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BURIED LANDSCAPES: GEOARCHAEOLOGY OF THE ROMAN HARBOR OF COMO (N ITALY)

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ABSTRACT: The town of Como (N Italy) was founded in 59 BC on the shores of the homonymous lake. Its present-day environmental setting derives from the interactions between lacustrine, alluvial and human dynamics. The lake coastline moved through time because of alluvial progradation, town expansion and land reclamation. Since 1700 AD, more than 200 m of land reclamation towards the North are observed from historical maps of the study area.
The harbor is a strategic infrastructure for a coastal town and its localization is a critical issue. Archaeological evidence found in the Como urban area points to a different position of the harbor during the Roman period and the Middle Ages; presently, those areas are buried below several meters of sediments due to land subsidence and the artificial filling of coastal areas.
The results of a geoarchaeological study aimed at understanding the evolution of the coastal area are presented here. Adopted methodologies include the collection of available archaeological and stratigraphic data and the analysis of a number of continuous core drillings both on the lake promenade and, for the first time in Como, on the lake bottom. Sedimentological and geotechnical investigations were performed and archaeological and vegetal findings were studied. A lithological unit consisting of organic silts rich in vegetal remains and archaeological findings has been identified. The thickness of this unit varies from less than 1 meter to 6 meters and it refers to a depositional environment characterized by shallow water and human influence; its deposition started during Roman Age, when the town was founded and an impressive reorganization of the drainage network took place. Geological cross-sections and map reconstructions enable us to define different phases of the town evolution. Our results highlight the role of geological research in reconstructing the recent evolution of buried and/or submerged environments: geoscience provides useful information when it is not possible to carry out expensive archaeological excavations at sensitive sites and allows to optimize resource utilization.

KEYWORDS: geoarchaeology; paleoenvironmental reconstruction; sedimentological analysis; lacustrine harbor; Como

1. INTRODUCTION

In areas of ancient civilization, the present-day urban setting can be understood only considering the interaction among natural and cultural factors. Geosciences are able to unveil the paleogeography and archaeological evolution at sensitive sites, such as coastal environments.

The town of Como (N Italy) offers the opportunity to apply a geoarchaeological approach at a lacustrine coastal site. Sedimentary sequences on the present-day coastal and harbor areas have been analyzed applying a "modern analogue" approach: their sedimentary signature is compared with stratigraphic and archaeological data available for several sites presently buried below the modern town and interpreted as urban harbors (*sensu* Marriner & Morhange, 2007) that were in use during different times since the foundation of the town in the Roman period.

Ancient harbors are unique archives of information concerning natural processes, climate forcing, occupation history and human use of a coastal or fluvial area; the study of harbor environments can shed light on the relations between natural dynamics and evolving human societies. A complete investigation has to deal with several scientific disciplines, such as archaeology, history, geology, geomorphology, biology and geochemistry; only through a multifaceted approach it is possible to crosscheck the results obtained by single techniques, that integrate and provide complementary data.

The goals of the present research can be summarized as follows: (i) reconstruct the development of the area at the interface between land and the lake by means of a multidisciplinary approach including lithological, sedimentological and geotechnical analyses and geologic cross-sections; (ii) constrain the evolution of the coastline and harbor infrastructures, both in time and space; (iii) differentiate natural and human-induced modifications on the local environmental setting; (iv) acquire independent experimental data derived from the analysis of sedimentary sequences drilled in the coastal area, in order to integrate them with already existing archaeological data.

2. GEOLOGIC SETTING AND COMO TOWN STRATIGRAPHY

The town of Como lies at the SW end of the western branch of Lake Como, located at the foothills of the Southern Alps and characterized by a lambda-shape. Lake Como main tributaries are located in the northern sector, whereas the only emissary outflows at the SE termination of the Lake, then reaching Po river. The closed, western branch of the lake is thus a perfect sedimentary trap, which collects sediments from a huge drainage basin, more than 4500 km2 wide (Fig. 1a). The historical downtown is built on a NW-SE elongated alluvial plain, gently rising from lake level (198 m a.s.l.) to

220 m a.s.l. at its southern margin.

