Coastal geomorphic response to volcano-tectonic activity in the Campi Flegrei Caldera: new insight from the geoarchaeological study of Portus Julius (Pozzuoli Gulf, Italy).

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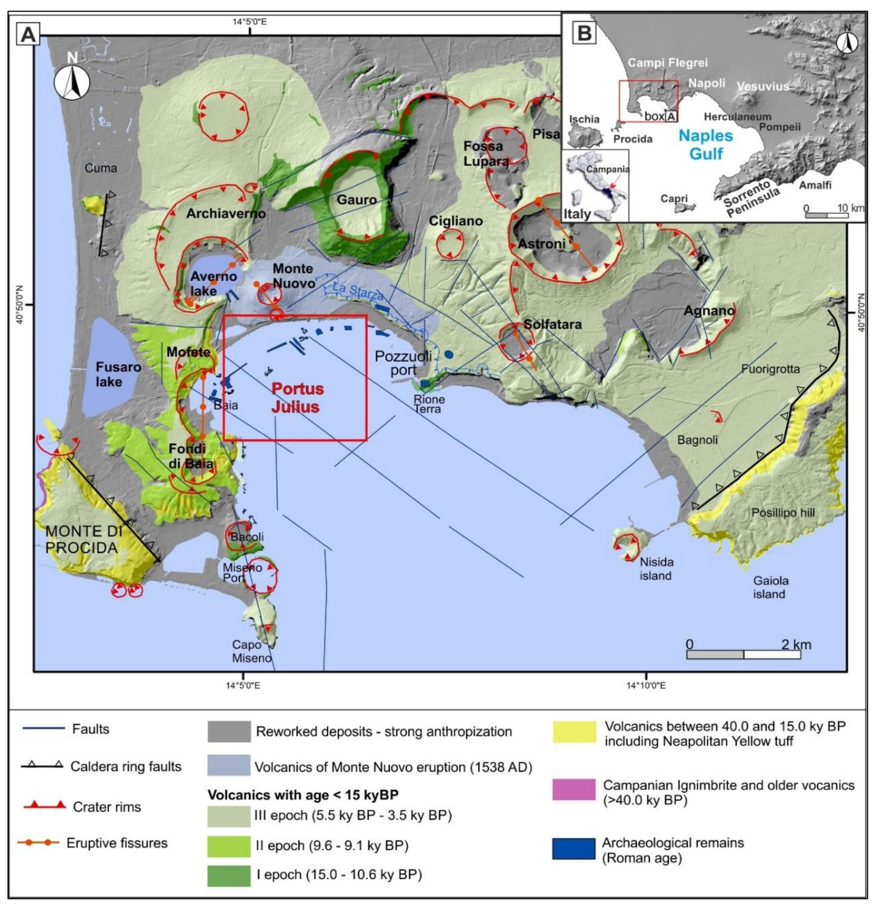

Figure 1. Geological map of the Campi Flegrei with the main volcanic events and the location of Portus Julius.

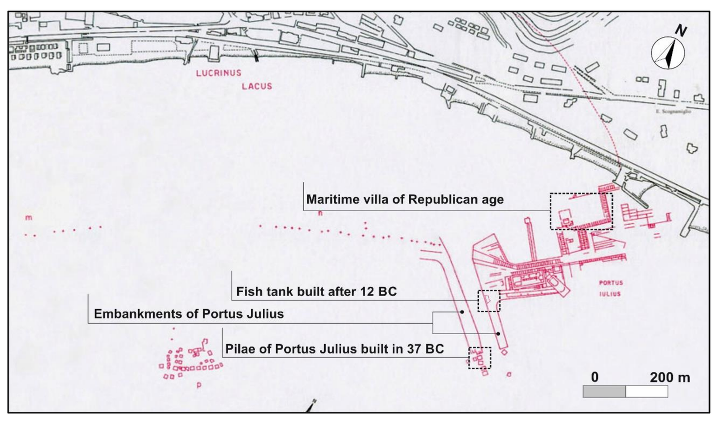

Figure 2. Archaeological map of Portus Julius with the archaeological sea level markers detected.

The Study Area

The ancient Portus Julius is one of the largest underwater archaeological sites in Italy and it represents a great point of interest for marine archaeology studies [1]. This site, located within the Campi Flegrei Caldera (Figure 1) and precisely inside the Underwater Archeological Park of Baia, it's a perfect example of submerged archaeological heritage that records fundamental traces of the ancient coastal morphologies, highly vulnerable to present coastal processes because of recent submersion.

