VENICE SUBSTRUCTURE COMPLEX

Research/Studies/Concepts/Antecedents

Exemplary research and studies for examining selected subterranean structures and foundations of Venice, Italy, as a function of their geologic context, origin and displacement of and within natural systems/materials dated back to the Tethys Sea and Alpine orogenic events.

The *Venice Substructure Complex* is characterized as a conformable Anthropocene, intrusive suite and super-positioned stratigraphic system. An integrated wooden piling system is understood as a unique, submerged, geo-sylvan environment displaced from its original sub-aerial habitat.

The Venice substructure is seen as a sea/land environment constructed of sea/land environments of Mesozoic, Tertiary Quaternary and Anthropocene ages.

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Spring 2016 Sabbatical/Residency
Emily Harvey Foundation / Venice, Italy

Venice Substructure Complex (VSC), describes a unique, largely hidden, structural system underlying the city of Venice. The origin of this assemblage, as considered in this study, is the contemporary landscape of Venice extended in geographic, geologic, climatic and cultural terms over an area of central and southern Europe. The configuration and materiality of the current Venetian landscape was shaped by the transformation of other, earlier, landscapes and seascapes as far back as the Jurassic Period. This transformation and the unique character of *VSC* evokes a conversation between the foundations of Venice with it's contemporary and historical environment. Further into this investigation, several analogs and concepts for envisioning ecological and artistic responses to this dialog are also set forth. The interaction of time and place within the Venetian terrain suggests analogs between natural and human activity, process and meaning. Materials displaced in time and space are a primal mechanism of change in the construction of landscapes, seascapes and cities, this theme in both natural and human systems is further echoed in this document.

Plate tectonic engagement of the Eurasian and African plate during the Mesozoic and Cenozoic set the stage for the formation of Italy, the Alps and Adriatic Sea, formative elements of the Venice landscape. As a result of this larger geologic dynamic, the upper 900 meters of Venetian lagoon sediments were deposited from natural terrestrial and marine sources in Quaternary time. In Anthropocene time the *VSC* was deposited on and into the upper layers of the lagoon sediments. Wooden foundation pilings are a primary component of the *VSC*. Creating a stable foundation for the architecture of Venice, a system of tree trunks taken from local forests and the foothills of the Alps were intruded into the sediments. The pilings were capped with wood of the same source and Jurassic era limestones primarily from the Istria peninsula of Croatia across the Adriatic from Venice. Layered onto this stone strata were fired bricks of primarily Pleistocene glacial sediments. The final element of the *VSC*, forming the streets (calle) and ground-floor surfaces at the top level, shallow, horizontal strata of primarily Oligocene trachyte and Cenozoic carbonates were set in place.

The image of an invisible forest preserved by it's anaerobic environment, displaced geographically and atmospherically from it's aerobic origin of local terrestrial terrain and Alpine foothills, encased in a sedimentary matrix of complex origin (Tethys Ocean sediments altered by plate tectonics of the Alpine Orogeny and subsequent glacial depositional and erosional processes) is compelling. Relating back to the flora and fauna of the Tethys Sea, Alpine soils derived from that mineral/biol-legacy form the nutrient systems of the forests themselves. The bricks of Alpine erosional sediments of Pleistocene age are local to Venice but also share geochemical and paleo-climatic relationships with the wooden pilings. The Istrian limestone directly makes a geologic connection with it's origin as carbonate sediments/reefs of the Mesozoic, Tethys/Neo-Tethys seas, consolidated by tectonic activity as part of the Apulian/Adriatic plate and associated Alpine and Dinaridian orogenies. This project also investigates conceptual ideas for the return of the displaced, anaerobic and submerged forest into a subaerial respiratory environment similar to it's origin: a re-distribution of the pilings as living trees as a parallel forest in current and future time. The *VSC* (and all of Venice) considered as a buoyant structure floating in the sediments of the Venice lagoon conjures elemental ship-like structures of environmental change and transit. The change in density of the piling placement for support of architecture into a diffuse habitat of a healthy, living forest becomes an evolution of the conversation of the city with it's environment.

Venice Substructure Complex, as described above, is characterized as a geologic and metaphorical formation. This description is similar in nature and perception to other projects such as the *San Francisco Wharf Complex*, 2012, where the wharf system of San Francisco is seen as a geologic structure in it's own right with Anthropocene/geologic, morphologic, depositional, transport and displacement analogs and ensuing conversations. Similar concepts arise between the Venician and San Francisco sites for possible environmental expressions of corresponding research. For Venice as for many other sites specific/literal information is often incomplete or conflicting. In the case of the wooden piling system beneath Venice several models of the piling layout and configuration were compared or consolidated to arrive at an general idea of the scope of the materiality and structure of the cities subsurface and their role in the larger formation. This study in not intended to be authoritative or act in the place of science, but as an exploration linking science, observation, history and site to reveal latent and poetic conversations of Land and Sea. Examples of additional, relevant antecedents that engage site, materiality and research include: the kiln/site projects, 1979-92, *Vanishing Ship (Greenhouse for Lake Lahontan)*, 1987, *Metafossil..*, 1992, *Deep Gradient/Suspect Terrain..*, 1993, the works in the exhibition, *Rising Sea..*, 1998, *Holocene Terrace* and related multi-beam sonar concepts, 1999, *Holocene Passage*, 2002, *Original Depositional Environment*, 2002, and *Rapson Group/Site Index*, 2004-13, among numerous others. Some of these projects are illustrated at the end of this document.

The Sea within the Land / The Land within the Sea / The Land within the Land / The Sea within the Sea

A special thanks to the Emily Harvey Foundation for the time, space and place to carry out this research and for the San Francisco Art institute for time and support in the form of a sabbatical semester, Spring 2016.

The material and structural stage was set for the *Venice Substructure Complex* in the Mesozoic Era by the conditions and environment of the Tethys Sea and its subsequent transformation by plate tectonics. The part of Italy that includes Venice is situated on the Apulian/Aptian micro-plate (also known as 'Adria') that extends from the western Po valley to the middle of southern Mediterranean Sea (fig 2). The journey and changes in geologic time of this plate have had a direct and indirect affect on the Venetian environment, creating the core elements of the *Venice Substructure Complex*. Venetian lagoon stratigraphy, Istrian limestones, clay for bricks as well as the soils supporting the forests of the Alpine foothills have their deep roots in the Mesozoic/Cenozoic ballet of plate tectonic genesis of the Mediterranean.

The central part of the Neo-Tethys Ocean during the middle-late Mesozoic was characterized by the slow northward motion of a complex puzzle of blocks, including parts of future Turkey, Greece, Dinarids, and Apulian/Aptian (Adria) micro-plates.

The Apulian/Aptian micro-plate consists of two blocks, a northern and a southern one, which have different lithospheric thicknesses. These were thought to have been united in a collision during the Triassic and to be a promontory at the edge of the African plate until subsequent separation. This separation began in the Middle and Late Triassic, when limestone began to be deposited in the area. Between the Norian and Late Cretaceous, the Adriatic and Apulian Carbonate Platforms formed as a thick series of carbonate sediments (dolomites and limestones), up to 8,000 meters (26,000 ft) deep. At the same time the Adrian and Apulian micro plates that were to become Italy were pushed into the Eurasian continent lithosphere by the convergence of the Eurasian and African plates creating a collision with the European plate initiating the Alpine orogeny (tectonic building of the Alps) that is still on-going.

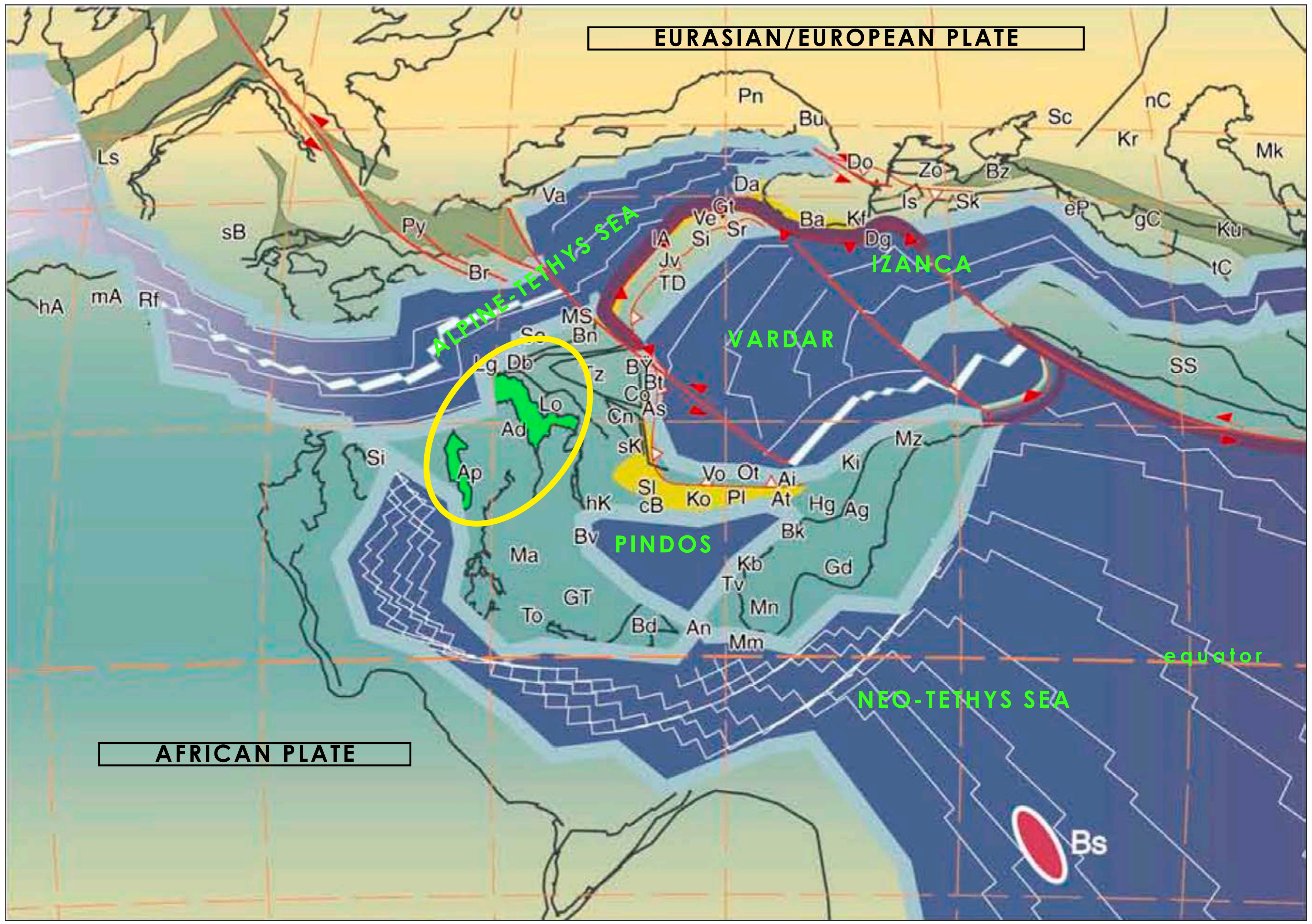


Fig 1. Adapted from: Valanginian Age (140-132 mya, early-Cretaceous) reconstruction of the western Tethyan realm, Stampfli, G. M., Borel, G. D., Marchant, R. & Mosar, J. 2002. Western Alps geological constraints on western Tethyan reconstructions. In: Rosenbaum, G. and Lister, G. S. 2002. In: Reconstruction of the evolution of the Alpine-Himalayan Orogen. Journal of the Virtual Explorer, 7, 75 - 104. (modified from Stampfli et al., 2001a; Stampfli and Borel, 2002), rift zone are shown in greenish color, foreland in orange color.

Relevant symbols: Ad, Adria s.str.; Ap, Apulia s.str.; DH, Dinarides-Hellenides; Is, Istanbul.

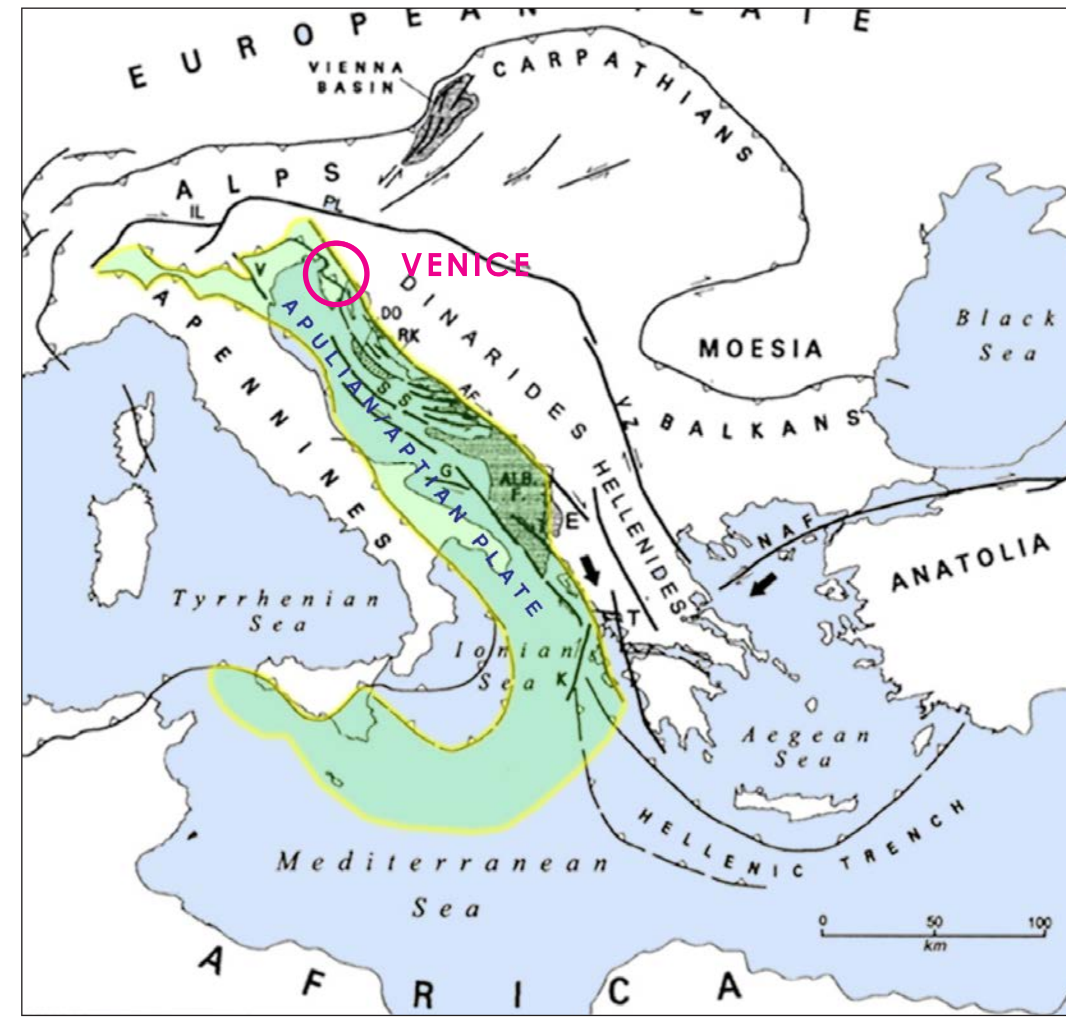


Fig 2. Battaglia, M., Murray, M. H., Serpelloni, E. and Burgmann, R.: *The Adriatic region: An independent microplate within the Africa-Eurasia collision zone*, Geophys. Res. Lett., 31(9), 2004.

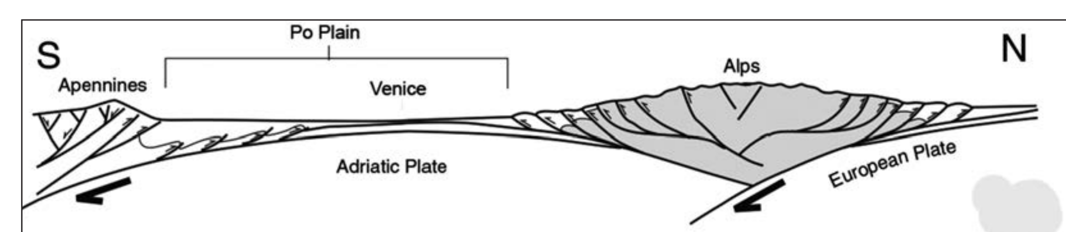


Fig 3. Schematic regional cross section through the Alps – Po Plain – Apennines system. E. Carminati, C. Doglioni, D. Scrocca, Magnitude and causes of long-term subsidence of the Po Plain and Venetian region.

Venice Substructure Complex: Pliocene/Pleistocene / Sea Level / Climate / Depositional Environment

From the Pliocene epoch (2.6-5.2 mya) to more recent time, climate fluctuations have been instrumental in the development of the contemporary landscape of Northern Italy and the lagoon of Venice. The sea level and climatic changes resulting from Pliocene warming, Pleistocene glacial extremes to the present created alternating deposits of maritime and alluvial sediments and morphology of the Venice lagoon, coastline and islands.

During glacial expansion, between 30,000 and 19,000 cal. yr B.P., alpine glaciers reached the alluvial plain in the piedmont area, and the paleo-plain extended into the northern Adriatic, with sea level about 120m lower than today. In this phase of marine low-stand, thick deposits accumulated on the plain by glacial melt-water streams. This includes a main aggradation event associated with the Brenta River alluvial system prior to 18,000 cal. yr B.P. as well as massive sedimentary deposits from other rivers of the Southern Alps, including the Piave, Adige, and Po. In addition to climatic variation, the Venetian area has experienced overall subsidence since the Late Pliocene due to this influx of sediment.