Two creeks, the Cosia and Valduce, drain the plain and strongly influenced the evolution of the town, and specifically of the area at the interface with the lake, in the last millennia. Nowadays they have been forced to flow underground, beneath the urban area, till their outlet into the lake (Fig. 1b). The sedimentary basin hosting the town is composed of more than 180 m of Late Quaternary loose sediments, settled in lacustrine, palustrine and fluvial environments. The basin is enclosed by two bedrock slopes, composed by Mesozoic pelagic carbonates (Medolo Group – Early Jurassic) to the NE, and deep sea turbiditic conglomerates (Gonfolite Group – Oligo-Miocene) to the SW (Fig. 1b; Michetti et al., 2013). The Gonfolite Group and the Mesozoic units are in tectonic contact along the Gonfolite Backthrust, a major regional N-verging structure bordering the Como urban area to the SW. Fault activity is testified by deformed Pliocene-to-Quaternary sediments (e.g., Bernoulli et al., 1989) but also more recent evidence of fault displacement, dating to Pleistocene-Holocene times, is recorded (Livio et al., 2011; Michetti et al., 2012).

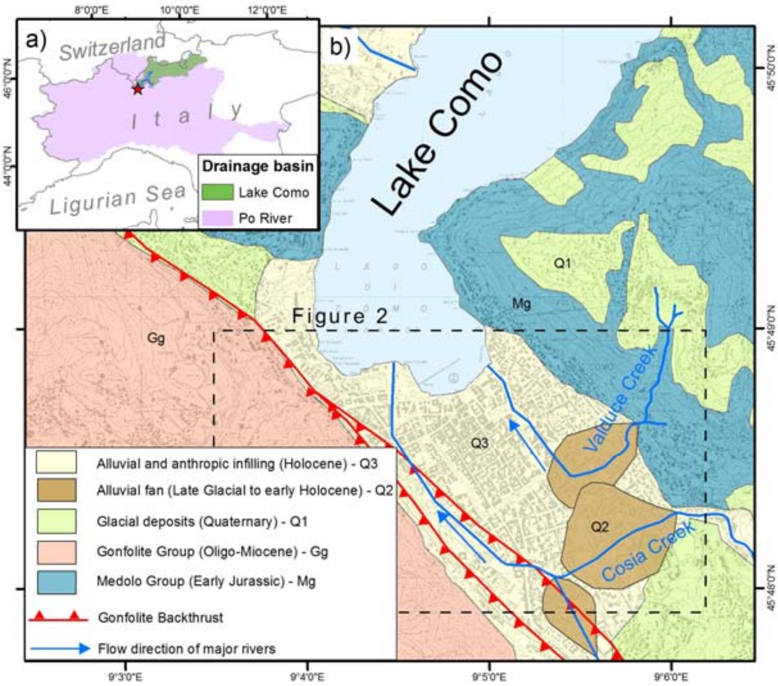

Fig. 1 - a) Geographical location of Como town; Lake Como and Po River drainage basins are also highlighted. b) Simplified geologic map of the study area, modified after Michetti et al., (2013). Topo map: CTR (Carta Tecnica Regionale), provided by Regione Lombardia, coordinate system: WGS84.

3. DATASET

3.1. Como town stratigraphy

In the last 40 years, several efforts have been conducted in order to reconstruct the stratigraphic setting of the Como urban area. During 1970s, a strong input to this research derived from the studies aimed at comprehend and mitigate the effects of land subsidence, namely the occurrence of severe damage to buildings; it was ascertained that subsidence was due mainly to the overexploitation of groundwater from the deep aquifer (Comune di Como, 1980). Since then, several studies dealt with the hydrogeological and environmental setting, the landscape evolution and with the geohazards of this area (e.g., Bini, 1987; Comerci et al., 2007; Comune di Como, 2011 and references therein).