During the Roman period, Portus Julius (Figure 2) experienced at least two different construction phases: a brief military phase (37 BC – 12 BC) during which the entry channel was built, with a length of 300 m and a protection of pier structures with huge *pilae*, and a long commercial phase (after 12 BC) during which the area was restored with the construction of numerous warehouses (*horrea*) and fish tanks. The fish tank here studied represents one of the few examples of *piscinae* related to commercial activities and not to private maritime villas and its recovery within the entry channel can be related to the presence of a fish market or areas intended for the production of the *garum*. According to the historical sources the harbor was abandoned during the IV century AD due to a bradyseismic crisis.

This study presents the results of high-precision surveys on the most reliable archaeological markers of the ancient sea level, aimed at the evaluation of the ground movements affecting the area of Portus Julius during the Roman period.

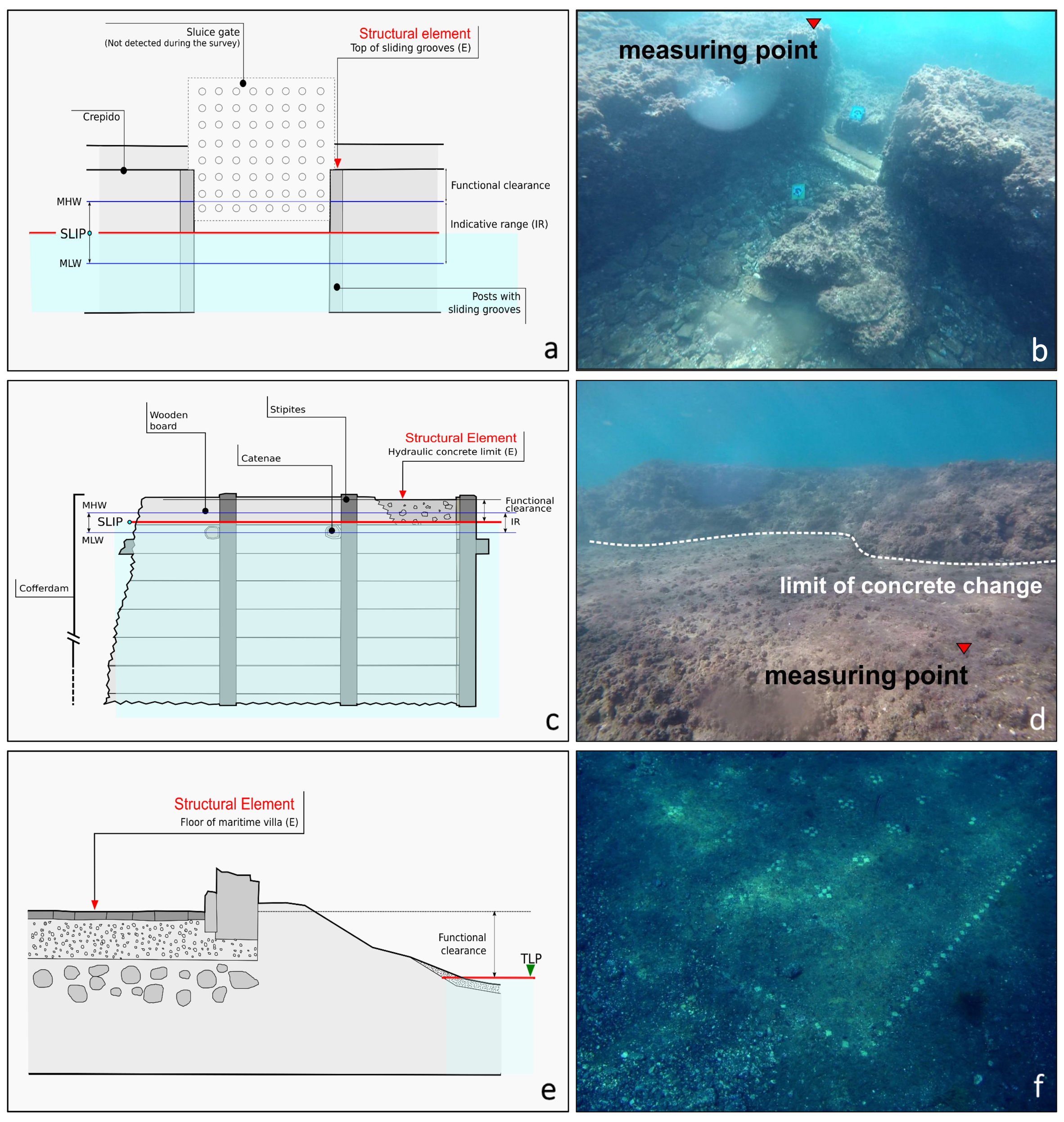

Figure 3. a: mesuring point in the fish tank (MHW: Mean High Water; MLW: Mean Low Water); b: intact sluice gate of the fish tank of Portus Julius; c: measuring point in the pila; d: concrete change in one of the pilae of Portus Julius; e: TLP in the villa close to Portus Julius; f: one of the floors of the maritime villa of Republican age.