Fig. 4. Mid-Pliocene Epoch (3.3-3.0 mya) Mediterranean sea levels. The first hominids, including Australopithecus and Homo habilis, appeared during this epoch. https://commons.wikimedia.org/wiki/File:Adriatic_sea_pliocene_(vector).svg

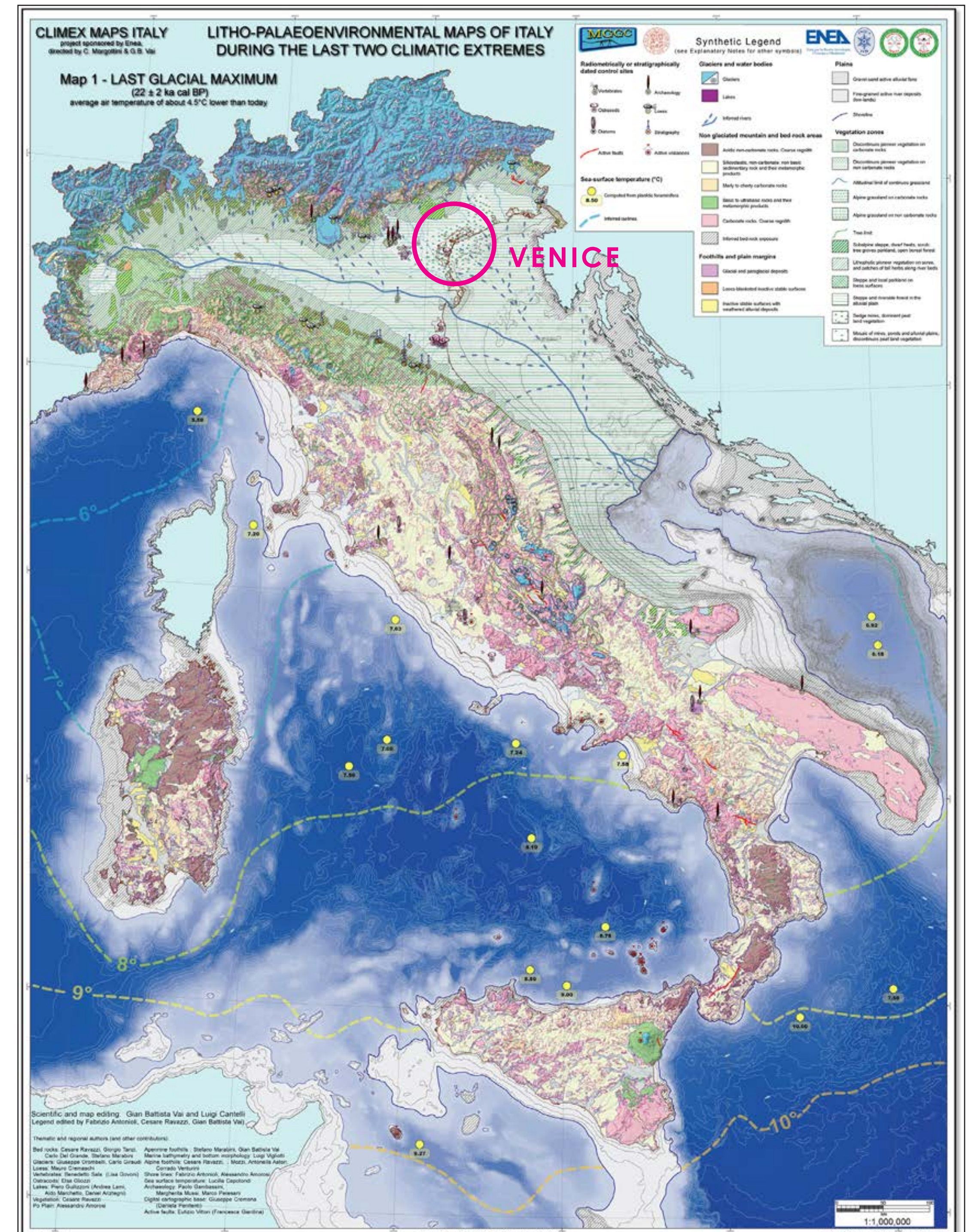


Fig 5. Reconstruction of the emerged land and exposed continental shelf during the largest marine transgression, during the last glacial maximum (Würmian glaciation), 22 +/- 2 ka ca BP.

The next phase of marine transgression (post-18,000 cal. yr B.P.), due to eustatic rise linked to melting ice caps, led to the formation of coastal lagoon systems. The basin of the Venice lagoon is around 900 m deep with sediments of both Alpine/fluvial and Adriatic/marine origins caused by alternating ingression and regression of the sea. The origin of the actual lagoon can be traced around to 6000 years ago, during a marine transgression during the Holocene epoch. The upper (Quaternary) basin sediments beneath the lagoon, including Anthropocene architectural deposits, can be divided into five facies groups with the last four as determined by Sandra Donnici, et.al (2011), see Fig. 8 caption, and used in this study for stratigraphic representation of the *VSC*. The city of Venice was constructed, on islands in the lagoon officially beginning in 421 AD with church of San Giacomo at the islet of Rialto (Fig. 8).

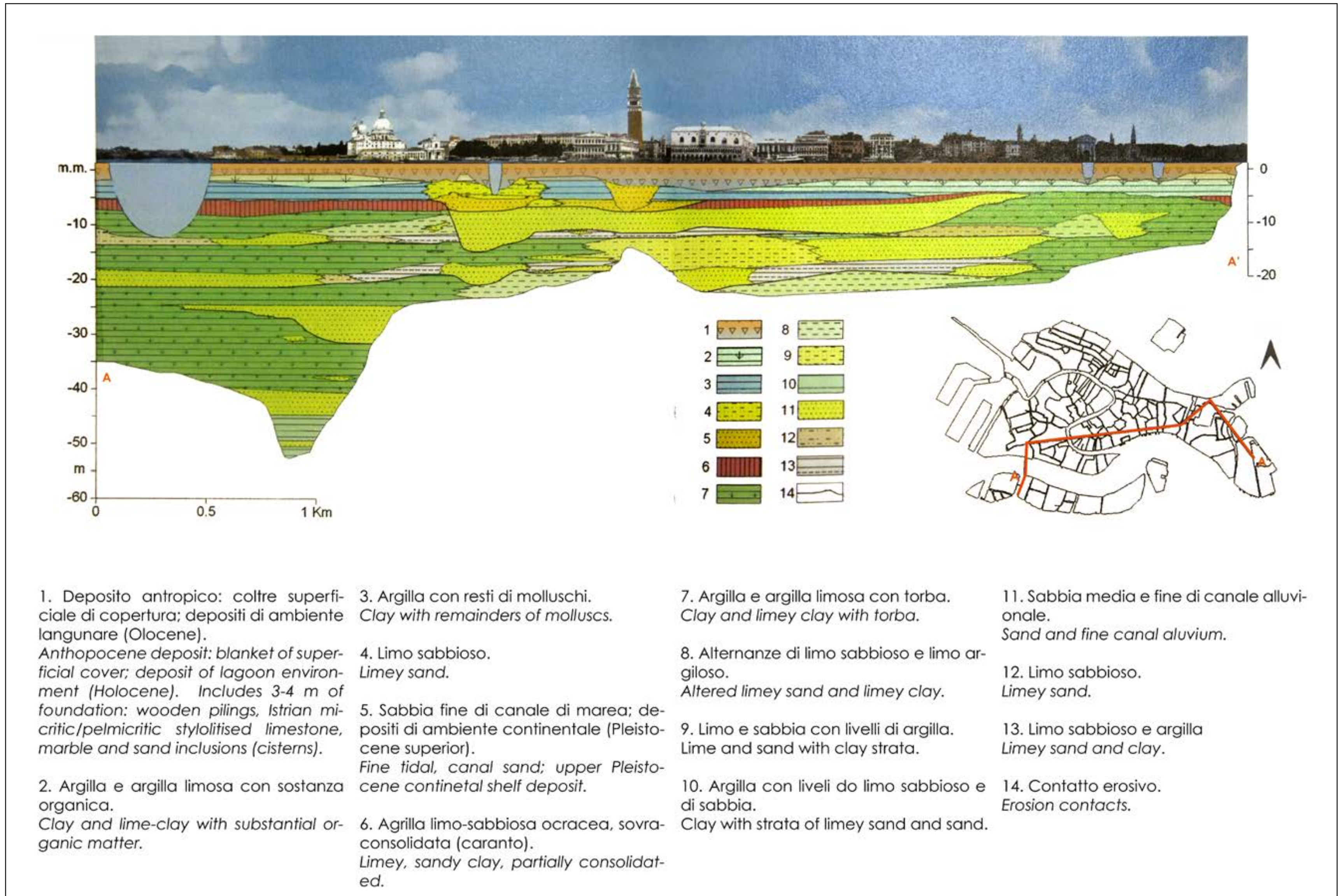


Fig. 6. Venice cross-section. Adapted from Zezza, Fulvio, *Venezia citta d'acqua*, Marsilio Edition, 2014. Translation of legend by artist.

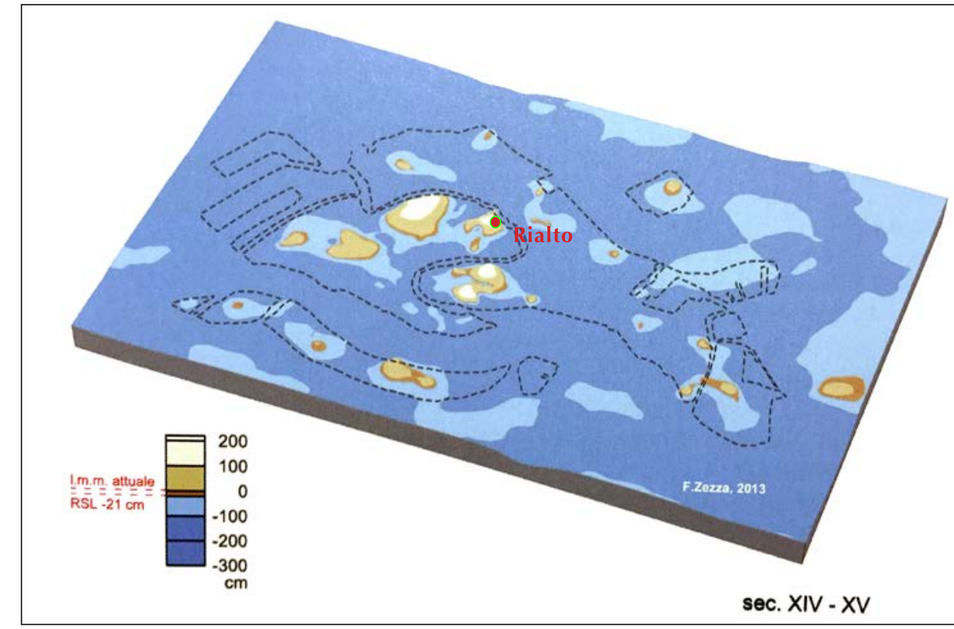


Fig. 8. Pre-city lagoon islands, contemporary Venice area shown by dotted lines, Islet of Rialto by a red mark. Adapted from Zezza, Fulvio, *Venezia citta d'acqua*, Marsilio Edition, 2014.

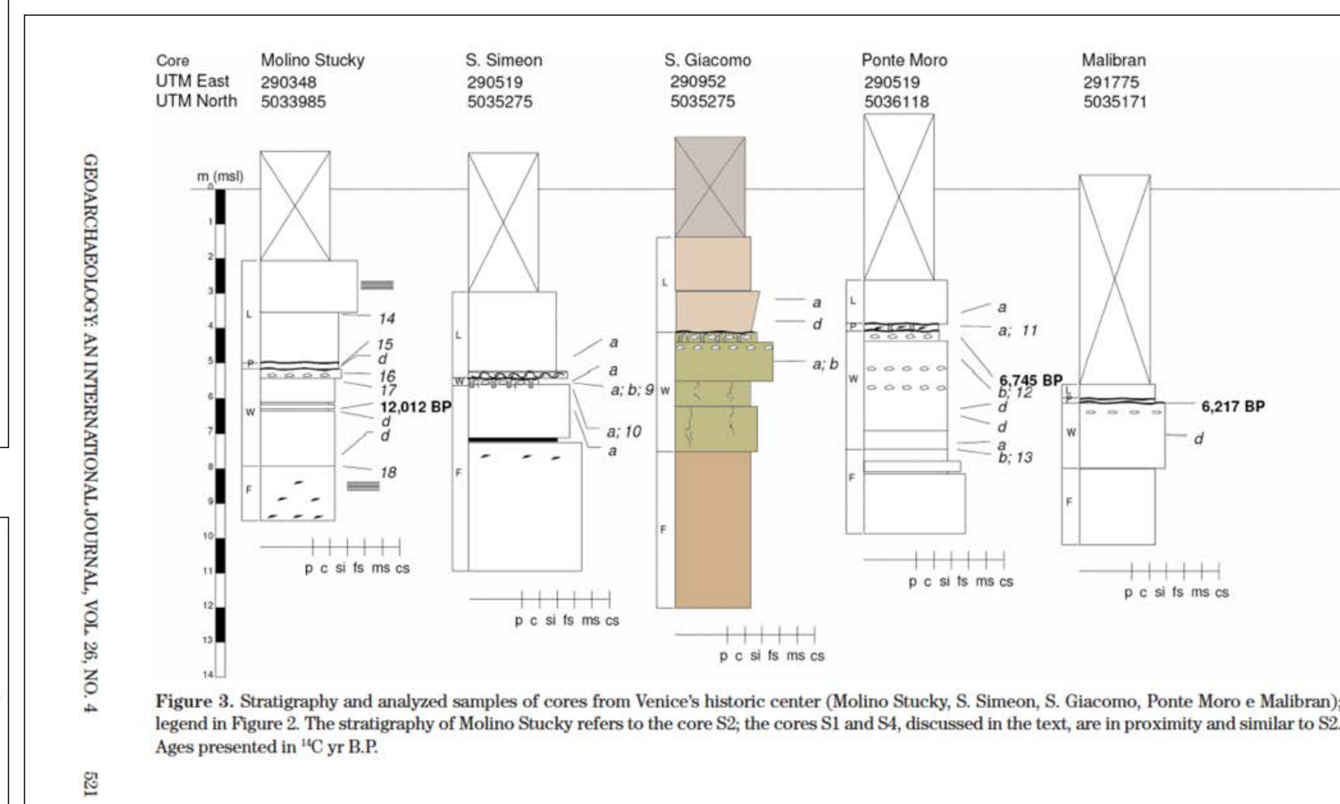


Fig 9. Core samples of Venice, S. Giacomo is near the case study site. Adapted from Sandra Donnici,1,* Rossana Serandrei-Barbero,1 Claudio Bini,2 Maurizio Bonardi,1 and Alberto Lezziero3,*The Caranto Paleosol and Its Role in the Early Urbanization of Venice*, Geoarchaeology: An International Journal, Vol. 26, No. 4, 514–543 (2011).