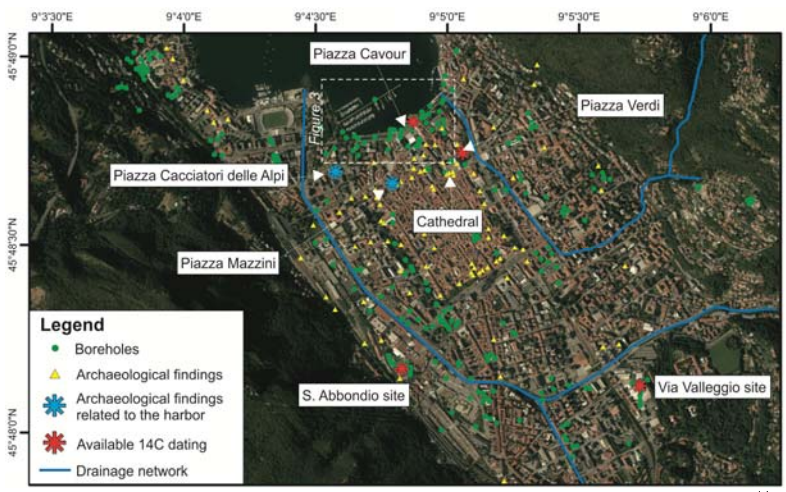

Fig. 2 - Map of the Como urban area, showing location of boreholes, available ^{14}C dating and archaeological findings. Basemap source: http://services.arcgisonline.com/ArcGIS/services

The general stratigraphy of the Como basin is based on the collection of more than 250 borehole logs, covering a territory of ca. 5 km2 and including the entire urban area (Fig. 2). Chronological data derives from twelve ^{14}C dating (Comerci et al., 2007; Ferrario et al., 2015b) covering the time period since ca. 18 cal ka BP.

Seven lithological units, here described from the top, were defined (Comune di Como, 1980; Comerci et al., 2007; Ferrario, 2013); borehole logs were analyzed accounting for the description of grain-size distribution, color, organic and artifact content and, where available, geotechnical index properties. Unit boundaries are based on lithological variations or appearance/disappearance of indicators such as archaeological or organic fragments. Our classification corresponds only partially with lithostratigraphic units, because our definition is primarily related to the deposition environment and the palaeogeography of the study area. This choice highlights lateral facies variations, one of the most prominent elements of interest for the present research.

Unit 1 is composed of heterogeneous reworked material (sands and fine gravels with silty matrix and sparse pebbles) with archaeological and vegetal remains. Unit 2 is made up of coarse alluvial sediments related to the post-Roman evolution of the Cosia delta, after the diversion of the riverbed that was realized for the land reclamation of the Como plain, as described below in more detail. Unit 3 is constituted by highly compressible plastic silts rich in organic matter and archaeological remains including bricks, pottery, glass fragments and leather tiers. The unit gives a very clear signature on geotechnical probes and is interpreted as the filling of harbor areas (see section 5). Unit 4 has a fluvial origin and is made up of Holocene coarse sands and fine gravels. Unit 5 is represented by laminated clayey silts with sandy horizons; vegetal fragments are dispersed or organized in aggregates or lenses. The unit deposited in a lacustrine\palustrine environment during latest Pleistocene and Holocene. The two lowermost units, not of interest for the present research, are constituted by late Pleistocene inorganic sandy silts with dropstones (Unit 6) and medium to coarse sands (Unit 7) representative of distal and proximal glaciolacustrine environments, respectively.

3.2. Historical evolution and archaeological data

The archaeological and historical database for Como is of excellent quality. The prehistorical, Roman and historical evolution of the city has been the subject of several publications and technical reports (e.g., Caniggia, 1968; Luraschi, 1987, 2002; Uboldi, 1993; Jorio, 2004) and is briefly summarized below.

The reconstruction is based on more than 100 findings in total, including masonries, pavings, floorings, burials, inscriptions and architectural elements (Uboldi, 1993; Fig. 2).

The oldest human occupation in the area is dated to the Iron Age, when the mountain slopes surrounding the basin started to be colonized (Uboldi, 1993). At that time, the plain was indeed an unhealthy, marshy area, frequently affected by debris flows and flooding events. The hypothesis that the plain was occupied by a Roman military camp in the II century BC is not accepted by all the authors (Caniggia, 1968; Luraschi, 1987). The foundation of *Novum Comum* is well dated and occurred in 59 BC under the Roman Consul Gaius Julius Caesar. The location of the future town was selected in a strategic position on the lake shore, along the trade itinerary between *Mediolanum* to the south, and Central Europe (Rhine and Danube valleys) to the north. The colonizers clearly aimed at taking advantage of Lake Como as a 60 km long N-S sailing route. The building of the town in the center of the sedimentary plain required an impressive reorganization of the drainage network and related mountain catchment. The Cosia and Valduce creeks were diverted from the center of the plain and forced to flow at the base of the SW and NE mountain slopes, respectively.