Methods

Direct surveys were carried out on three different types of archaeological sea level markers, by using a metric roll and a depth gauge, to measure the size and submersion of the archaeological investigated structures related to different constructive phases of the port. These submersion measurements were corrected with respect to the tidal level and the barometric pressure taken from the tide gauge in the Port of Naples. Among those sea-level markers, the fish tank's sluice gate (*cataracta*) (Figure 3a, 3b) and the concrete change of the *pilae* (sensu Mattei et al., [2]) (Figure 3c, 3d) are considered high-precision sea level index points (SLIPs) [3, 4].

The former RSLs were calculated considering the Indicative Range (IR, sensu Shennan et al. [3]) and the functional clearance of each marker using the following equation:

$$SLIP_{marker}(m) = E - fc_{marker} - IR/2$$

The third marker (Figure 3e, 3f) is a floor belonged to a maritime villa built on the ancient sandy coast, therefore considered a terrestrial limiting point (TLP, [3, 4]).

Moreover, a morphometric reconstruction of the fish tank - key element of our geoarchaeological interpretations - has been carried out to obtain a detailed morphometric analysis of the marker and to preserve a 3D documentation of this important and unique historical testimony (Figure 4).

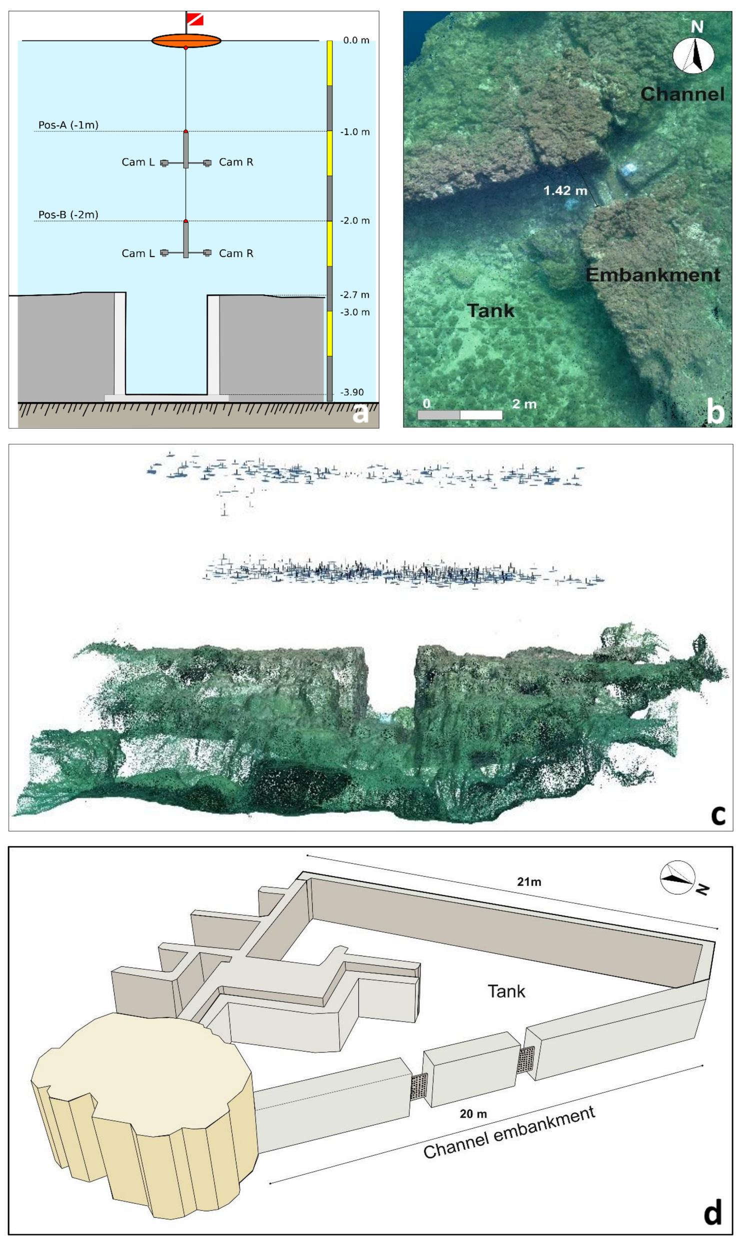

Figure 4. a: reconstruction of the photogrammetric system used during the survey; b: zoom of the 3D reconstruction of the well preserved gate; c: positon of the photogrammetric cameras during the survey; d: 3D sketch of the surveyed fish tank.