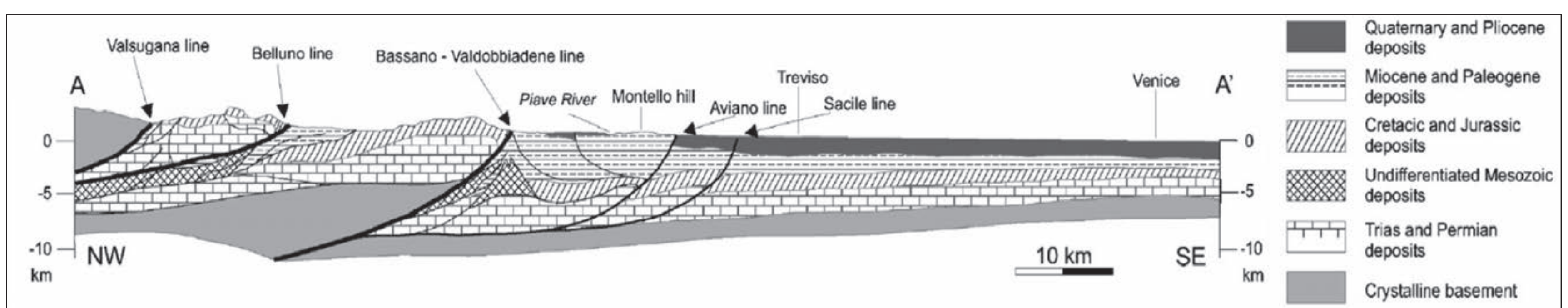
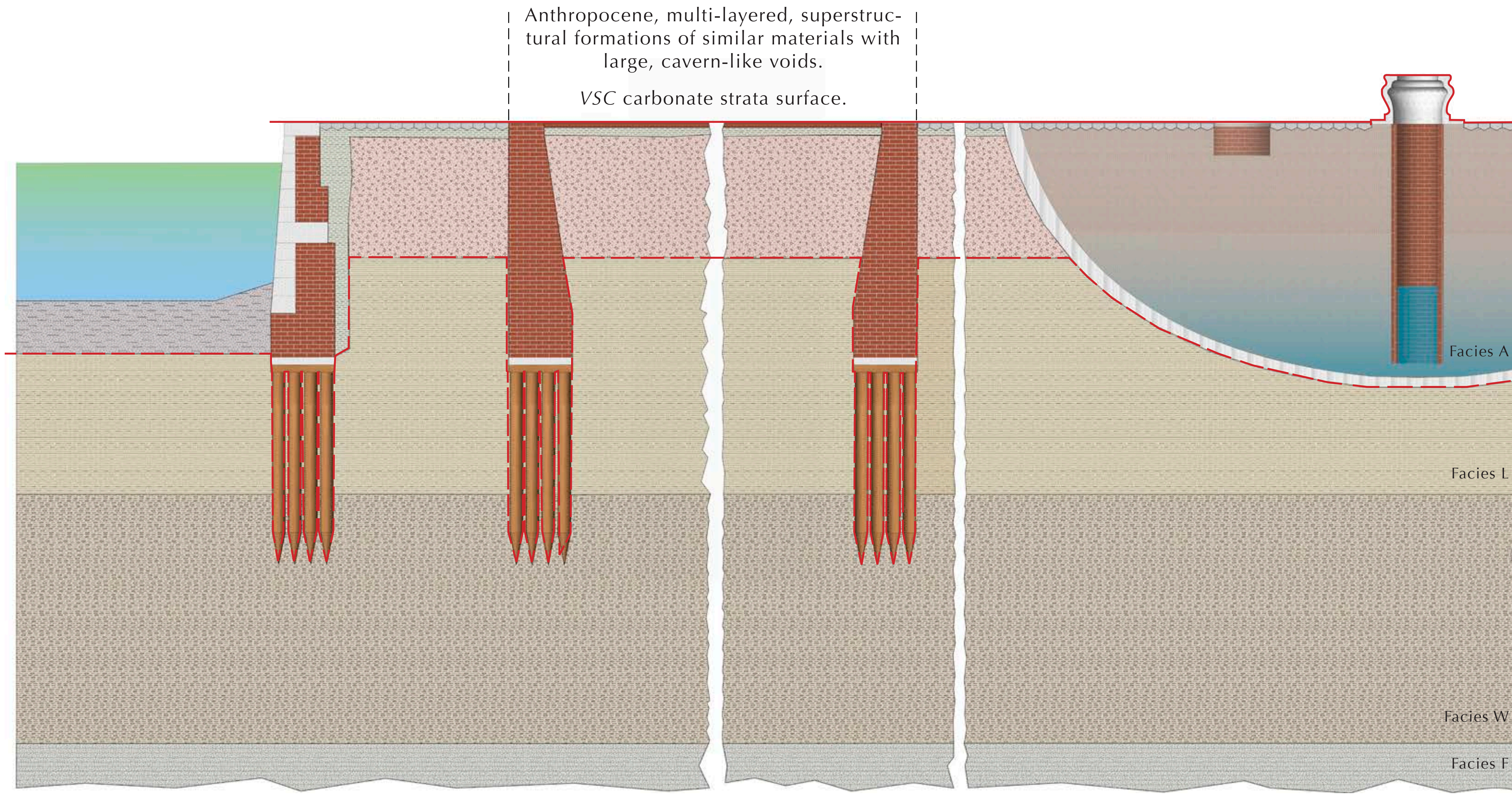


Fig. 7. Geological cross-section of the Venetian–Friulian area. Alessandro Fontana, Paolo Mozzi, Aldino Bondesan, *Alluvial megafans in the Venetian–Friulian Plain (north-eastern Italy): Evidence of sedimentary and erosive phases during Late Pleistocene and Holocene*, Quaternary International, 189 (2008) 71–90.

Venice Substructure Complex: Subsurface Stratigraphy/Cistern Section

Cross-section of typical structural/tectonic relationships and stratigraphic components of the *Venice Substructure Complex* (VSC), developed from models 1/1A and 2 (Fig. 24, 25, 26). The VSC extends from the top of Facies A (as shown below) to at least the bottom of Facies F (full thickness not shown). The overall thickness of VSC typically varies from 8.5m to about 14m from the top of the section, depending on a wide range of thickness of the A, L, P, W and F Facies across the entire Venice site. In certain definitions, the thickness of the VSC may continue for the full 900m depth of the Quaternary sediments of the Venice lagoon area. The VSC is focused on the subterranean stratigraphy and hybrid Anthropocene/Quaternary assemblages and does not include major super-structural formations of built architecture above Facies A, as shown below. The cistern well-heads typically of Istrian limestone or other limestone/marble are included in the VSC as integrated components of the cistern element.



Facies A (Anthropocene Formations/Sediments) - includes: structural and stratigraphic configurations of compacted and undifferentiated Anthropocene sediments with occasional, cavern-like voids, hydrologic, Quaternary sand inclusions/systems, rectilinear, meta-agrillitic/indurated mudstone strata (fired brick) of Holocene clays inter-fingered with assorted clastics in complex calc-silicate matrix (mortar), Jurassic Istrian limestone inter-fingered strata, Oligocene trachyte and variable-colored Mesozoic carbonate upper strata and recent wooden vertical/horizontal organic dikes (pilings/maderie-zattere). Deposition by human agency using contemporary technology.

Anthropocene Substructure Formations/Sediments / Facies A

Holocene/Pleistocene Sediments / Facies L/P/W/F

Facies L (Lagoonal Sediments) - Gray and dark gray silt and silty clay, containing mollusk shells and vegetal remains. Intertidal and subtidal mud flats with intercalated tidal channel sand deposits. Lagoonal environments related to the Middle Holocene marine ingression and the following marine highstand.

Facies P (Palustrine Sediments) - Dark greenish gray clay and silt with small vegetal inclusions. This environment appears to have preceded the Middle Holocene marine ingression. General to Venice but not in this area.

Facies W (Altered Alluvium/Caranto) - Fine-textured alluvial deposits with abundant iron mottles and calcitic nodules. Latest Pleistocene and the Early to Middle Holocene (ca.14,500–6000 14C yr B.P., or ca. 17,500–7000 cal. yr B.P.). A calcic paleosol, buried by Middle to Late Holocene marine transgressive deposits, represents a subsurface layer long known in the Venice area as "caranto." The caranto exhibits relatively high compressive and shear strength, making it an important substrate for architectural foundations of Venice.

Facies F (Fluvial Plain) - Massive gray silt inter-layered with coarsening upward sequences of silty clay, silt, sandy silt, and fine micaceous sand with structureless or laminated medium to coarse sand. These sediments were deposited during the LGM (last glacial maximum) and are interpreted as floodplain deposits interlayered with levee and crevasse splay deposits.

Venice Substructure Complex rests on Tertiary through Permian deposits on crystalline basement.

Fig 10. Schematic view: *Venice Substructure Complex* section.

Venice Substructure Complex: Substructure Stratigraphy Models

There are three principal models from different sources used for configuring and visualizing the *Venetian Substructure Complex*. Model 2 shows the general system of foundation elements and placement for architecture and cisterns. Model's 1 (with 1A) and 3 show different scales and densities for piling distribution. Models 1 and 1A show a distribution of an average of about 8 m^2. Model 3 shows an average of 16 pilings/m^2. A combination of model 1, 1A and 2 were used to create the distribution study for Melio an San Stae Islands in this document.

The Venipedia/Canal Walls website gives one model for a typical canal wall structure. In this model, the canal walls are made up of 5 main elements. Wood pilings serve as the base support of 5-10 wood pilings driven into the ground per square meter. Each wood piling is 2-8 m long and 10-30cm in diameter. On top of the pilings, three planks of 5cm thick wood are laid. On top of the wooden planks are a 20-30cm thick layer of Istria limestone (referred to as arenaria). Mattone (rectilinear, meta-agrillitic/indurated mudstone - fired brick) are then laid on top of the limestone, they are layered in tiers for a couple meters until the canal bed meets the water. The next layer of wall is composed of a combination of bricks and Istria stone. Cadena/ciavariol are large Istrian limestones that are laid horizontally in increments in the canal wall. The top-most layer of the canal wall is often listolina, large Istria Stones that cap off the canal wall. Tera da soan (impermeable clay) is typically placed behind the wall to prevent water from seeping through the canal wall and eroding infrastructure.

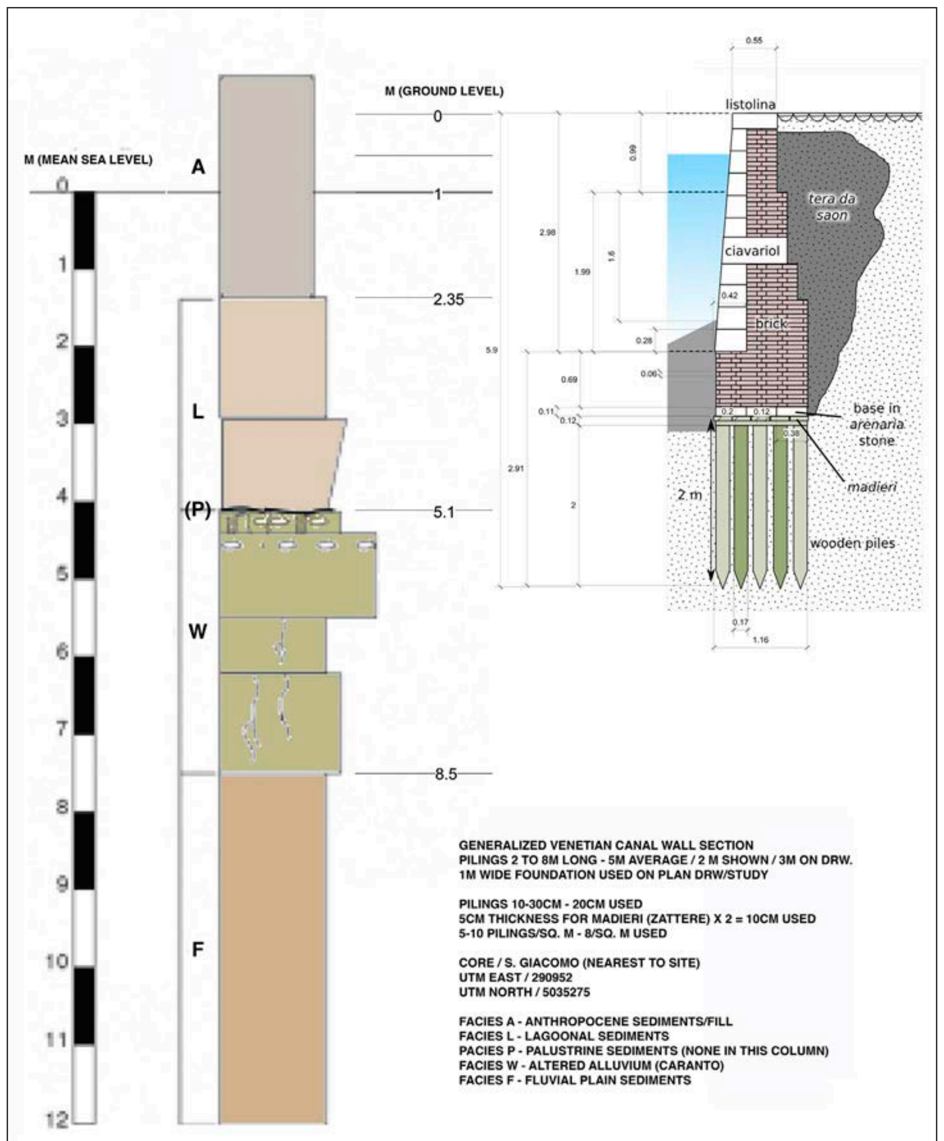


Fig 11. Model 1 - Adapted from, Venetian canal wall section from http://www.venipedia.org/wiki/index.php?title=Canal_Wall, correlated to core sample from S. Giacomo, near the case study site. Adapted from Sandra Donnici,1,et al.,*The Caranto Paleosol and Its Role in the Early Urbanization of Venice*, Geoarchaeology: An International Journal, Vol. 26, No. 4, 514–543 (2011). Sizes in meters.

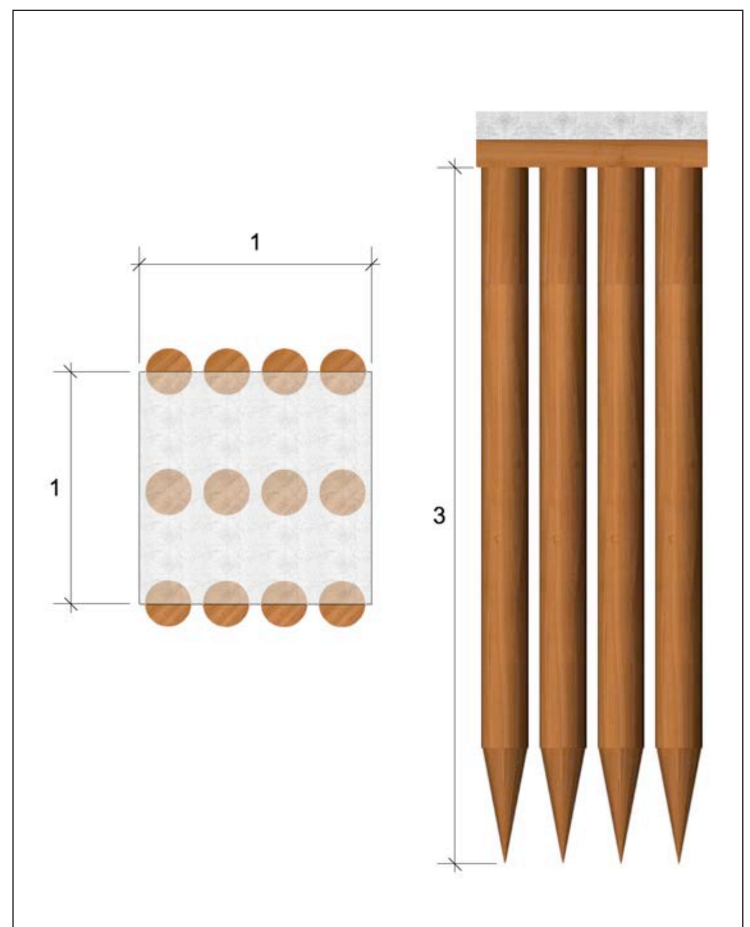


Fig 12. Model 1A - Detail diagram of the lower substructure from model 1, showing 8 pilings/m^2 at a length of 3m, distribution and scale used for illustrations of the *VSC* in this document.

Fig 13. Model 2 - Adapted from, *The Building Blocks of Venice, Preserving Knowledge of a City's Infrastructure and Maintenance*, Worcester Polytechnic Institute, Fabio Carrera, Frederick Bianchi, et. al., 2011.

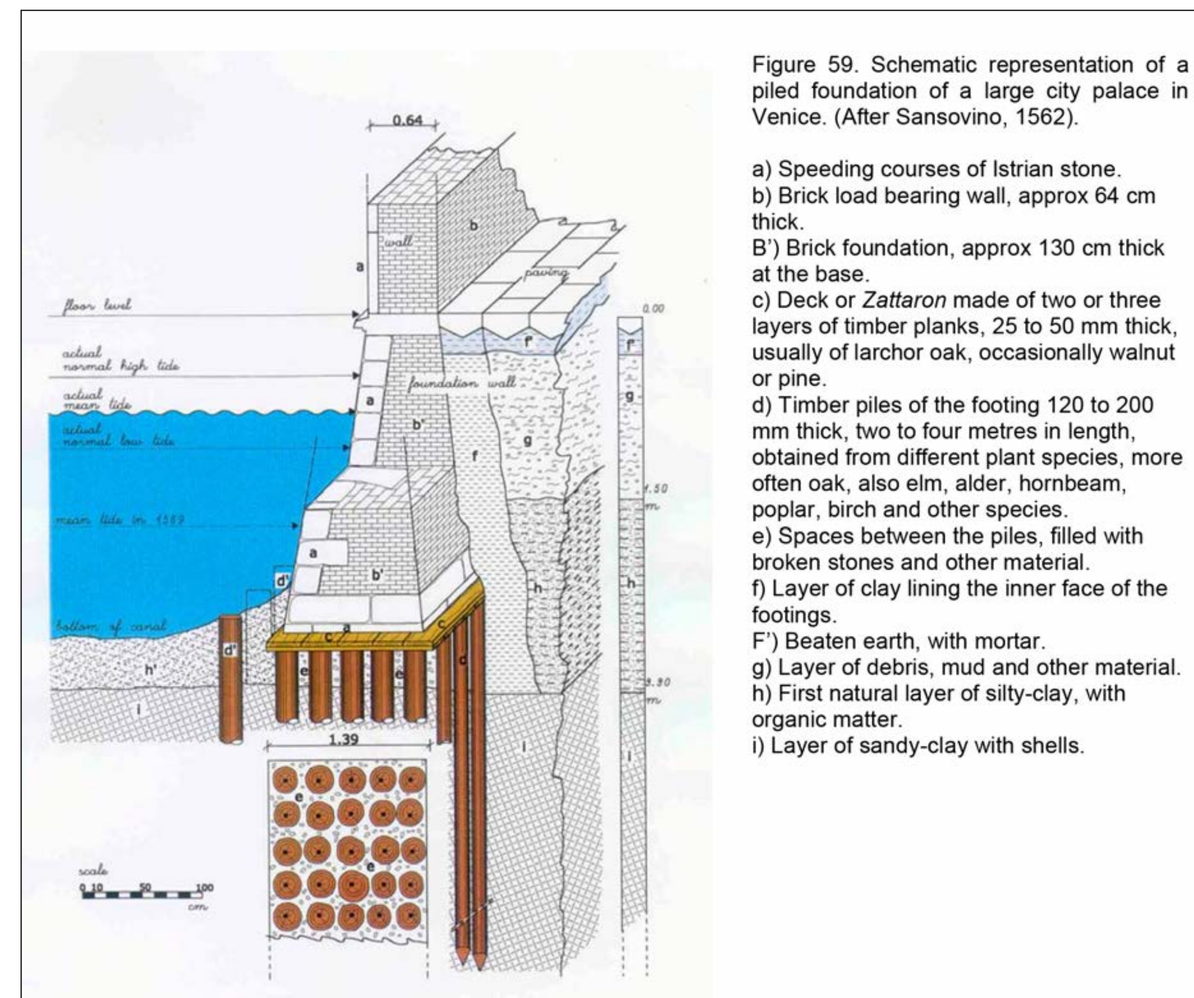


Fig 14. Model 3 - Adapted from, *Preserving cultural heritage by preventing bacterial decay of wood in foundation poles and archaeological sites* / EVK4-CT-2001-00043 Wageningen / European Commission 2005.