Northwards the town was naturally protected by the lake, whereas on the other three sides town walls were built. During I-III century AD, several expansions towards the north are recorded, related to at least three phases of land reclamation (Caniggia, 1968). Since the beginning of Middle Ages (IV-V century AD), many more edifices were built close to the lake, but the coastline position was substantially stable till XVIII century.

Historical sources, as well as archaeological findings, refer to different harbors; however, their precise location and the definition of the times in which were active are not well known. At Piazza Cacciatori delle Alpi (Fig. 2), during 1999-2000 archaeological excavations, three parallel structures interpreted as Roman quays were unearthed (Jorio, 2004); at Piazza Mazzini a monumental marble block resting upon wooden remains, interpreted as the rests of a boat, was found (Uboldi, 1993).

4. METHODS

The coastal area was studied through different drilling investigations aimed at characterizing the site for an engineering project for mitigating the flood hazard:

- 1997 drillings: 10 cores were drilled, each one 60 m deep; *in situ* tests were performed and 9 piezometer and a magnet extensometer were installed inside the drilling holes. Laboratory tests were performed on 88 undisturbed and 9 remolded samples and 5 CPTU tests were carried out.
- 2010 drillings: the survey was performed for hydrogeological purposes mainly; 11 piezometers were installed in drillings up to 25 m deep and a number of permeability tests were done.
- 2013 drillings: 5 continuous core drillings and 2 more cores for cross-hole seismic tests were realized; for the first time, some drillings were made on the lake bottom. Subsoil properties in static and dynamic conditions were defined and *in situ* and laboratory tests were performed.

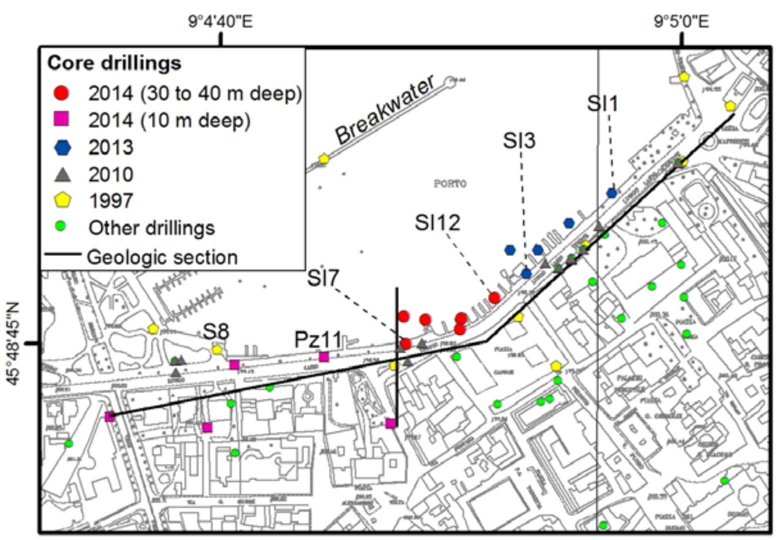

Fig. 3 - Location of available stratigraphic data in the present coastal area and trace of the geologic sections (Fig. 8).

Lab code	Sediment core depth (m)	Elevation (m a.s.l.)	Conventional date (^{14}C a BP)	2s calibration (cal. a BP)
LTL13422A	11.98	186.7	703 ± 40	730 – 560
LTL13423A	16.94	181.7	1443 ± 50	1420 – 1270
LTL13424A	17.47	181.2	6447 ± 45	7431 – 7278
LTL13425B	38.40	160.3	6570 ± 45	7570 – 7420

Tab. 1 - ^{14}C-AMS ages and calibration of wood fragments from core SI3 on the lake shore area of Como.

Results gained from these investigations have been analyzed mainly from an engineering perspective (Ferrario et al., 2013, 2015a, b).

Here we present the results of a geoarchaeological study conducted on new sedimentary sequences, collected in 2014 on the western portion of the lake shore. Cores were drilled by a machine-operated drill rig, core diameter is 86 mm. A total of 6 cores, 30-to -40 m deep, were drilled on the promenade as well as on the lake bottom. Five more cores, 10 m deep, were equipped with piezometers.

