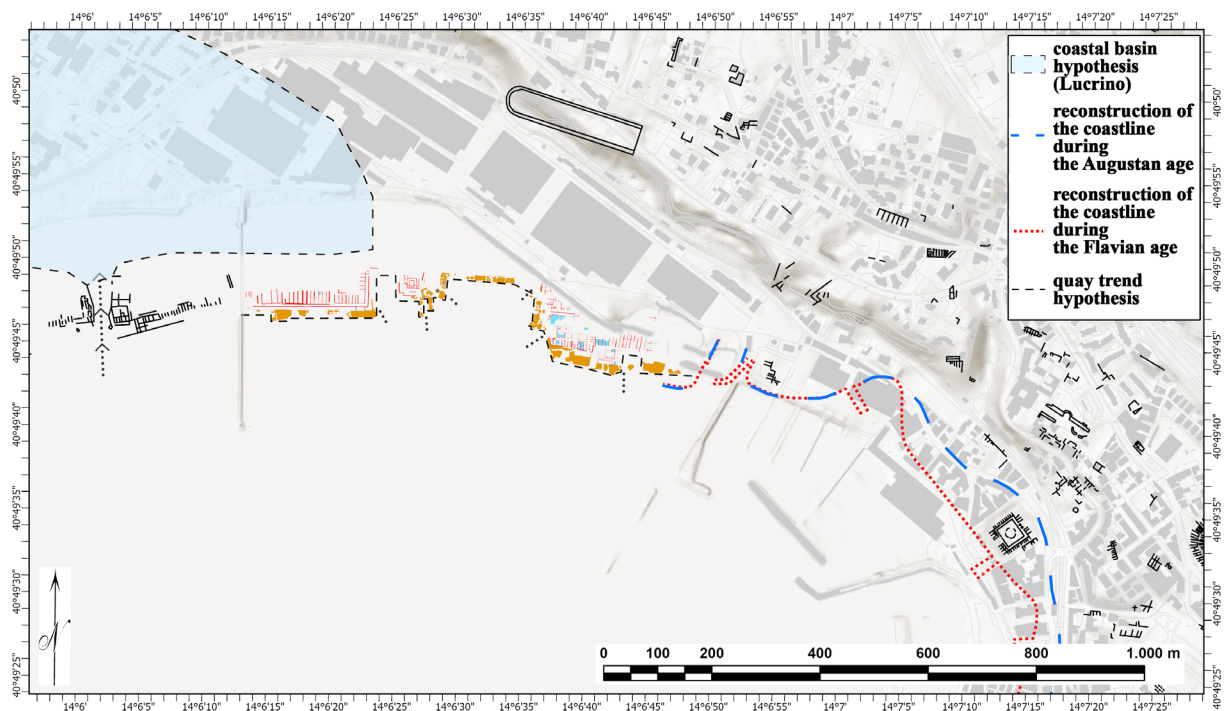


Figure 15. Geoarchaeological reconstruction of the *ripa puteolana* (elaboration by M. Silani).

4. Conclusions

The systematic collection of archaeological, geomorphological, urban, and volcanological data, together with precise topographic positioning, has made it possible to reconstruct the coastal landscape evolution of a sector of the Campi Flegrei caldera, which in recent millennia has been characterized by intense volcanic and bradyseismic dynamics. The interaction between subsidence and uplift, coastal sedimentation, and anthropic interventions aimed at refunctionalizing coastal structures is, for the first time, thoroughly documented and illustrated in this work. The accurate method of measurement, analysis, and contextualization should certainly be applied to other sectors of the caldera, where changes in the land-sea relationship over time may allow the reconstruction of the magnitude of ground deformation, as well as the definition of its rate and spatial variability. The systematic mapping and measurement of archaeological structures and geomorphological features have made it possible to trace with precision the descending bradyseismic phase during the Roman period, showing that, at varying rates, the submergence of previously emergent land was already underway and intensified until the 4th century AD. However, it was only in the 13th-14th centuries (Di Vito et al., 2016; Rosi et al., 2025), during the uplift phase preceding the eruption of Monte Nuovo, that the structures began to re-emerge. New data collected along the *ripa puteolana* highlight significant interventions inside storage and goods-handling buildings, carried out to counteract this descending bradyseismic phase. The rise in sea level made it necessary to raise the walking surfaces, with floors being rebuilt at higher elevations – between 30 and 70 cm above the previous levels. This phenomenon is particularly evident during the 2nd and 3rd centuries AD in the warehouses and other buildings along the *ripa puteolana* and corresponds to the progressive changes in floor levels documented from the Flavian period onward in the *Macellum*, the main observatory of bradyseismic variations in Pozzuoli. Finally, it is worth noting that most of the structures described remain below sea level, despite the current uplift having reached a total of 4.3 m since the 1950s. This indicates that subsidence of the caldera floor is the dominant process, onto which uplift phases – such as that preceding the Monte Nuovo eruption and the current one – are superimposed.

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