A vertical wooden piling and horizontal strata system represents a specialized Anthropocene intrusive member of the *Venetian Substructure Complex*. The wooden pilings and members were extracted from forests in the northern Adriatic region, at times considered the Venetian *Terraferma*. During the 9th–11th centuries A.D., local woods such as poplar, alder, and elm were the favored building material. When local wood was depleted, at the beginning of the 13th century, coniferous wood (fir, pine, and larch) begin to be harvested from the southeastern slopes of the Alpine foothills and brought down the Adige, Brenta, Piave, Tagli, Amento and Isonzo rivers in the form of rafts by zattiere for use as pilings, ships and architectural structures. The forests of the *Terraferma* were managed as sustainable resources through strict codes limiting the harvesting and use for Venetian projects.

The wooden, tree-trunk pilings were pounded into the existing Holocene sediments of the lagoon to form a hybrid, conformable strata of the lagoon stratigraphy. The number and extent of the pilings used is conjectural, as most information seems to come from archaeological investigations as construction documents of foundation structures from medieval and renaissance times are largely unavailable. For the purpose of this study, several models were consulted as shown in subsequent pages to create a hypothetical/statistical sense of their extent and density within the *Venice Substructure Complex*. The pilings have largely resisted decay due to the anaerobic environment of sediment encasement, this is being challenged by new studies.

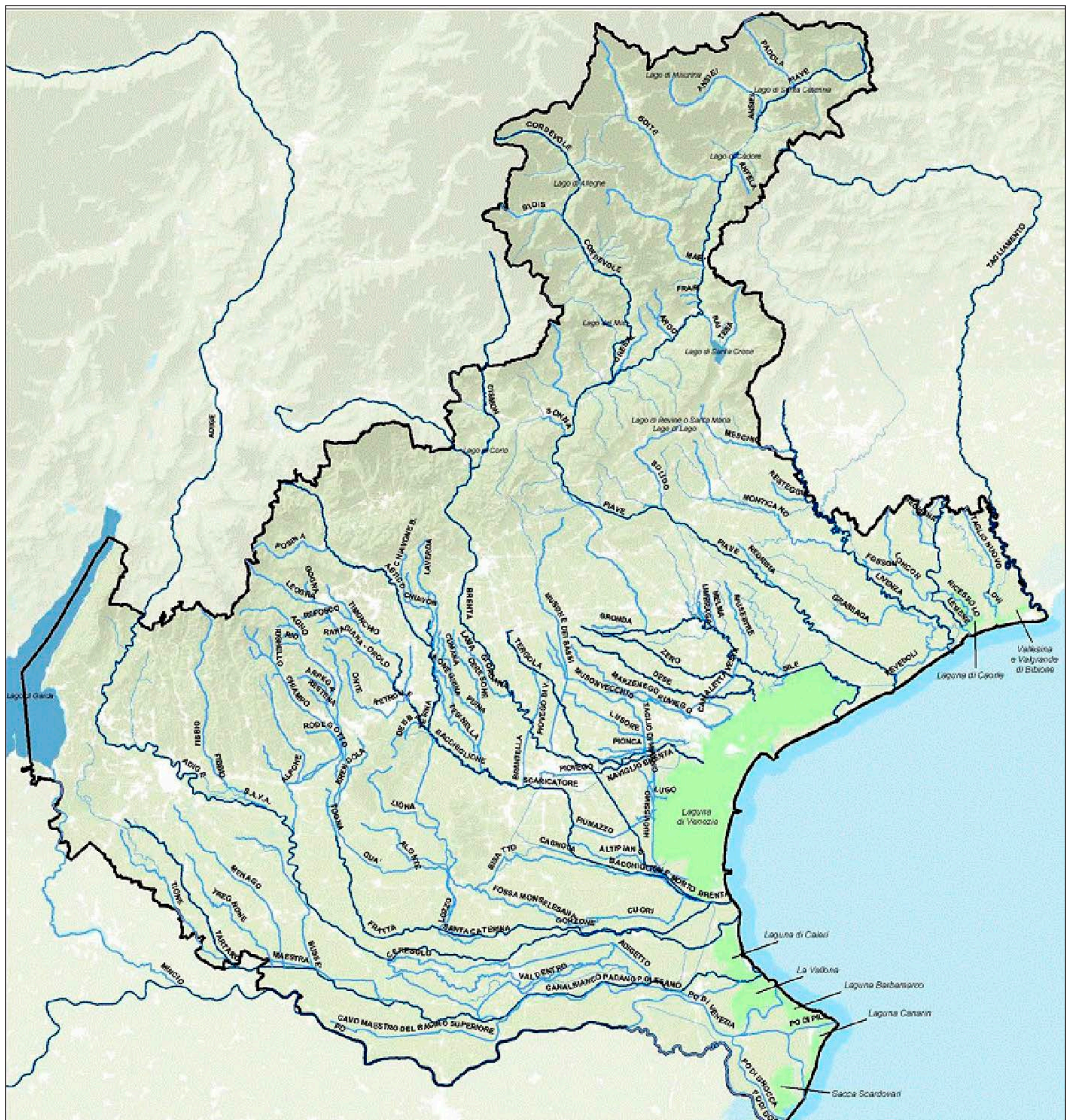


Fig. 15. Contemporary River/Watershed Map/Vento - Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto - http://www.arpa.veneto.it

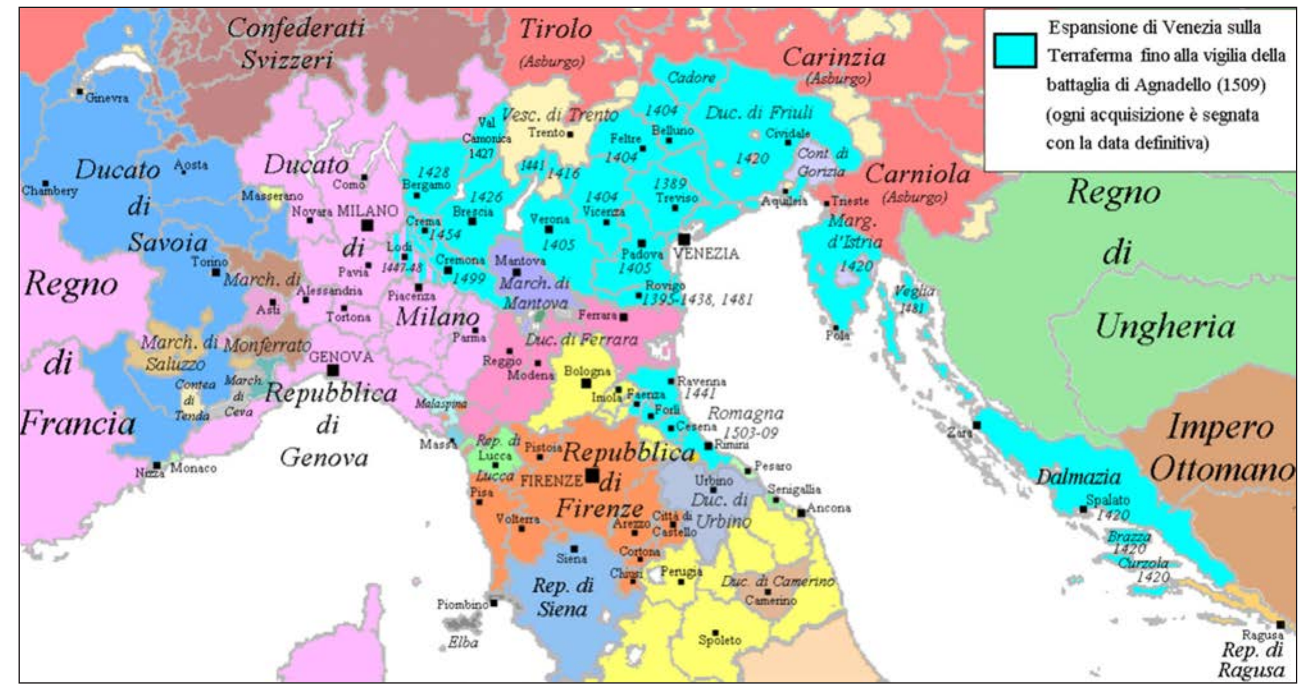


Fig. 16. Venician *Terraferma* (lt. blue, see map legend) 1509, http://it.wikipedia.org/wiki/Utente:-kayak

Fig. 17. Zattiere,http://www.lavecchiapadova.it/02-TESTI/ALTRE/PDF/EL%20BUTA.pdf

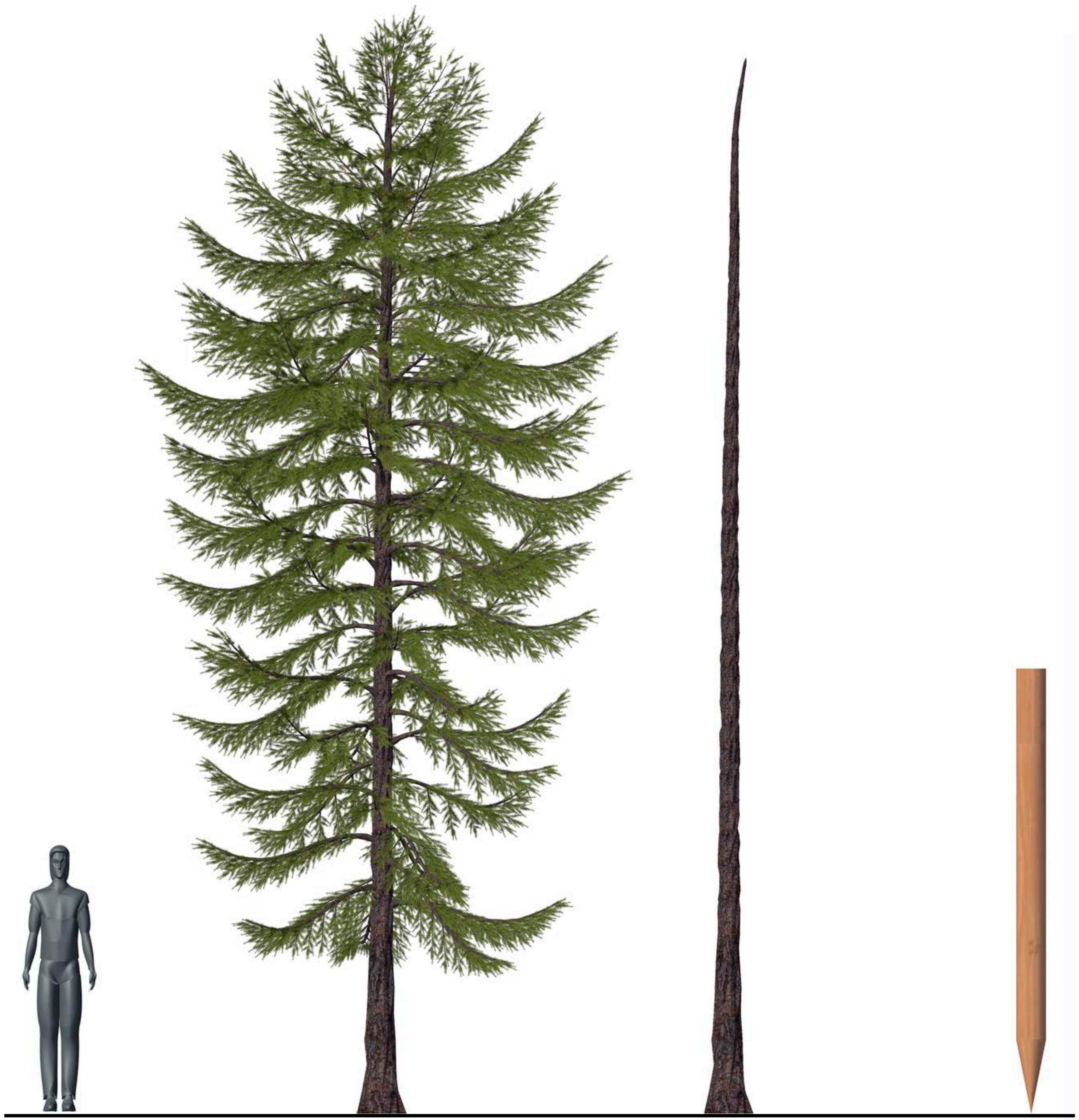


Fig. 18. Approximate comparison: 7.5m larch tree and isolated trunk / 3m x 20cm diameter piling. Roughly estimating 1 piling/tree of this size/species, residual wood used for other purposes.

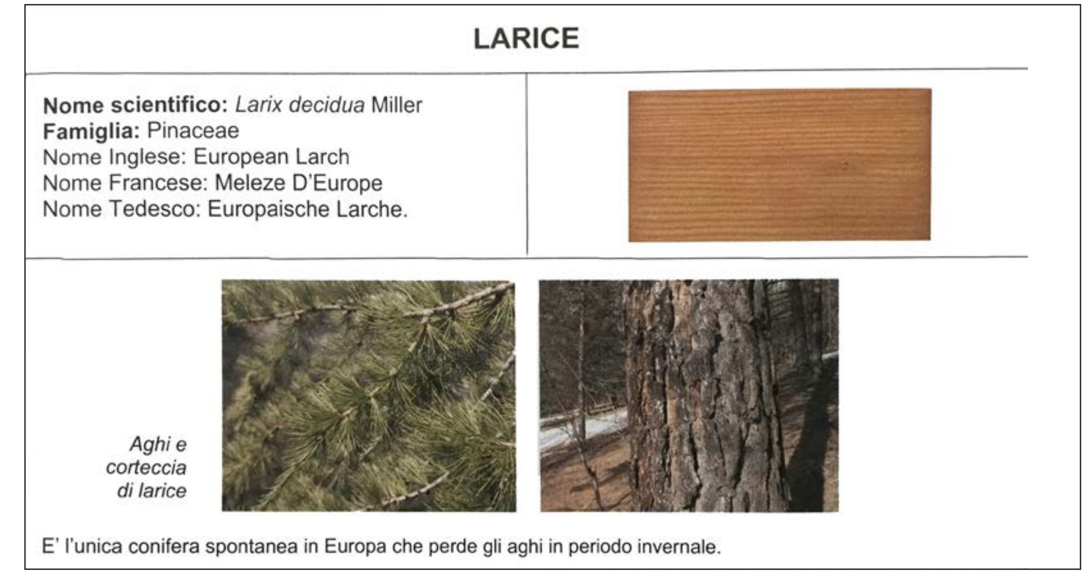


Fig. 19. Exemplary scientific study of wood piling, G. BISCONTIN; F. IZZO; E. RINALDI; A CURA DI, *Il sistema delle fondazioni lignee a Venezia*, VENEZIA, CORILA, 2009. (ISBN 9788889405116)

Fig. 20. Excavation and repair of a site in Venice, showing foundation pilings. Allo Squero, Venice, It.

Venice Substructure Complex: Istrian Limestone Strata/Face

The Istrian limestone, known as Pietra d'Istria, is an integral part of the *Venetian Substructure Complex*. Quarried historically and currently in Kirmenjak (the closest town to the quarries) on the Istria Peninsula of Croatia, directly across the northern Adriatic from Venice. The Istrian limestone is used extensively in Venice due to it's high impermeablility to water and high compressive strength.

It is characterized as a dense micritic or pelmicritic stylolitised limestone from the Tithonian age (152-145 mya) of the Upper Jurassic Period. This may be characterized as a deeply buried, pellitic limestone with a microcrystalline calcite matrix, and may originate from biogenic sources in a lime mud matrix. As shown in Fig. 1, the Adriatic and Apulian micro-plates upon which reefs and carbonates were deposited, was near the equator. The depositional environment of the Adriatic and Apulian Carbonate Platforms is thought to be in subtidal, intertidal and supratidal environments similar to the present day Bahama Islands.