Ancient city maps and historical chronicles have been studied for precisely reconstructing changes in the coastline since XVII century AD (Caniggia, 1968; Gianoncelli, 1975): maps were georeferenced and line drawing of the main features was realized in ArcGIS environment.

Chronological constraints since latest Pleistocene are provided by a number of ^{14}C dating (Comerci et al., 2007; Ferrario et al., 2015b; Tab. 1) obtained at several sites in the Como basin and integrated with information deriving from the archaeological record (Uboldi, 1993; Jorio, 2004). Calibration was carried out applying Oxcal software (https://c14.arch.ox.ac.uk/oxcal/OxCal.html, last accessed January 2015) and the IntCal13-calibration curve (Reimer et al., 2013).

4.1. Drillings: *in situ* tests

The elevation of each core was calculated based on the municipal 1:2,000 scale topo map acquired in 1994; the elevation of cores on the lake bottom was calculated by subtracting water depth at each point.

Digital photographs were taken of every sediment core and, as soon as the sediments were collected, pocket penetrometer and shear values were measured. A detailed lithostratigraphic description was based upon grain size estimation, texture, color (with Munsell soil color chart), presence of organic substance and artifacts. Peculiar archaeological findings and some organic sample suitable for ^{14}C dating were collected.

4.2. Drillings: laboratory tests

Two Sediments were sampled for analysis under laboratory conditions: the main physical parameters and a preliminary estimate of the biological content were investigated. Sampling was not based on a regular spatial interval, but more emphasis was put on the most interesting parts of the sequence, namely where lithological markers or peculiar sedimentary features are present.

Four different kinds of samples were taken: (i) Ca. 100 g of wet sediments were collected in small plastic containers for texture analysis, exoscopic indicators (degree of roundness and angularity) and organic abundance estimation; at this stage of the research, 20 to 35 samples were taken for each of the 30-to-40 m deep drillings. (ii) A total of 21 samples for grain size analysis with sieving and sedimentation procedure were stored in plastic bags. (iii) Natural density and unit weight were calculated on 109 samples collected through steel or plastic cylinders of known volume. (iv) Undisturbed samples were taken with Osterberg samplers for geotechnical probes.

Water content, grain size and unit weight have been determined on all the cores, indeed two specific cores (SI7 and SI12) were selected for determination of organic abundance.

Grain size determination was performed through sieving and sedimentation procedure, according to ASTM D422 procedure and results were statistically analyzed. Bulk density was calculated dividing dry weight by the sampler known volume.

Sediment samples of the above-mentioned category (i) were analyzed with the following procedure: they were weighted immediately after the sampling and then oven dried at 105°C in order to calculate water content. They underwent mechanical sieving for sorting out coarse fraction (> 2 mm), very coarse sand (2 mm – 850 µm), medium to coarse sand (850 – 250 µm), fine sand (250 – 150 µm), very fine sand (150 – 63 µm) and silts/clays fraction (< 63 µm). These categories were defined considering the predominance of fine sediments and the almost negligible amount of material larger than 250 µm.

On the finest fraction color was determined using the Munsell chart, whereas the sand fraction was examined under a stereoscopic microscope (Carl Zeiss KL 200, magnification 8 – 50 x). Organic abundance, roundness and angularity were estimated by comparison with reference charts representing four classes (for organic abundance: 1, absent; 2, rare; 3, present; 4, abundant).

5. RESULTS AND DISCUSSION

Obtained data allowed to document with unprecedented detail the Holocene evolution of the area, the first human influence before the foundation of Como and finally the dramatic hydraulic and geomorphic changes induced during Roman and historical times. Sedimentological proxies are discussed in the following according to their relation in respect of the local harbor evolution.

5.1. Pre-harbor environment: natural processes and first anthropic influence

During the Last Glacial Maximum (LGM), the area nowadays hosting the town of Como was fully covered by ice. The sedimentary sequence in the Como basin was generated by the retreat of the glacier front towards the north: a proglacial lake formed at an elevation of 270 m a.s.l. and inorganic glaciolacustrine proximal (Unit 7) and distal (Unit 6) deposits settled. With the inception of a milder climate, the deposition of palustrine organic silts (Unit 5) begun; this moment is dated at 18.5 – 17 ka BP (via Valleggio and Piazza Verdi sites; Comerci et al., 2007; Ferrario et al., 2015b) and the lake stood at ca.