Results and Conclusions

From the submersion values, a RSL of -4.7/-5.0 m MSL related to the period before the 37 BC from the living floors, a RSL of -3.1 m MSL related to the 37 BC from the *pilae* and a RSL of -3.1 m MSL related to the 12 BC from the fish tank were determined.

The results achieved in terms of the RSL variations allowed us to reconstruct the evolution of the coastal sector over the last 2100 years (Figure 5). It is possible to affirm that, at the end of the Republican Age, the study area was shaped as a low coastal sector located next to a sandy spit, above which the former *Via Herculanea* was constructed (Figure 5).

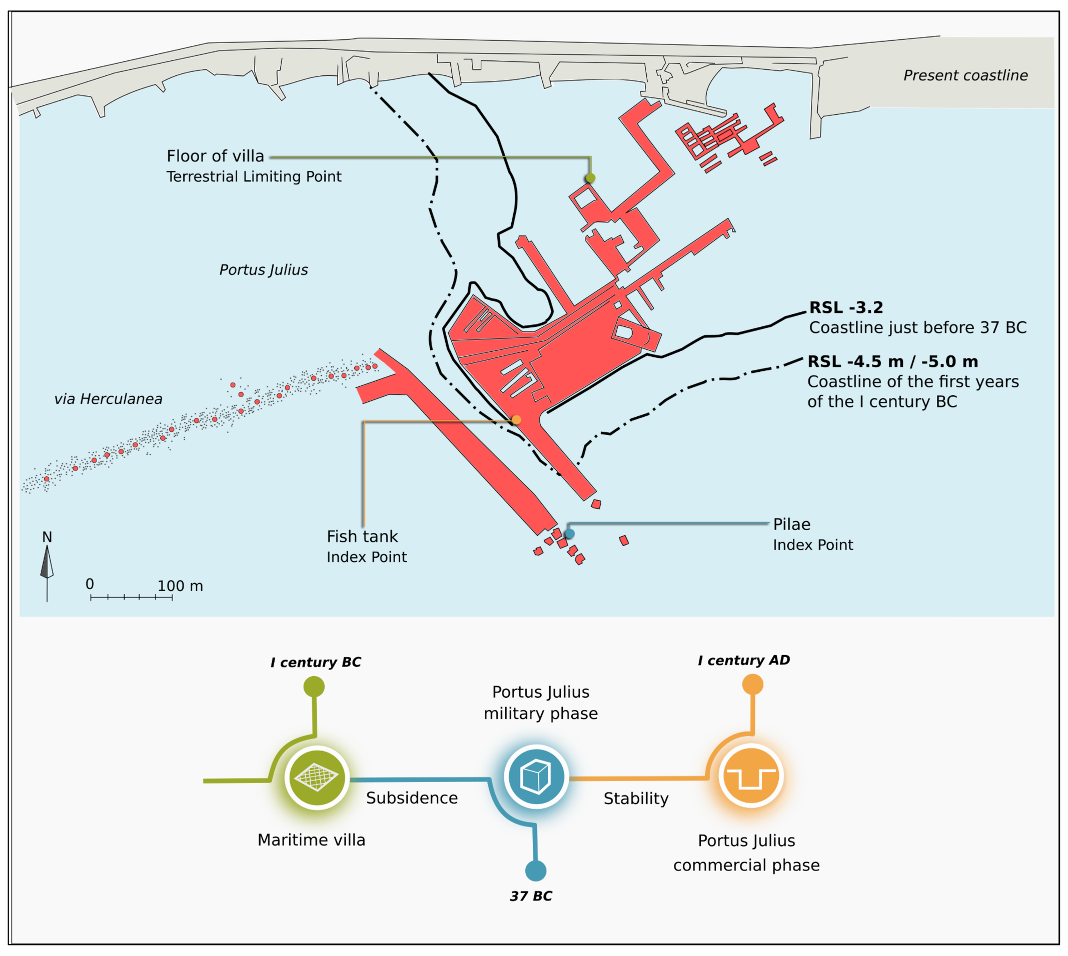

Figure 5. Reconstruction of the probable coastline during the first years of the first century BC (continuous black line) when the maritime villa was built and the coastline in 37 BC (stretch and point black line), after the 2 m of subsidence, when the Portus Julius was built.