Fig. 21. Istrian limestone quay, Grand Canal, Venice, Italy

Fig. 22. Istrian limestone quarry, Kirmenjak, Croatia. Image from http://www.stonesofcroatia.co.uk

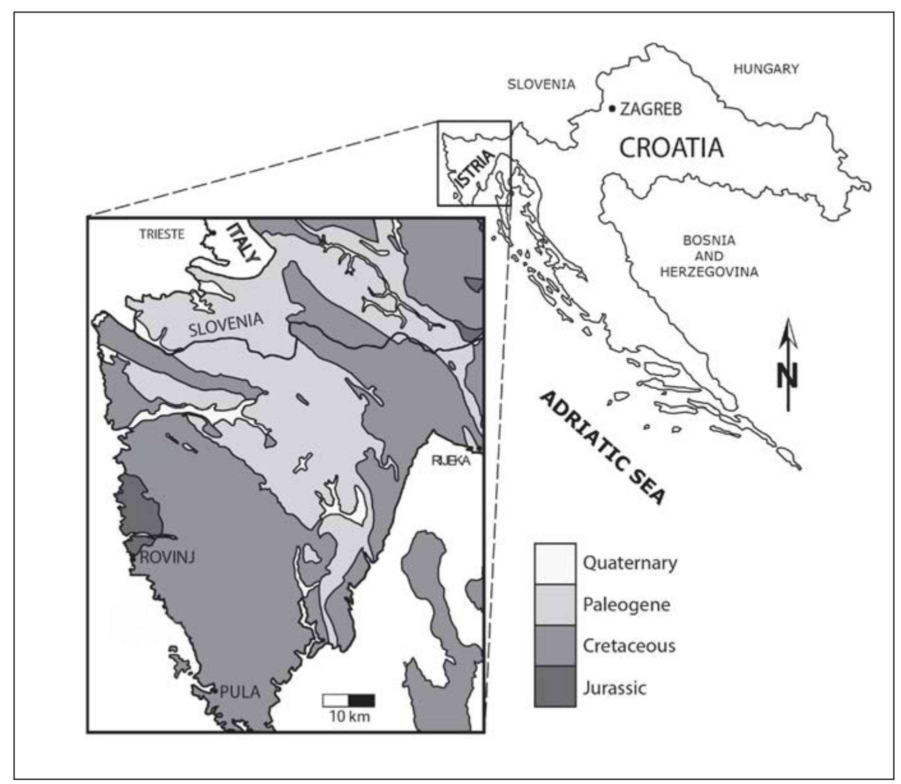


Fig. 23. Geographic and geologic setting of the Kirmenjak locality in Istria, Croatia (modified after VELIC, I., TIŠLJAR, J., MATICEC, D. & VLAHOVIC, I,1995: *Opci prikaz geološke grace Istre* [*A review of the geology of Istria* – in Croatian]. – In: VLAHOVIC, I. & VELIC, I. (e ds.): 1*st Croatian Geological Congress, Excursion Guide-Book*, 5–30.).

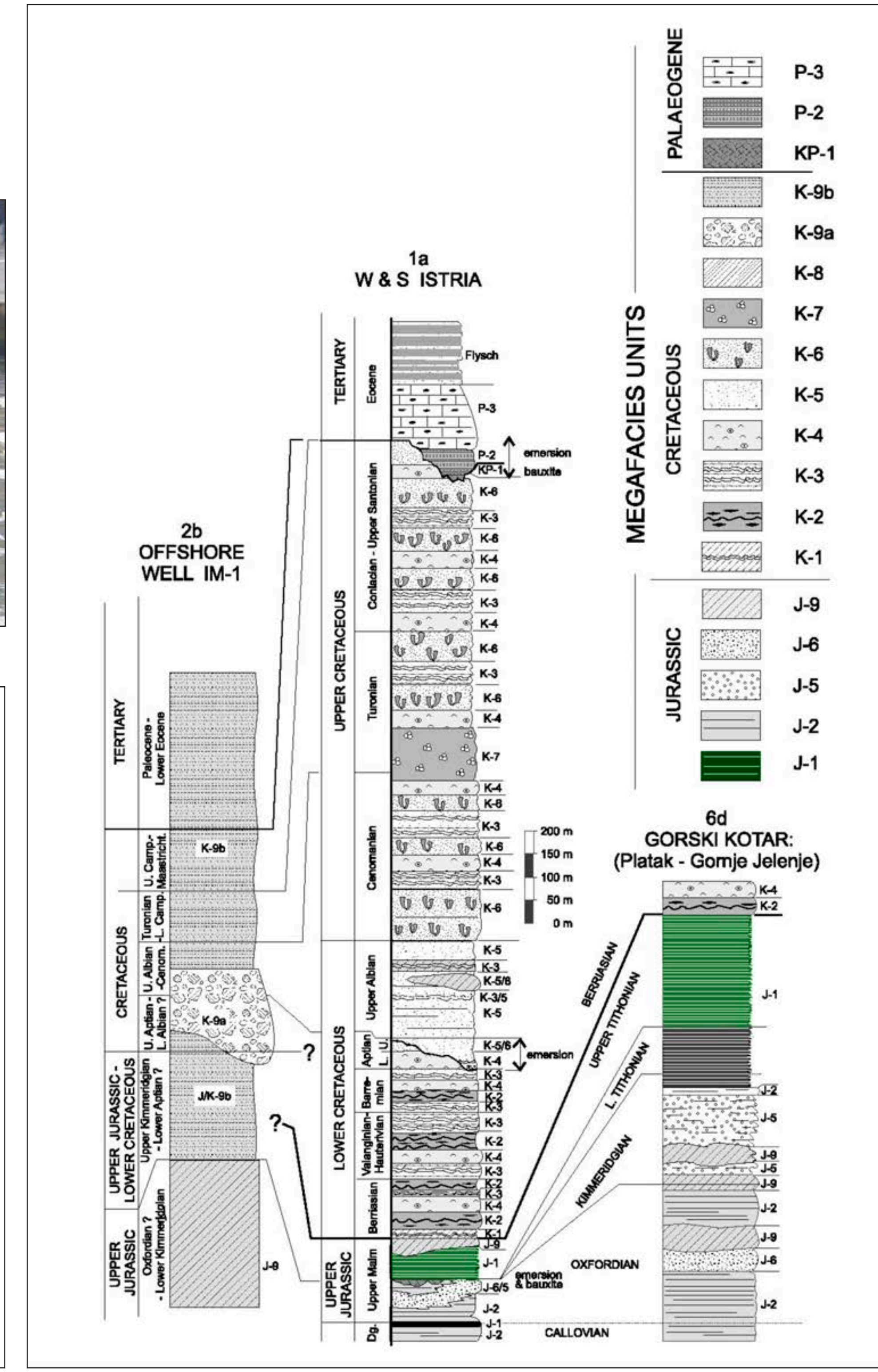


Fig. 24. Geographic and geologic setting of the Kirmenjak locality in Istria, Croatia. Green coloring (J-1) Upper Tithonian Limestone. (Adapted from: Josip TIŠLJAR, Igor VLAHOVIC, Ivo VELIC and Branko SOKAC, *Carbonate Platform Megafacies of the Jurassic and Cretaceous Deposits of the Karst Dinarides*, Geologia Croatica 55/2 139–170 7 Figs. ZAGREB 2002.

Venice Substructure Complex: Brick Strata

The brick strata of the *Venice Substructure Complex* is another substantial structural component of Facies A. It is deposited in sequential, offset horizontal members, integrated with Istrian limestone elements, resulting in vertical structures above the wooden piling system. It generally forms a barrier between lagoon waters and the rest of the complex or as a foundation for strata above the VSC. The brick strata itself is composed of meta-agrillitic/indurated mudstone strata (fired brick) of Holocene clays inter-fingered with assorted clastics in complex calc-silicate matrix (mortar).

The raw materials of the brick strata may be traced back to the Mesozoic Tethys ocean depositional environment subsequently, folded, eroded and minerologically transformed during the Alpine Orogeny and glaciation into recent time. The clays are generally fluvial and glacial deposits of Würmian time (115,000-11,700 YBP, the last glacial cycle from Eemian time to the beginning of the Holocene) deposited in the upper layers of the Venetian lagoon and plain.

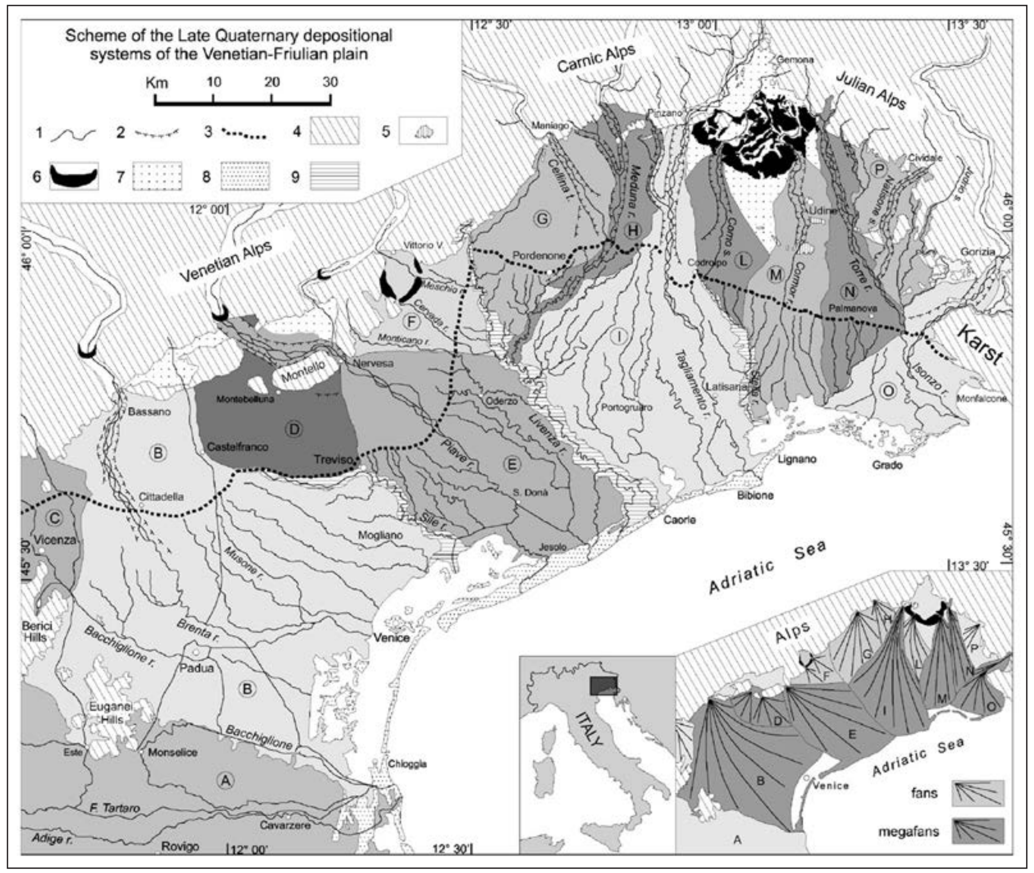


Fig. 25. Scheme of the Late Quaternary depositional systems of the Venetian–Friulian Plain. Symbols: (1) river, (2) fluvial scarp, (3) upper limit of the spring belt, (4) mountains and hills, (5) tectonic terraces, (6) endmorainessystems, (7) interfan and intermontane deposits, (8) coastal-deltaic systems and (9) groundwater-fed river systems. Grey-tone areas: (A) Adige Alluvial Plain, (B) Brenta megafan, (C) Astico fan, (D) Montebelluna megafan, (E) Piave megafan, (F) Monticano–Cervada–Meschio fan, (G) Cellina fan, (H) Meduna fan, (I) Tagliamento megafan, (L) Corno fan, (M) Cormor megafan, (N) Torre megafan, (O) Isonzo megafan and (P) Natisone fan. From: Alessandro Fontana, Paolo Mozzi, Aldino Bondesan, *Alluvial megafans in the Venetian–Friulian Plain (north-eastern Italy): Evidence of sedimentary and erosive phases during Late Pleistocene and Holocene*, Quaternary International 189 (2008) 71–90.

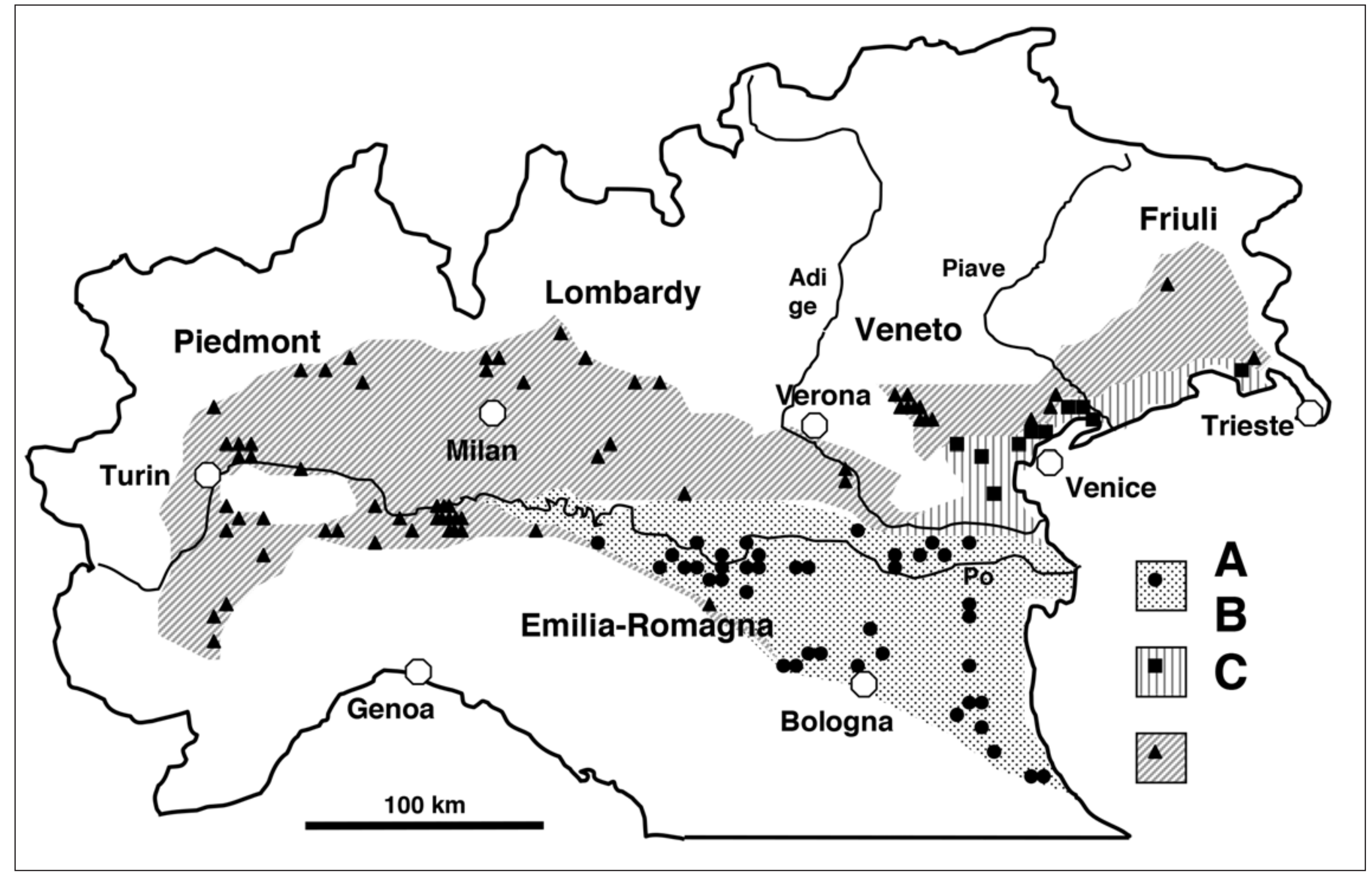


Fig. 26. Distribution of contemporary, continental clay sources and corresponding quarries in northern Italy. Holocene fluvial clays from the Po plain (A) and the Venetian plain (B); Pleistocene eluvial clays (C). M. Dondi, G. Ercolani, B. Fabbri, G. Guarini, M. Marsigli and C. Mingazzini, *Major Deposits of Brick Clays in Italy, Part 1: Geology and Composition,* Tile & Brick International, 15 (1999) [4] 230-237, [5] 360-370,

Fig. 27. Upper portion of *Venetian Substructure Complex*, brick strata, in-situ.

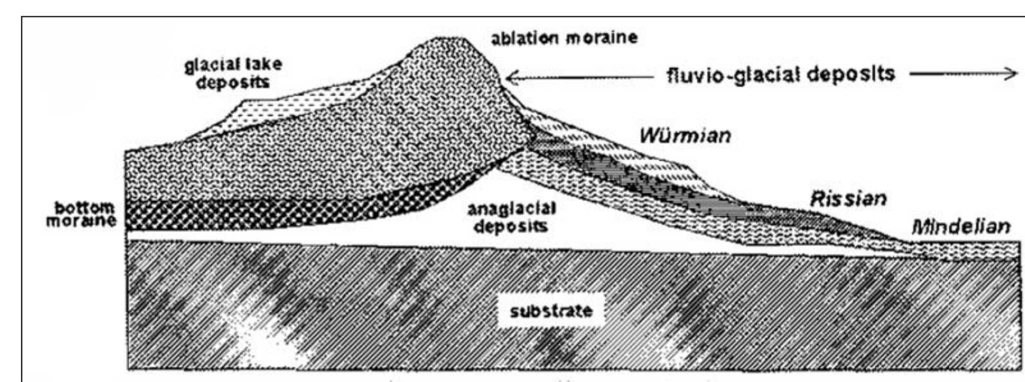


Fig. 28. Cross-section of a typical glacial depositional system with a strong vertical exaggeration. Brick clays are recovered essentially from the weathered fluvio-glacial deposits. M. Dondi, G. Ercolani, B. Fabbri, G. Guarini, M. Marsigli and C. Mingazzini, *Major Deposits of Brick Clays in Italy Part 1: Geology and Composition*, Tile & Brick International, 15 (1999) [4] 230-237, [5] 360-370,

Venice Substructure Complex: Hydrologic Basins / Trachyte/Carbonate Strata

The top-most strata of the *Venice Substructure Complex* consists of hydrologic structures: Holocene sand-filled basins, as well as shallow exterior/interior layers of Oligocene trachyte and Mesozoic carbonate patterned rock. 231 existing basins are distributed throughout Venice as a source of fresh water filtered through the basin's sand until the 19th century. Central and extending above the surrounding pavement are wellheads/cisterns of Jurassic Istrian limestone or Veronese marble extended by brick to or near the bottom of the basins (see Fig 18 below). Filtered water was accessed through the wellheads.