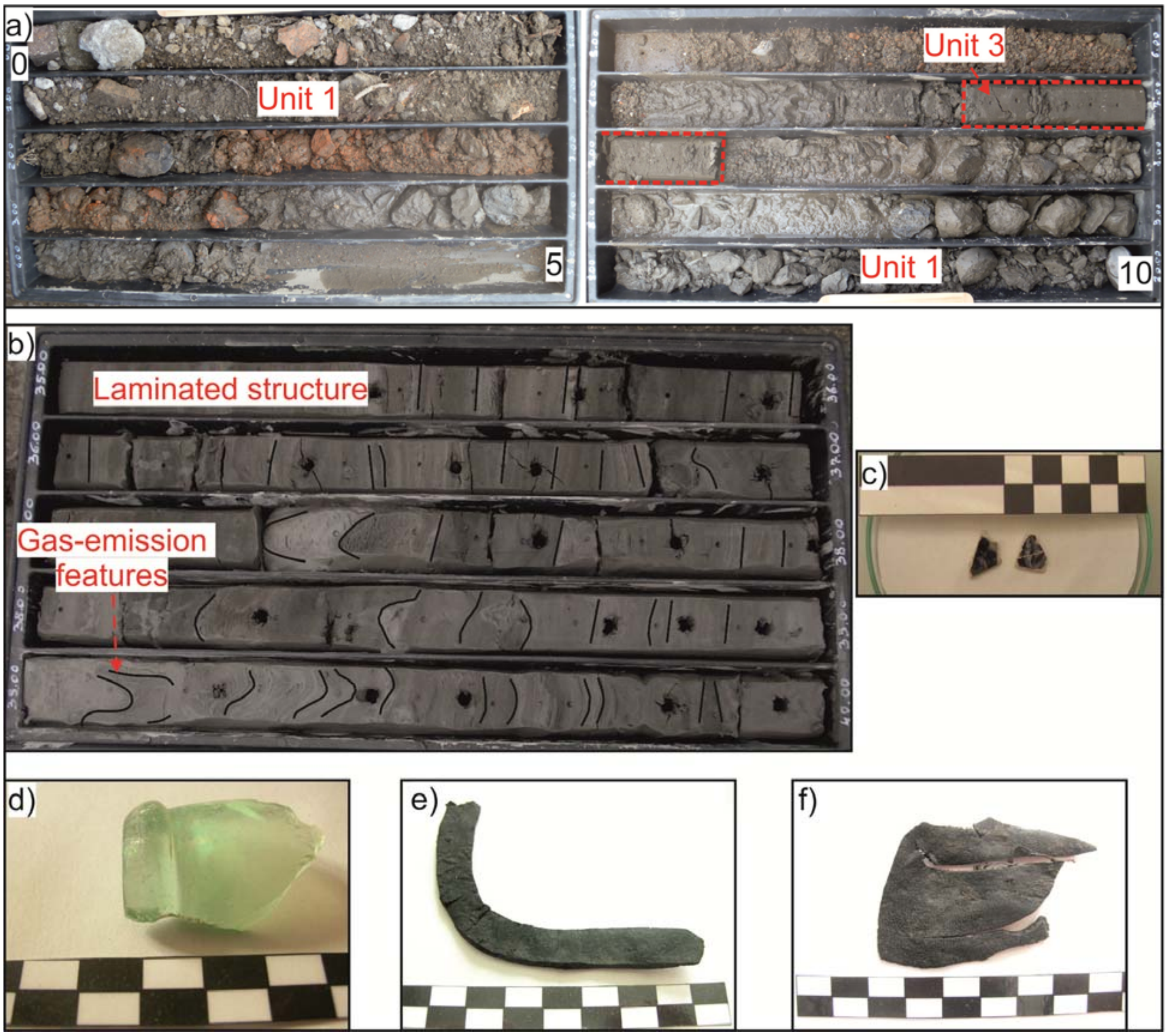

Fig. 4 - Sedimentary structures and archaeological findings recovered from the drillings: **a**) Unit 3 intercalated between anthropic reworked material of Unit 1 (SI1, depth: 6.70-7.20 m below ground surface, 2013 drillings); **b**) laminated structure and gas-emission features in Unit 5 (SI3, depth: 35.00-40.00 m, 2013 drillings). The holes in the core represents pocket penetrometer and vane borer measurements; **c**) pottery fragments, age uncertain (PZ11, depth 7.20 m, 2014 drillings); **d**) glass fragment, Early Middle Ages (SI3, depth 8.00 m, 2013 drillings); **e**) and **f**) leather tiers, Imperial Age? (SI3, depth 13.12-13.18 m, 2013 drillings). Borehole location is shown in Fig. 3.