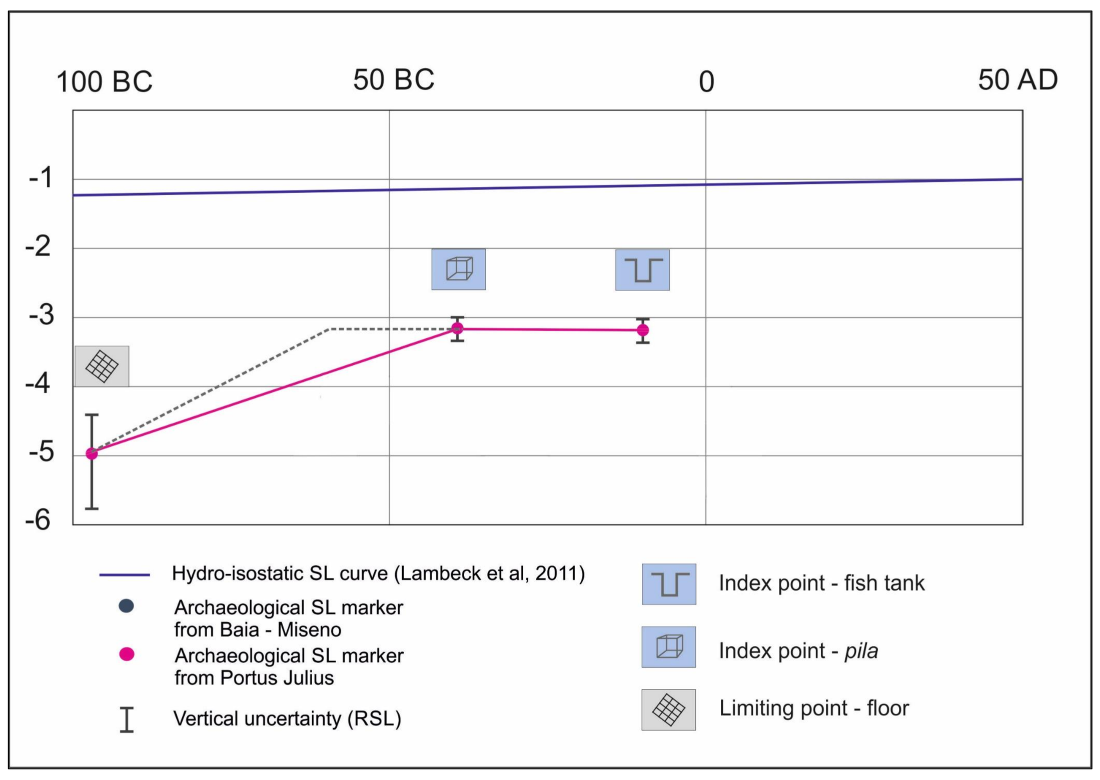

Figure 6. The RSL data derived from the geoarchaeological study of Portus Julius compared with the Hydro-isostatic SL curve of Lambeck et al., 2011.

The maritime villa, analyzed in this paper, was located near to the above-mentioned spit in a flat area at a depth of about −3.5 m MSL. Therefore, considering its functional clearance, an RSL at −4.70/−5.2 m MSL can be presumed for that period. The RSL at −3.2 m MSL measured from the *pilae* demonstrates that some subsidence had already occurred when the military port was built in 37 BC. As well, we can suppose that the subsidence, which produced an increase in the water depth, encouraged the construction of the harbor facility.

Finally, the standing of the RSL from the fish tank at about −3.2 m MSL, even after 12 BC, demonstrates that the area experienced a period of volcano-tectonic stability .

Moreover, by comparing our measurements with the Glacio-Hydro-Isostatic Adjustment (GIA) models proposed by several authors [5, 6] (Figure 6), it is possible to determine that the only contribution of the vertical ground movements (VGMs) occurred between the early first century BC and the early first century AD. In this period, the GIA produced an SL variation in our study area of a centimetric amount (from −1.05 to −1.09 m MSL). Consequently, at the same time and in terms of VGMs, the study area suffered a subsidence of about 4.00 meters, and experienced a rapid increase (bradyseismic crisis) of another 2.00 m before 37 BC.

References:

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