Extensive areas of the *Venice Substructure Complex* are covered with a thin strata of rectilinear Oligocene trachyte paving stones laid out in regular patterns and interlocking block patterns or brecciated clastic (terrazzo) carbonates. The trachyte was traditionally quarried in the Venetian Volcanic Province, Euganean Hills. The trachyte strata has occasional inserts or large interspersed arrays of carbonate rock that vary from marbles, Istrian, and Batonian age (middle Jurassic) bio-micritic 'Verona' limestones.

Fig 29. Shallow interior carbonate strata/pattern of marble and limestone blocks.

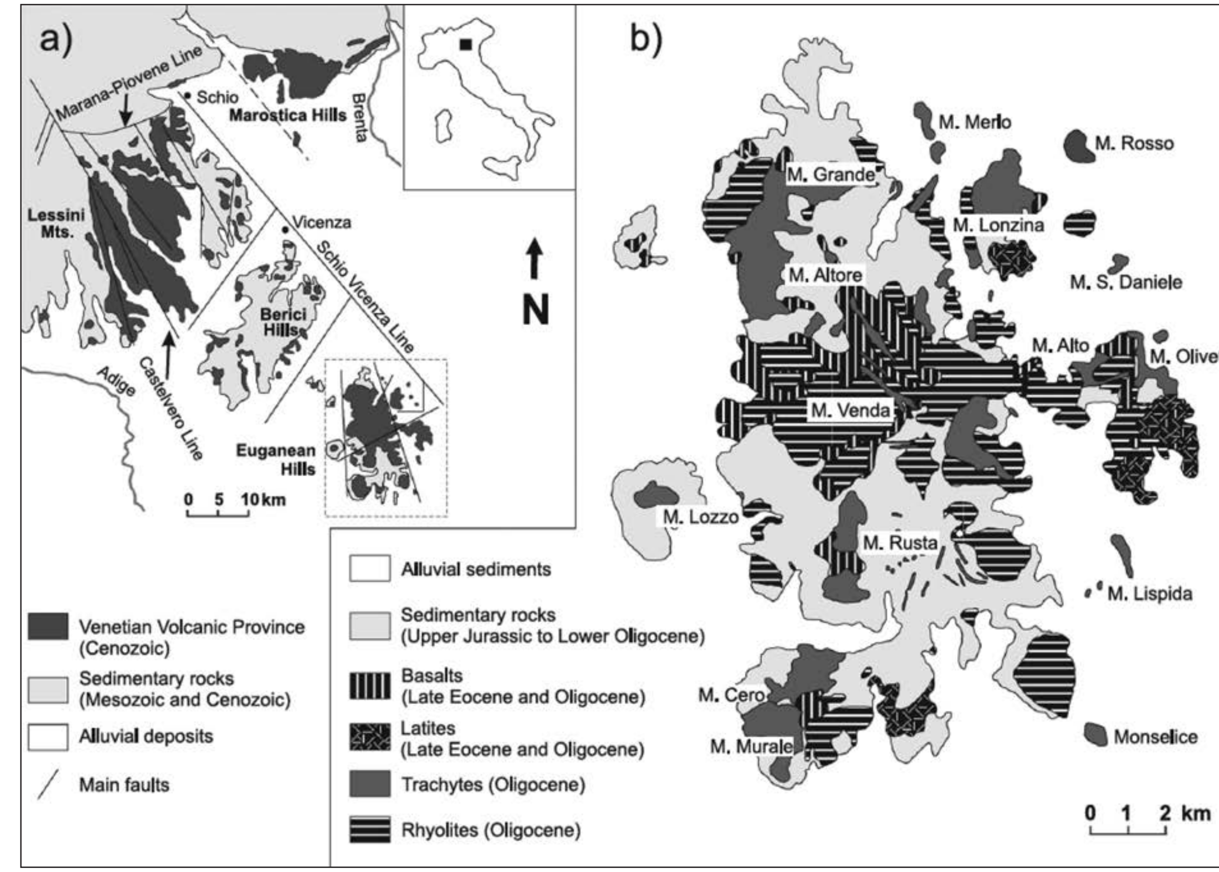


Fig. 31. Adapted from, Lara Maritan, Claudio Mazzoli, Raffaele Sassi, Fabio Speranza, Angela Zanco and Paola Zanovello, *Trachyte from the Roman aqueducts of Padua and Este (north-east Italy):a provenance study based on petrography, chemistry and magnetic susceptibility,* Eur. J. Mineral, 2013, 25, 415–427

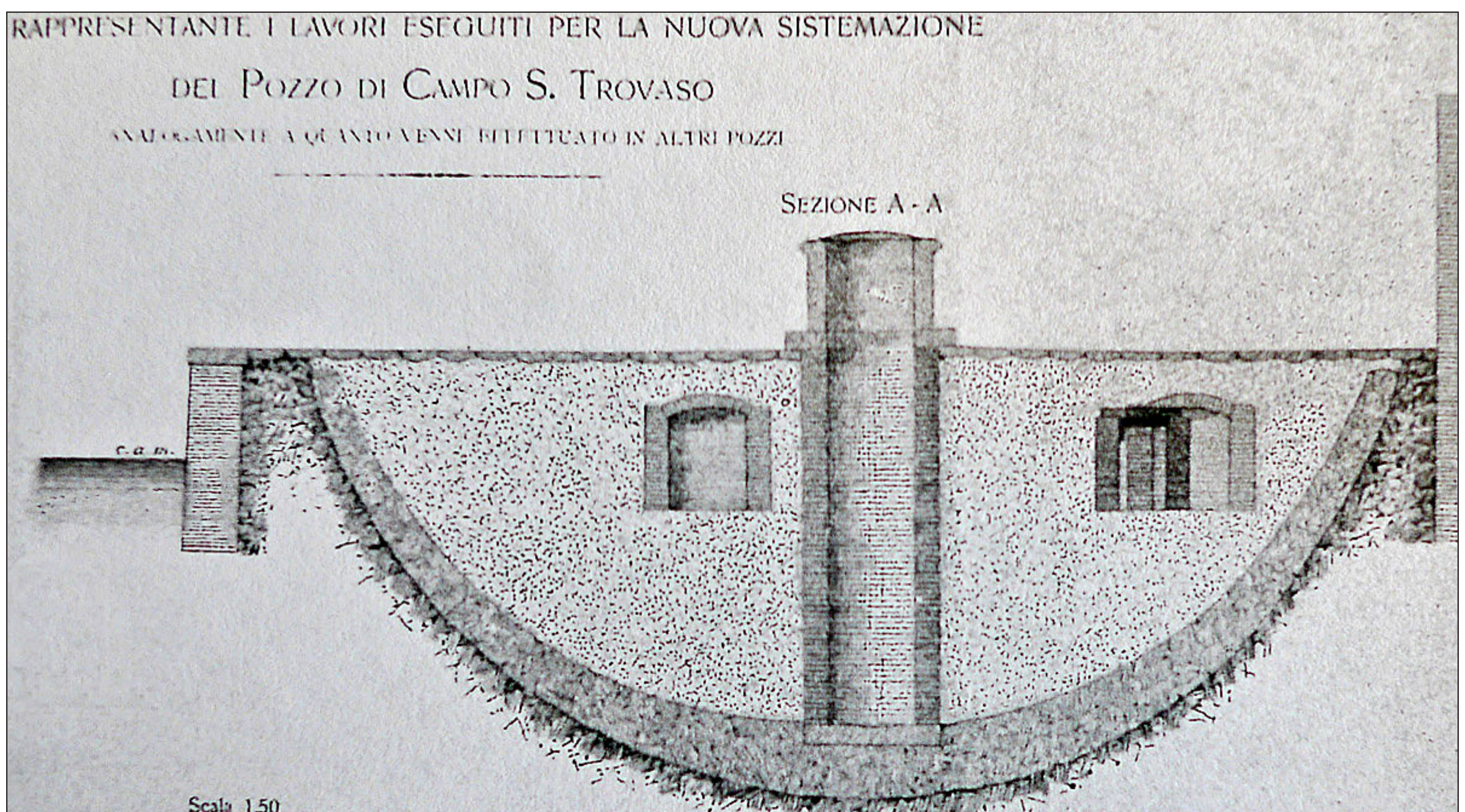


Fig 30. Historical drawing of Venetian cistern system. See Fig. 20.

Fig 32. Oligocene trachyte/Jurassic Istrian limestone field with Istrian well head over Holocene sand hydrologic basin.

Venice Substructure Complex: Melio/San Stae Islands (Site Case Study)

The *Venice Substructure Complex* encompasses the 6 Sestieri of Venice: Cannaregio, Castello, Dorsoduro, San Marco, San Polo and Santa Croce, minus the more recent two large transport islands to the far west that are not considered part of the original foundation system of the main lagoon islands of Venice. The island of S. Michele is considered part of Canneregio, and S. Giorgio Maggiore as well as Fisola/S. Biagio as part of Giudecca.

Two islands in the San Polo Sestieri: Melio and San Stae, were selected to develop case studies for the foundation/piling systems. The two islands were of reasonable size, had a good range of building and site types and were close to the research center for daily on-site studies, measurements and observation. As will be shown later in this document, depending upon which model is used for piling density there is theoretically/statistically between 39,000 and 78,000 pilings beneath these two islands with a total of 28,738 m^2 of surface area, giving a overall density of between 1.37 and 2.72 pilings/m^2. With the calculated area of Venice being considered in this study of 5,809,001 m^2, a total potential piling count of 7,969,949 to 15,800,483 pilings/tree trunks are supporting the architecture of the city and a major organic intrusion into the lagoon sediments below as a major component of the *Venice Substructure Complex*.

The cistern-based hydrologic system of historic Venice is a critical part of the *Venice Substructure Complex*. In a more advanced iteration of the VSC the extensive clay tile roof strata, as a hydrologically integrated part of the cistern system, evident in these image, even though separated from the substructure by the multi-storied subaerial built environment/architecture, may be considered. The roof strata in the context of the VSC becomes a floating membrane high above made of primarily the same meta-agrillitic/indurated mudstone structures of Holocene clays with assorted clastics in complex calc-silicate matrix, as the brick and mortar elements of the mid-section of the VSC.

Fig. 33. Lower left: Map of Venice from 1650 by Matthäus Merian the Elder - Hebrew University of Jerusalem and the Jewish National and University Library
Fig. 34. Upper right: Aerial View of Venice indicating the location of the islands of Melio and San Stae, Google Earth Pro / 2016 TerraMetrics.
Fig. 35. Lower right: Detail view of the location of the islands of Melio and San Stae with one edge along the Grand Canal, Google Earth Pro / 2016 TerraMetrics.

Venice Substructure Complex: Melio/San Stae Islands / Site Case Study

The *Venice Substructure Complex* mapped on top of the calle/canal plan of the Melio and San Stae islands of Venice beneath the perimeters of the island's canal and subaerial architecture with the piling density of 8 pilings/meter^2 using models 1/1A and 2 (Fig. 11, 12, 13) of this document. The two known cistern's of these islands are also indicated on the diagram. The total number of pilings represented is approximately 39,000.

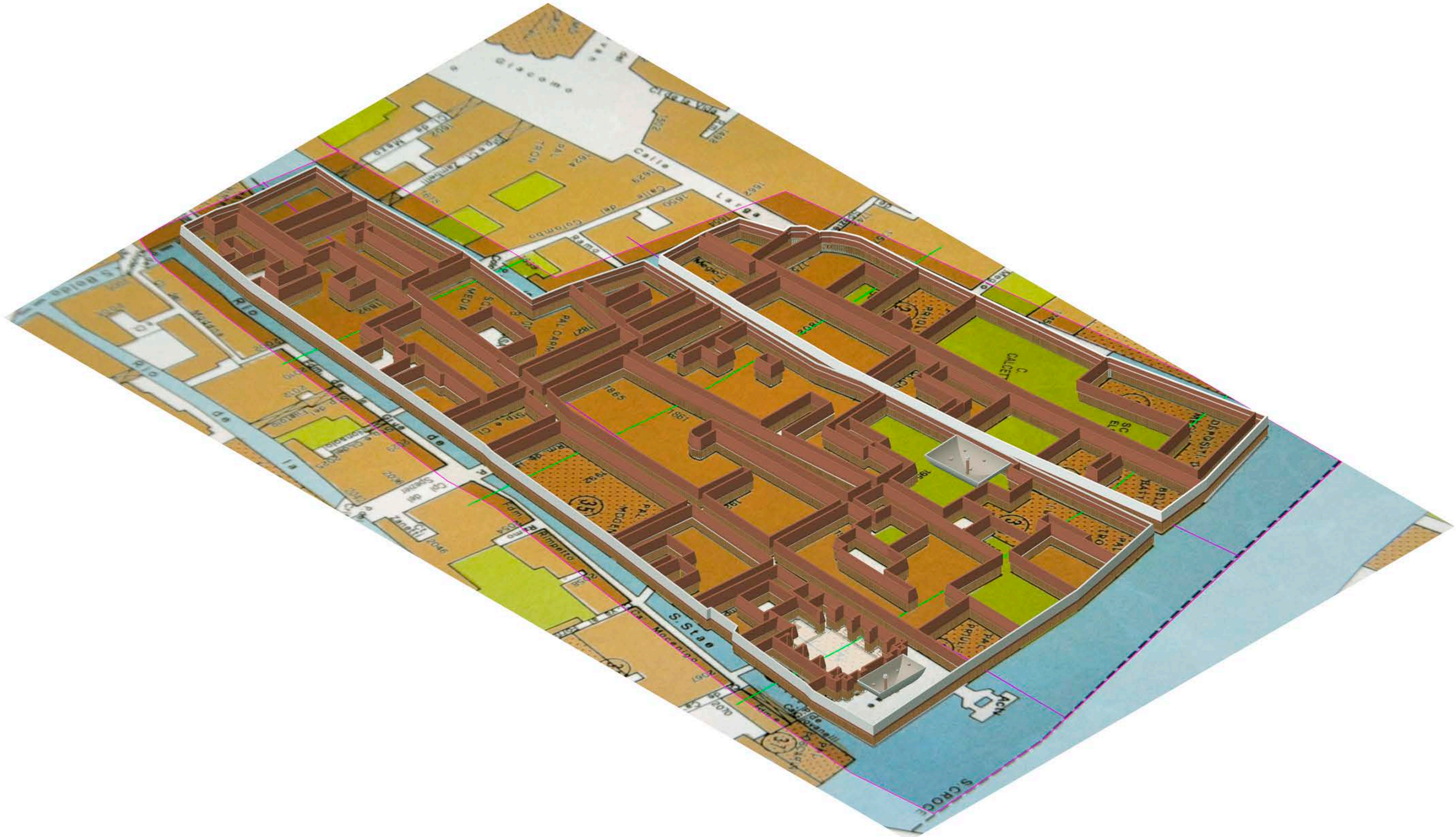


Fig 36. Orthographic aerial view, Meilio/San Stae Islands, VSC structure, map adapted from: Nadali, G. Paolo and Vianello, Renzo, *Calli, Campielli e Canali,* Helvetica Editrice, 2013, drawing by author.

Venice Substructure Complex: Melio/San Stae Islands / Substructure with Sediment/Canal / Substructure without Sediment/Canal

A view looking up at the *Venice Substructure Complex* of Meilio and San Stae Islands indicating the relationship of the *VSC* to surrounding sediments, and as an isolated structure. As in Fig. 36, the density of 8 pilings/meter^2 located beneath the perimeters of the island's canal and subaerial architecture - models 1/1A and 2 (Fig. 11, 12, 13) of this document, is shown. The total number of pilings in represented in each diagram is approximately 39,000.