215 m a.s.l.

Vegetation history has been reconstructed by means of palaeobotanical analyses on the Piazza Verdi cores (Martinelli, 2014). A succession starting from few pioneer herbaceous species, through arboreal species (Lateglacial), continental forests (Bölling/Allerød interstadial) and mixed mesophilous forests (Holocene) developed. The first human influence is attested on the basis of the local fire history since 8.2 ka BP and progressively intensified, because of deforestation, agriculture and livestock farming.

Unit 5 has been dated at several sites, namely S. Abbondio (Castelletti & Orombelli, 1986; Comerci et al., 2007), via Valleggio (Comerci et al., 2007) and Piazza Verdi (Ferrario et al., 2015b).

Unit 5 was cored both in SI12 (5.72 – 30.00 m depth) and SI7 (17.37 – 40.00 m) drillings. It is constituted by sandy clays rich in organic matter and vivianite, an iron orthophosphate that is formed under reducing redox environments and alkaline conditions. The unit settled in a lacustrine-palustrine environment. Vegetal fragments are dispersed or organized in aggregates or lenses. Usually an alternation of mm-thick organic strata and mm-to-cm inorganic strata is present. Locally, layers are convolute or inclined up to 40° and flame-structures (Fig. 4b) are present, pointing to possible reworking of sediments. We interpreted these features as related to gas emission, but other triggering mechanisms cannot be ruled out, including sediment overload, earthquake shaking, storm, lake-level variations and biological activ-