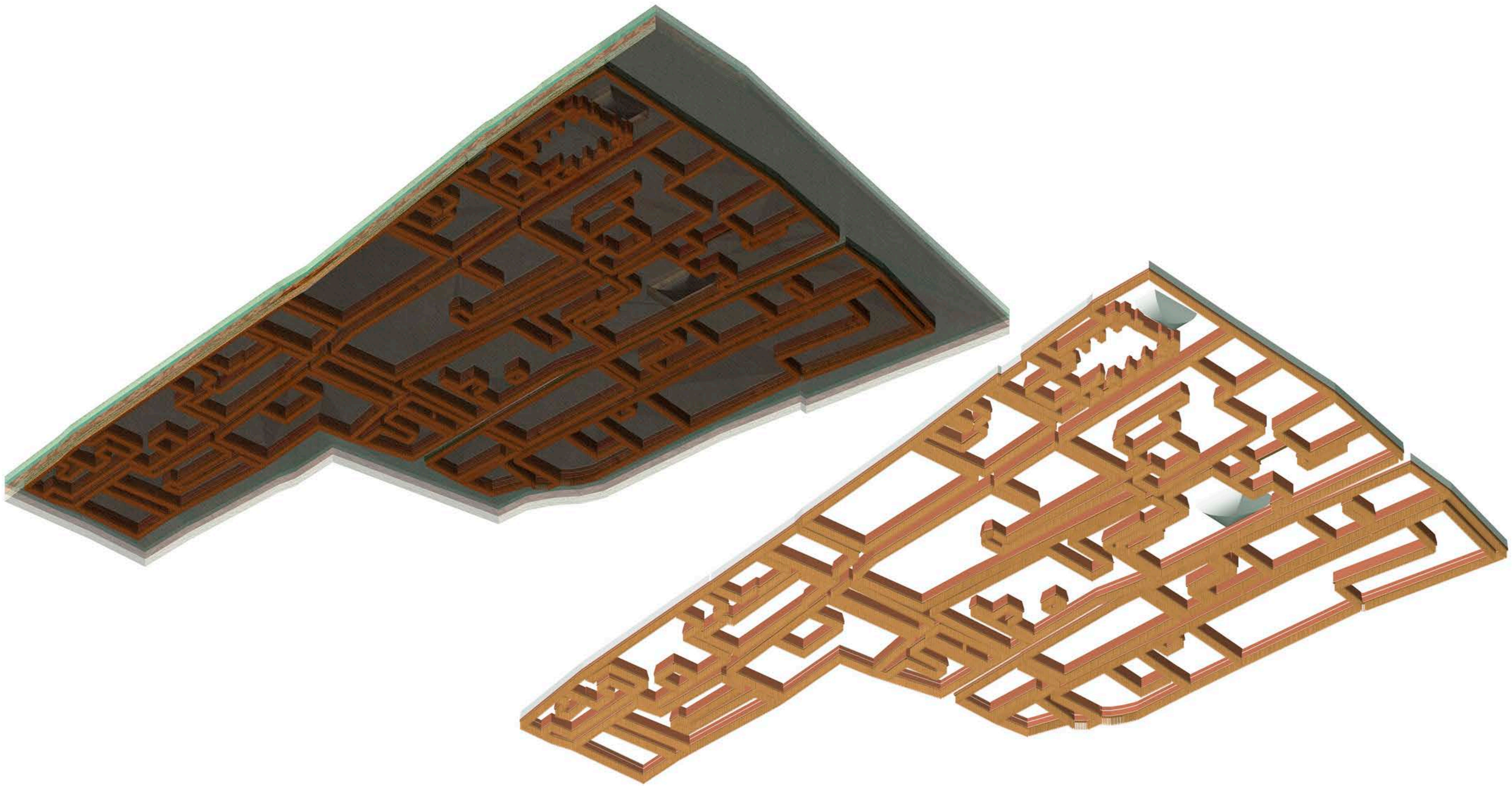


Fig 37. Left image: orthographic view from below of Meilio/San Stae Islands, *VSC* structure with 9m sediment and canals,
Right image: orthographic view from below of Meilio/San Stae Islands, isolated *VSC* structure.

Venice Substructure Complex: Theoretical Scope of Wooden Pilings/Displaced Forest

As described earlier in this document, there are two principal models being used to determine the piling system beneath Venice. Models 1 and 1A (Fig. 11 and 12) show a distribution of an average of about 8 pilings/m^2, Model 3 (Fig. 14) shows an average of 16 pilings/m^2. Depending upon which model is used for piling density there is theoretically/statistically between 39,000 and 78,000 pilings beneath the islands of Meilio and San Stae. The islands have a total of approximately 28,738 m^2 of surface area, giving a overall density of between 1.37 and 2.72 pilings/m^2. With the calculated area of Venice being considered in this study of 5,809,001 m^2, a total potential piling count of 7,969,949 to 15,800,483 pilings/tree trunks are supporting the architecture of the city, acting as a major organic intrusion into the lagoon sediments, representing an a displaced, anaerobic forest and defining hybrid organic/inorganic strata of the *Venice Substructure Complex*.

Due to the number of variables with a differential ratio of nearly 2:1 an average number of 12,000,000 pilings has been determined to be the operative/optimum amount of pilings/tree trunks within the *Venice Substructure Complex* and used in this document for further studies and proposals. The diagrams below begin to illustrate the scale of materiality that 12,000,000 pilings represent.

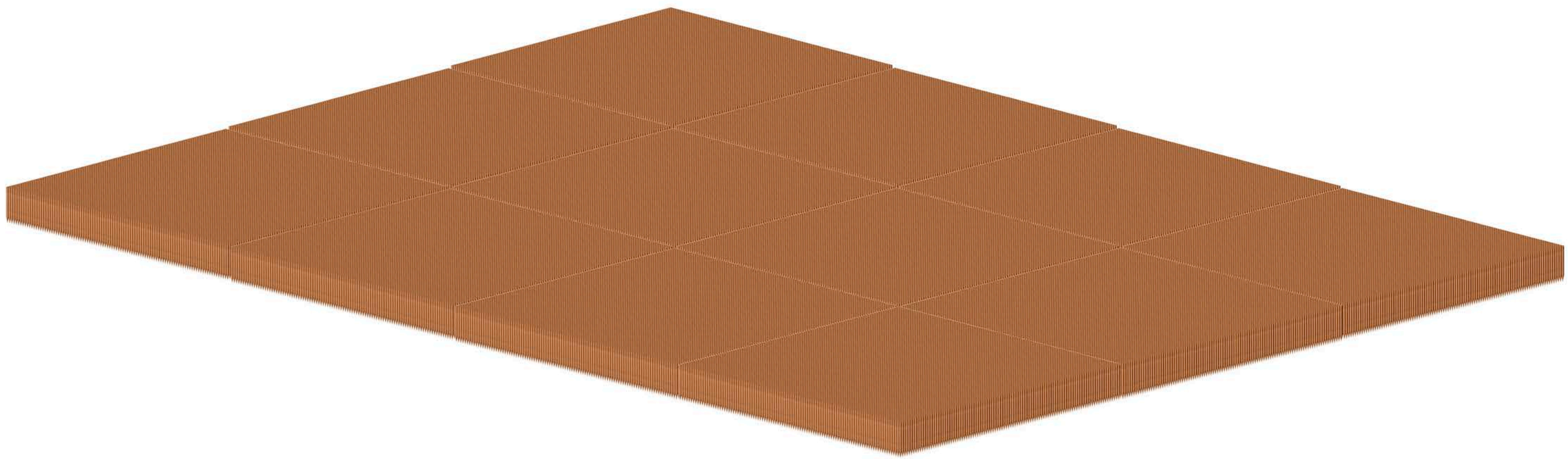


Fig 38. Illustration of 12 segments @ 1,000/segment totaling 12,000 pilings at approximately 3m in length, or 1/1000 the total number of pilings.

Fig 39. Scale diagram showing 1 @ 12,000 pilings (orange area) in relationship a grid of 1,000 relative segments or 1/1,000 the total number of pilings.

Venice Substructure Complex: Aerial Views

The *Venice Substructure Complex* includes the primary structural/foundation elements of Venice from lagoon sediments to extensive, shallow ground-level strata of two primary types, cisterns, as well as surficial flora with roots growing in the VSC. The diagrams below give schematic views and details of the primary components from an aerial perspective with the architectural overburden not visible.

Fig 40. Site view of *Venice Substructure Complex* to Facies W (Altered Alluvium/Caranto) strata - See Fig. 10.

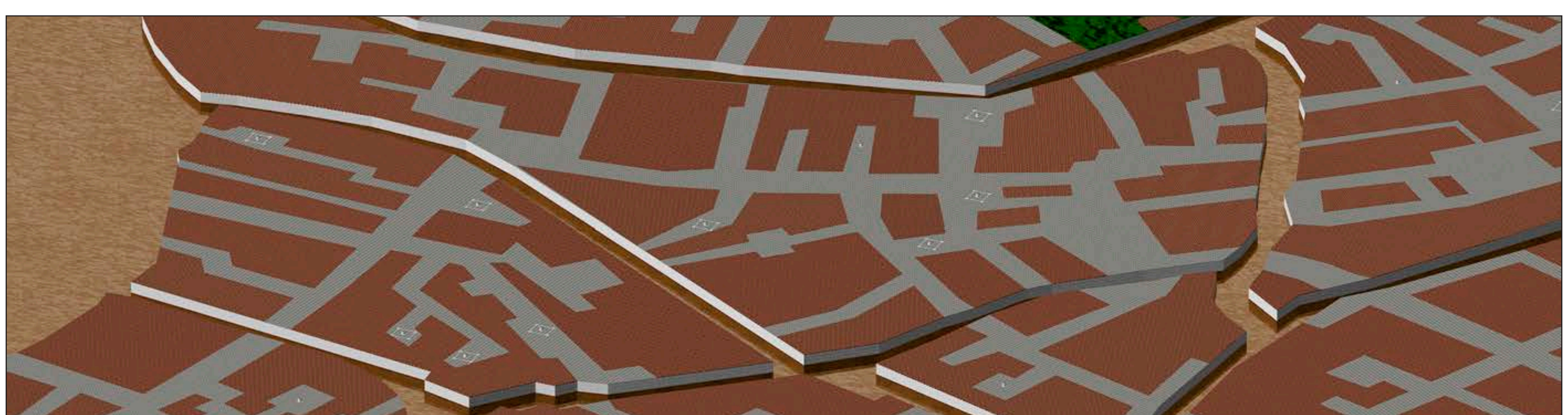


Fig 41. Detail site view of *Venice Substructure Complex* to Facies W (Altered Alluvium/Caranto) strata.

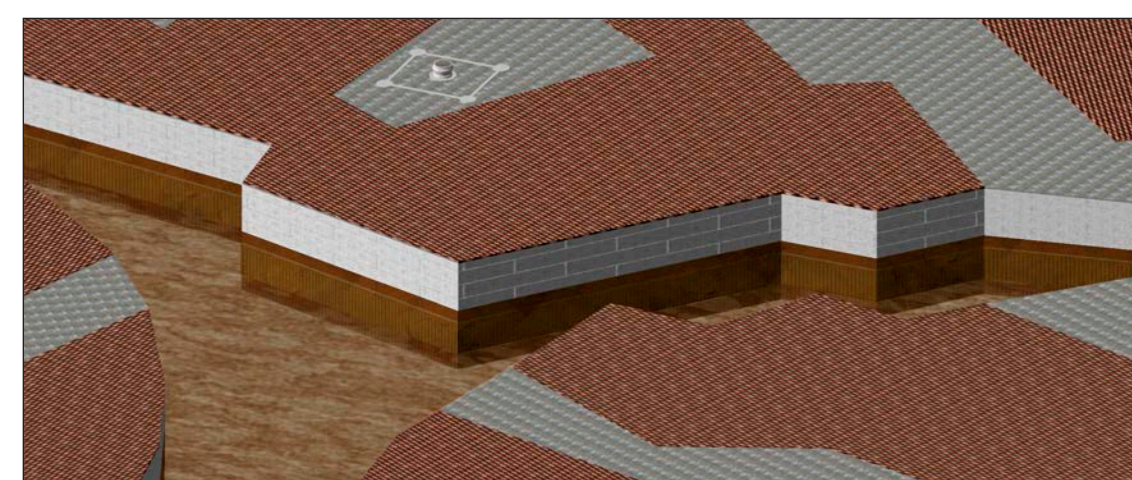


Fig 42. Detail site view of *Venice Substructure Complex* to Facies W (Altered Alluvium/Caranto) strata.

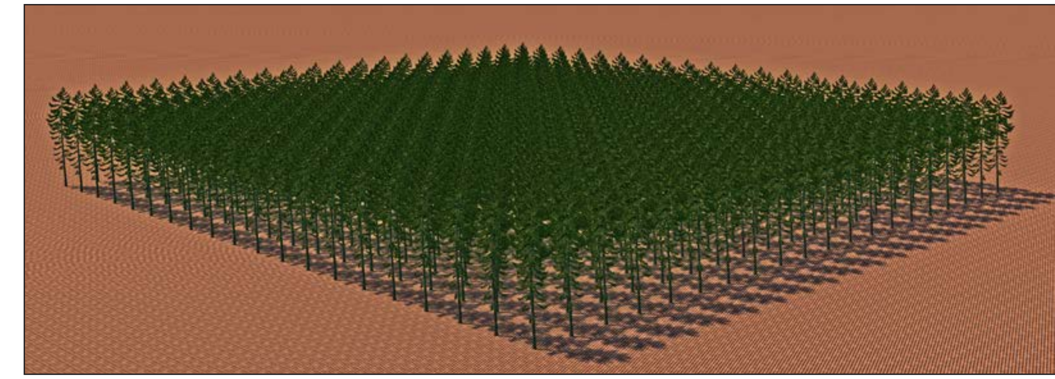
Venice Substructure Complex: Site Study - *Forest Ship* / *Cistern Ship*

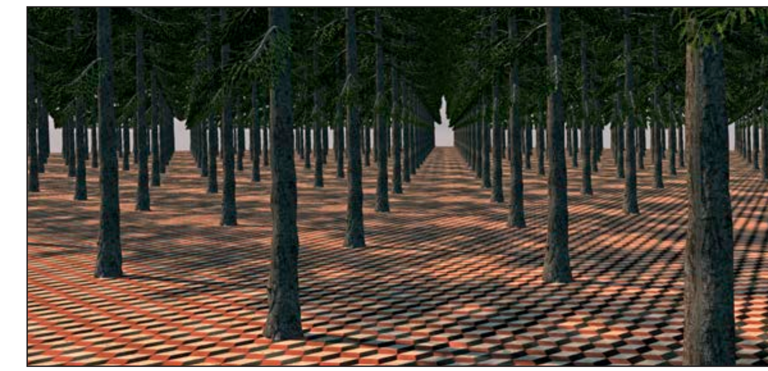
This study for *Forest Ship* and *Cistern Ship* a conceptual proposal for large-scale landscape projects as expressions of *Venice Substructure Complex*. The placement over the Venice lagoon is for scale reference, only. Final site and configuration to be determined if ever seriously considered. *Forest Ship* is a 30,000 acre (121.4 km^2) ship with 12,000,000 trees planted at 400 trees/acre (400/4046.85 m^2). *Cistern ship* is comprised of replicas of the 231 cisterns of Venice in a large hydrologic reservoir/ship. Both ships are oriented along vectors related to Apulian/Aptian plates and the on-going Alpine orogeny in Anthropocene time. *Forest Ship* and *Cistern Ship* are oriented to theoretically collide in later Anthropocene time.

Fig 43. *Forest Ship* and *Cistern Ship* / aerial view in scale relationship with the Venice lagoon, oriented to vectors of Alpine orogenesis.

Venice Substructure Complex: Forest Ship

Forest Ship, is a conceptual proposal for a landscape project that extends the conversation of *Venice's Substructure Complex* with it's environment. The ship is proposed as an allochthonous structure of carbonate rocks (Istrian limestone and Veronese marble among others) with a forest superstructure, voyaging in a sediment sea. The surface area of the ship is 30,000 acres (121 km^2) of larch (or related trees) forest planted at 400 trees/acre giving a total of 12,000,000 trees, a theoretical average of the number of pilings beneath Venice. This structure completes the aerobic/anaerobic/aerobic cycle of the original forests submerged beneath Venice through a symbolic replanting of those trees as a living forest in the open air. *Forest Ship* by it's vectored orientation to the Alpine orogeny, suggests the journeys latent in the landscape created by a much vaster ship of the Auplian/Adriatic plate through the lost Tethys and Pennine Seas of Mesozoic/Cenozoic time. The ship may also canted at a very shallow angle, recalling the low-angle thrust faults and formation of Alpine nappe structures.





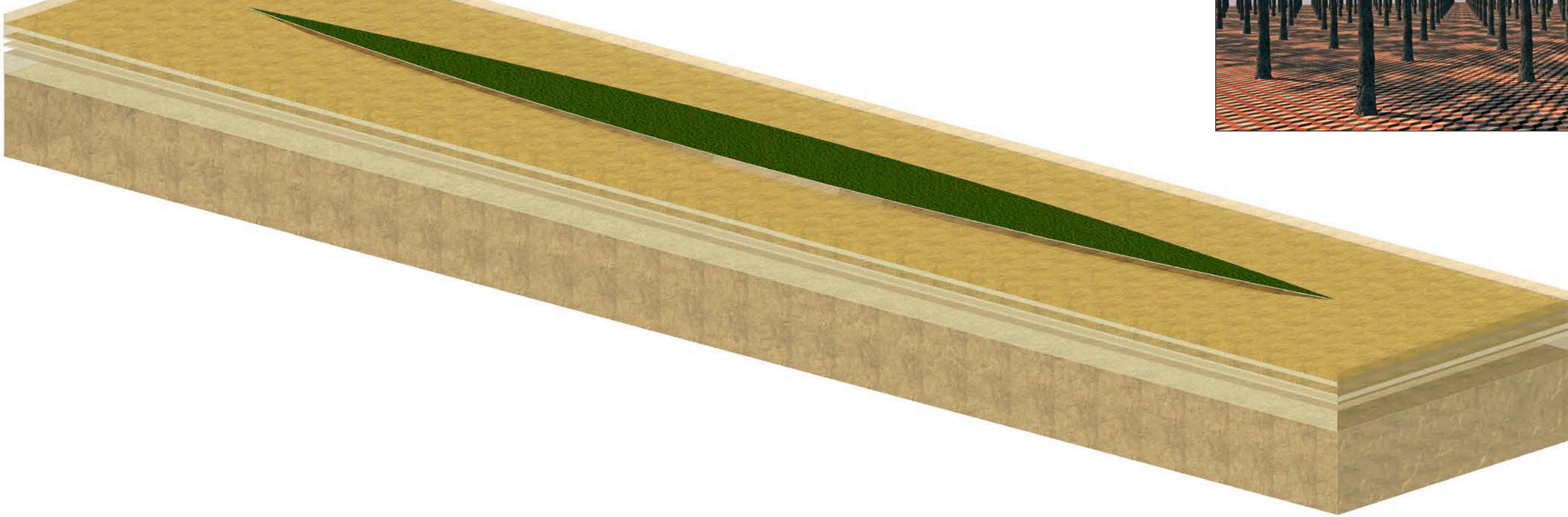


Fig 44, 45, 46. Main image: orthographic image of *Forest Ship* in situ with 12,000,000 tree superstructure. Upper right images: studies of 1 acre of 400 trees of larch forest with patterned carbonate floor of the *Venice Substructure Complex.*

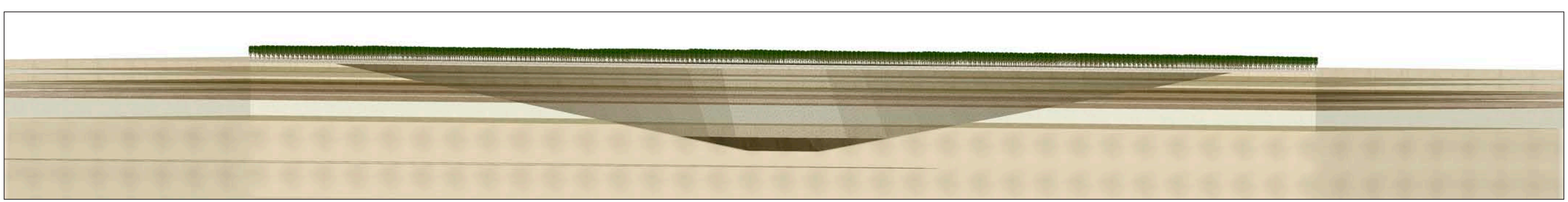


Fig 47. *Forest Ship*, sectional view of Istrian limestone hull with forest superstructure (not to scale) floating in a sediment sea. The structure may also be canted at very low thrust-fault-like angle along it's longitudinal axis.

Venice Substructure Complex: Cistern Ship

Cistern Ship is another form of the *Venice Substructure Complex*, extending the conversation of Venice's substructure with it's environment. The ship is proposed to be of carbonate rock (Istrian limestone) with a top deck/superstructure of Oligocene trachyte paving stones punctuated with 231 Istrian limestone cisterns with brick-lined wells penetrating into the depths of the sand-filled hull. *Cistern Ship* is a hydrologic reservoir and filtration system floating in a sedimentary sea. The cisterns are the water gathering system of Venice until the 20th century. *Cistern Ship*, like *Forest Ship*, is aligned with tectonic plates and forces forming the landscape of northern Italy and the continuing evolution of the Alps.

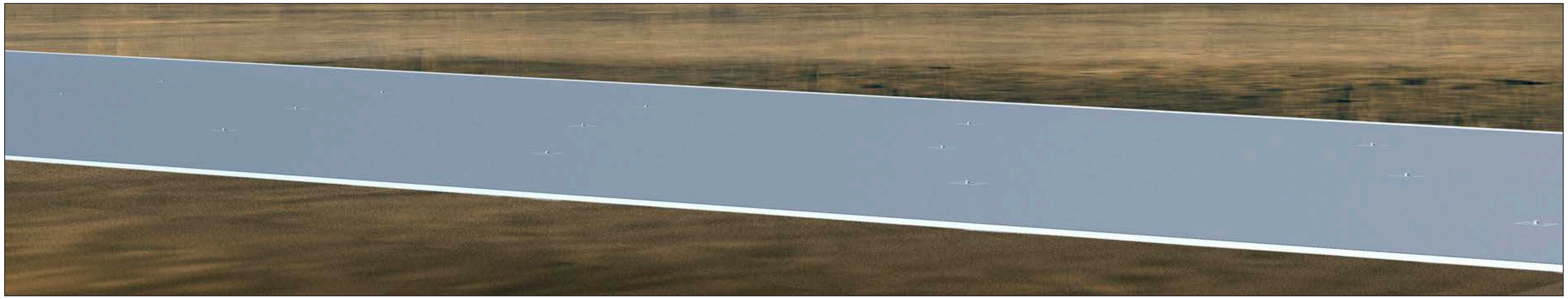


Fig 48. *Cistern Ship*, low-angle, detail view of Istrian limestone cistern superstructure on a deck surface of Oligocene trachyte paving stones.

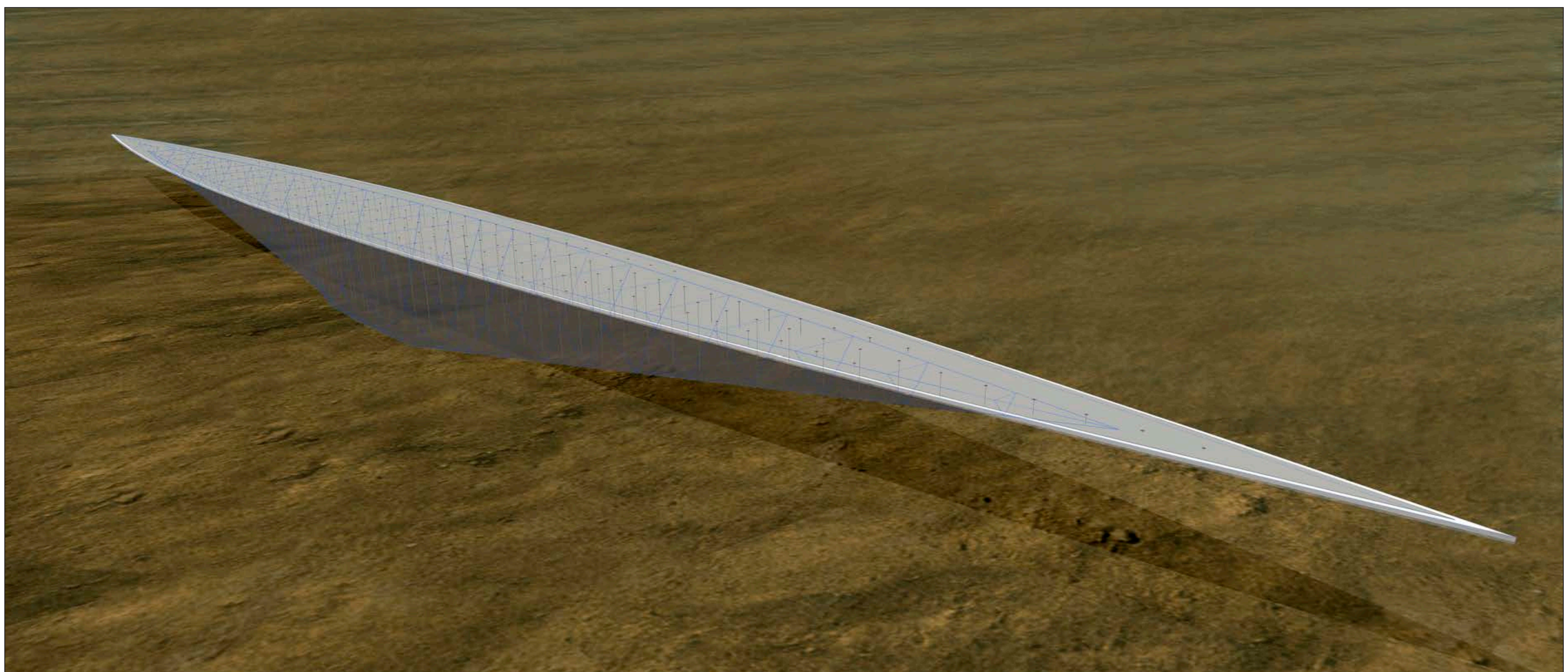


Fig 49. Transparent perspective view of *Cistern Ship* floating in a sedimentary sea. A superstructure of 231 Istrian limestone cisterns with wells penetrating into the depths of the sand-filled ship hull.

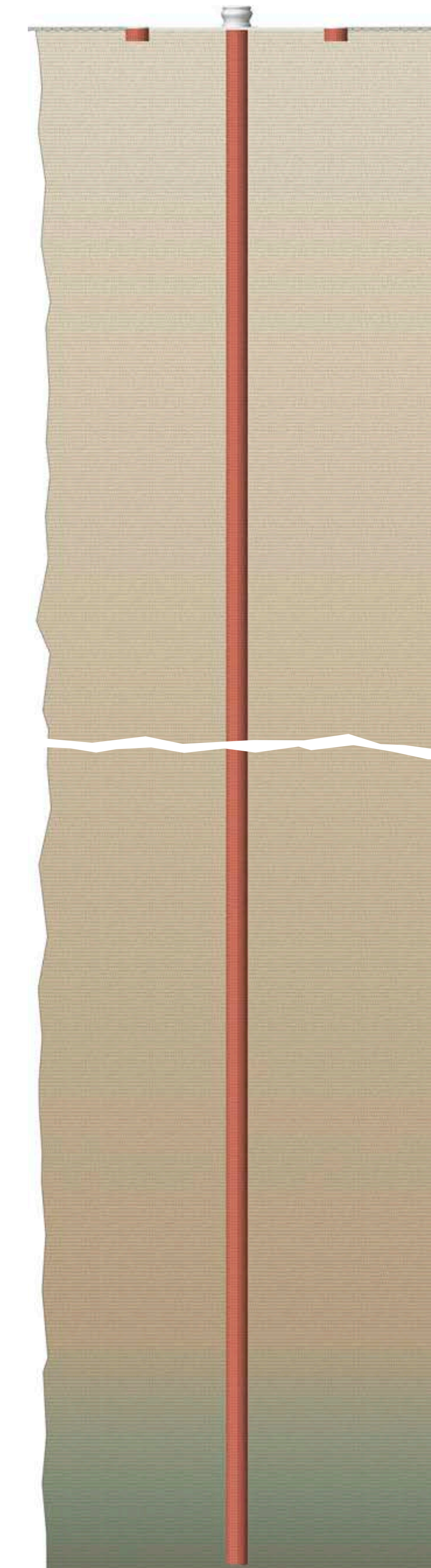


Fig 50. Study: *Cistern Ship*, cistern section.

Venice Substructure Complex: Cardinal Point Survey

Cardinal Point Survey is a geographic survey of the *Venice Substructure Complex*. It was designed to introduce a experiential component into the research of Venice. As a walking survey and documentation, each of the furthest accessible northern, southern, eastern and western cardinal points of the Venetian islands considered part of the VSC were explored. At each point, telescopic and wide-angle photos were taken in each of the four directions as well as a 360 degree HD video scan. In some cases the furthest most cardinal point was not accessible, a secondary point was used in it's place.

Fig 51-55. Map of Venice with images taken at each of the cardinal points: North, East, South and West.

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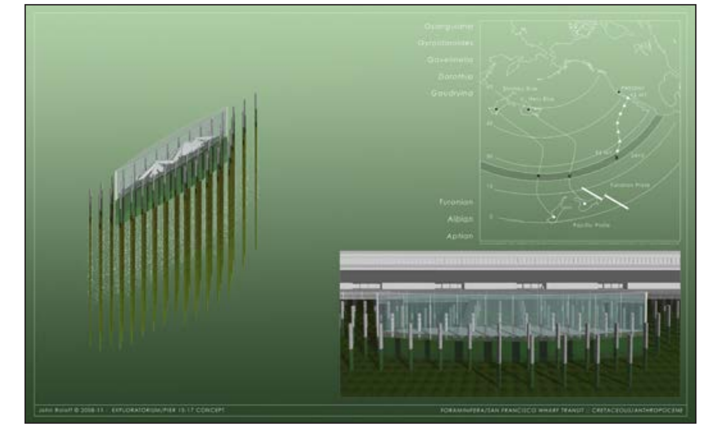
Preserving cultural heritage by preventing bacterial decay of wood in foundation poles and archaeological sites / EVK4-CT-2001-00043 Wageningen / European Commission 2005.

In addition to the above, many websites, especially http://www.venipedia.org, numerous books and papers in both Italian and English were consulted as well as providing a wealth of additional information for additional research.

SELECTION OF EXEMPLARY ANTECEDENTS AND WORKS RELATED TO *VENICE SUBSTRUCTURE COMPLEX* / 1992-2015

Metafossil (Pinus: ponderosa, radiata, balfouriana) / 1992
http://www.johnroloff.com/metafossil_page.html

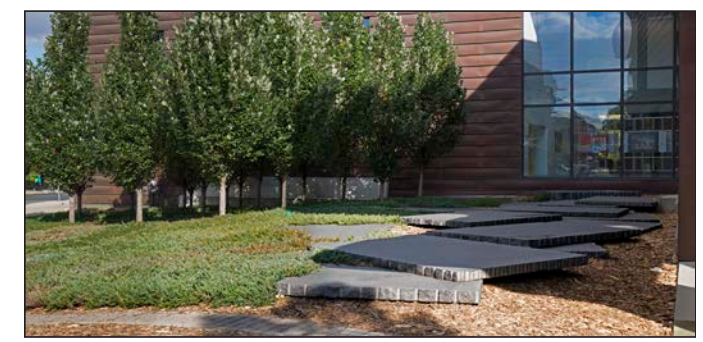
Franciscan/Manhattan Formation / Lance Fung Gallery, NYC, NY / 1998
http://www.johnroloff.com/franciscan_manhattan_page.html



Foraminifera/San Francisco Wharf Transit::Cretaceous/Anthropocene / 2008-2011
https://vimeo.com/105900403

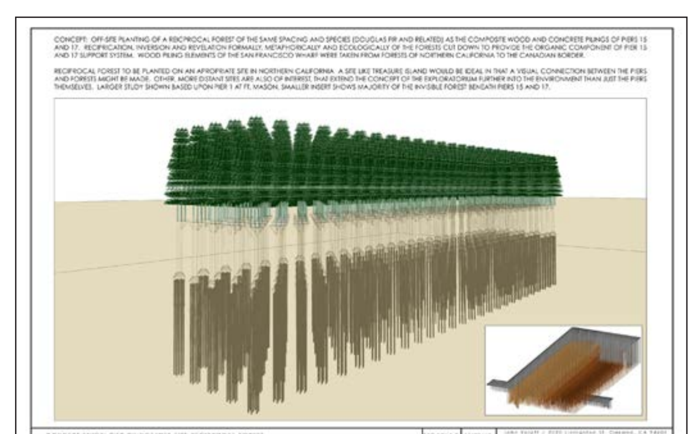
Deep Gradient/Suspect Terrain / Yerba Buena Gardens / San Francisco, CA / 1993
http://www.johnroloff.com/yerbabuena_ship_page.html

Seventh Climate (Paradise Reconsidered) / Seattle, WA / 2006
http://www.johnroloff.com/seattle_page1.html



Site Index/Rapson Group / College of Design/Rapson Hall
University of Minnesota / Minneapolis, MN / 2004-2013
http://www.johnroloff.com/umn.cala_index1.html

Gradient (Biscayne Giant) / Carbonate Falls (Marsh Lettuce)
http://www.johnroloff.com/biscayne_giant_page.html



San Francisco Wharf Complex / Phase I & II / 2008-12
http://www.johnroloff.com/pier15-17_studies_page1.html

San Francisco Wharf Complex/American Industrial Center Carbonate Group
2015
https://vimeo.com/138269748

Bio: John Roloff

John Roloff is a visual artist who works conceptually with site, process and natural systems. He is known primarily for his outdoor kiln/furnace projects done from the late 1970's to the early 1990's as well as other large-scale environmental projects, gallery installations and objects investigating geologic and natural phenomena. Based on an extensive background and ongoing research in the earth sciences, his work since the late 1960's engages poetic and site-specific relationships between material, concept and performance in the domains of geology, ecology, architecture, ceramics, industry and mining, metabolic systems and history. The ship is a central image of his work, metaphorically evoking psychological and transformative processes of the sea and land in geologic and Anthropocentric time. He studied geology at UC Davis, Davis, CA with Professor Eldridge Moores and others during the formative days of plate tectonics in the mid-1960's. Subsequently, he studied art with Bob Arneson and William T. Wiley also at UC Davis in the late 1960's. In addition to numerous environmental, site-specific installations in the US, Canada and Europe, his work has been included in exhibitions at the Whitney Museum of American Art, UC Berkeley Museum, San Francisco Museum of Modern Art, Smithsonian Institution, *Photoscene Cologne* and the Venice Architectural and Art Biennales, *The Snow Show* in Kemi, Finland and most recently, *Artlantic: wonder*, Atlantic City, NJ. Public art works that explore geologic and related concepts can be found at sites such as: Yerba Buena Gardens, San Francisco, CA, University of Minnesota, Minneapolis, MN, I-5 Colonnade Park, Seattle, WA and Stanford University, Palo Alto, CA. He has received 3 artist's visual arts fellowships from the NEA, a Guggenheim Foundation fellowship, a California Arts Council grant for visual artists and a Bernard Osher Fellowship at the Exploratorium in San Francisco, CA. He is represented by Anglim Gilbert Gallery in San Francisco and is a Professor of Sculpture/Ceramics at the San Francisco Art Institute.

More information is available at www.johnroloff.com.