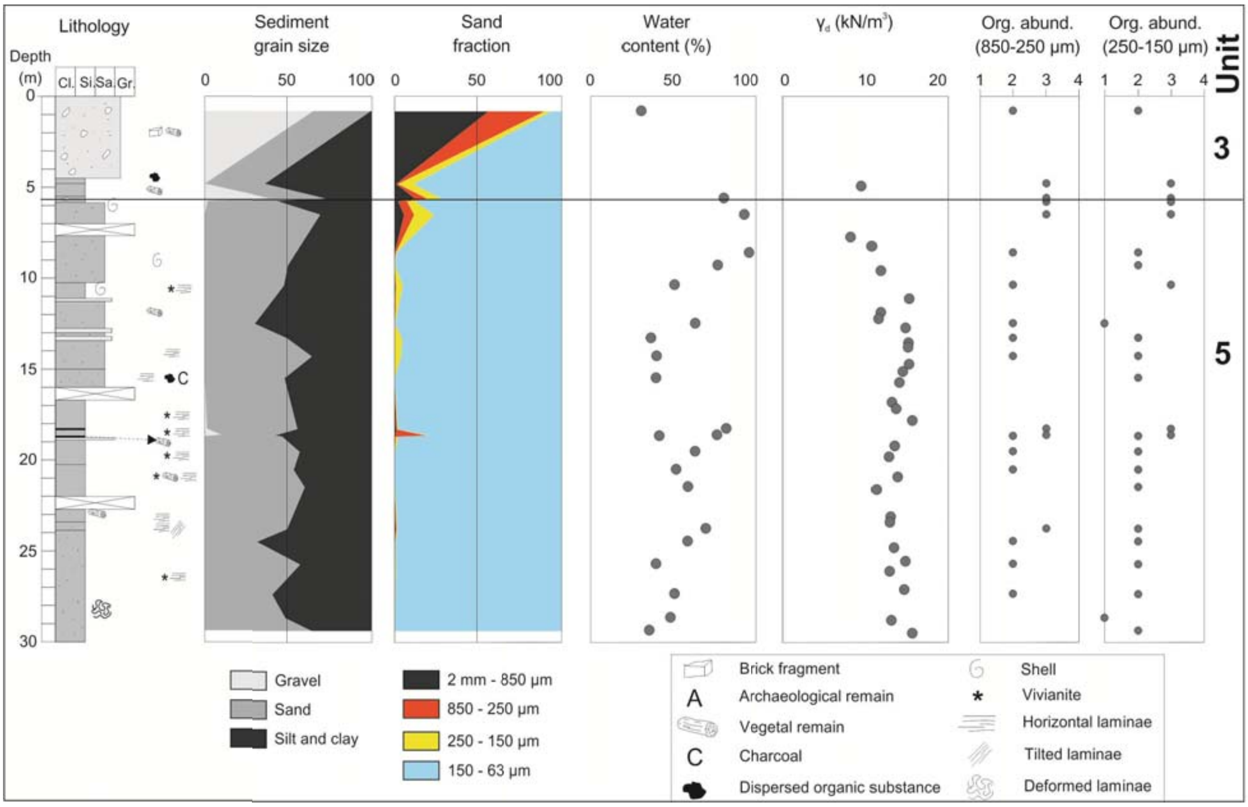

Fig. 5 - Sedimentology and organic abundance of core SI12. Lithological description is based on in situ analysis of the core (cl: clay; si: silt; sa: sand; gr: gravel), whereas grain size, water content and unit weight derive from laboratory measurements. The abundance of organic material (org. abund., 1: absent; 2: rare; 3: present; 4: abundant) is estimated by means of a stereoscopic microscope.

ity. The elevation of the base of the unit was ascertained with the 1997 drillings and runs at 50-60 m depth in the western sector of the lake shore, while it increases to 20 m depth in the eastern sector.

Sedimentological analyses performed on 50 samples taken from cores SI12 (Fig. 5) and SI7 (Fig. 6) allowed to accurately characterize the index properties of Unit 5. Water content is highly variable in SI12 (35-90%), whereas in SI7 is more clustered (35-60%); unit weight increases with depth, from ca. 10 to 16 kN/m3.

The coarse fraction (> 2 mm) is very low, in the order of 1% and composed both by mineral or biological fragments; sand varies between 20 and 70%, with an average of 49% in SI12 and 46% in SI7. The finest fraction (< 63 μm) corresponds to 30 – 85% of the sediment texture (average 49 and 53% for SI12 and SI7, respectively). Concerning the sand fraction, it is composed almost only by very fine sand (150 – 63 μm).

The sedimentation of Unit 5 went on for several millennia; the unit is generally overlaid by alluvial deposits. A wood fragment collected from SI3 at 38.40 m depth (see Fig. 3 for location) yielded an age of 7.5 ka BP (Ferrario et al., 2015b; Table 1).

The boundary between Unit 5 and 4 is a diachronic erosive surface, being younger moving towards the north. This limit has been dated at 5.8 and 4.5 ka BP at via Valleggio and Piazza Verdi sites, respectively (Comerci et al., 2007) and corresponds to the progradation of the Cosia alluvial fan on the palustrine basin. Considering the age difference and the distance between the two sites, an average velocity of progradation of almost 1 m per year can be estimated. The fast progradation abruptly ceased ca. 2 ka BP when the foundation of *Novum Comum* occurred.

Unit 4 thickness ranges from 10 to 25 meters, depending on the distance from the river course. The thickness rapidly decreases from south towards the lake, where the unit is absent. Unit 4 was not cored during the 2014 drillings because it pinches out few meters southward.

5.2. Harbor environment

The boundary between Unit 5 (or Unit 4, where present) and the overlying Unit 3 is an unconformity marked by: (i) the appearance of sandy clays of low consistence and extremely rich in water; ii) a change in color, from grey to dark brown; iii) the presence of archaeological findings (bricks, potsherds, glass); iv) a sharp signature on the geotechnical parameters, namely a decrease in cone resistance and an increase in the friction ratio recorded by CPTUs (Ferrario et al., 2013).

Driven by these observations, we interpreted this limit as the Harbor Foundation Surface (HFS, *sensu* Marriner & Morhange, 2007), marking the beginning of human modification of the basin.

Sediments of Unit 3 are definitely homogeneous in lithology and belong to the OH-MH category in the Casagrande plasticity chart; water content is extremely

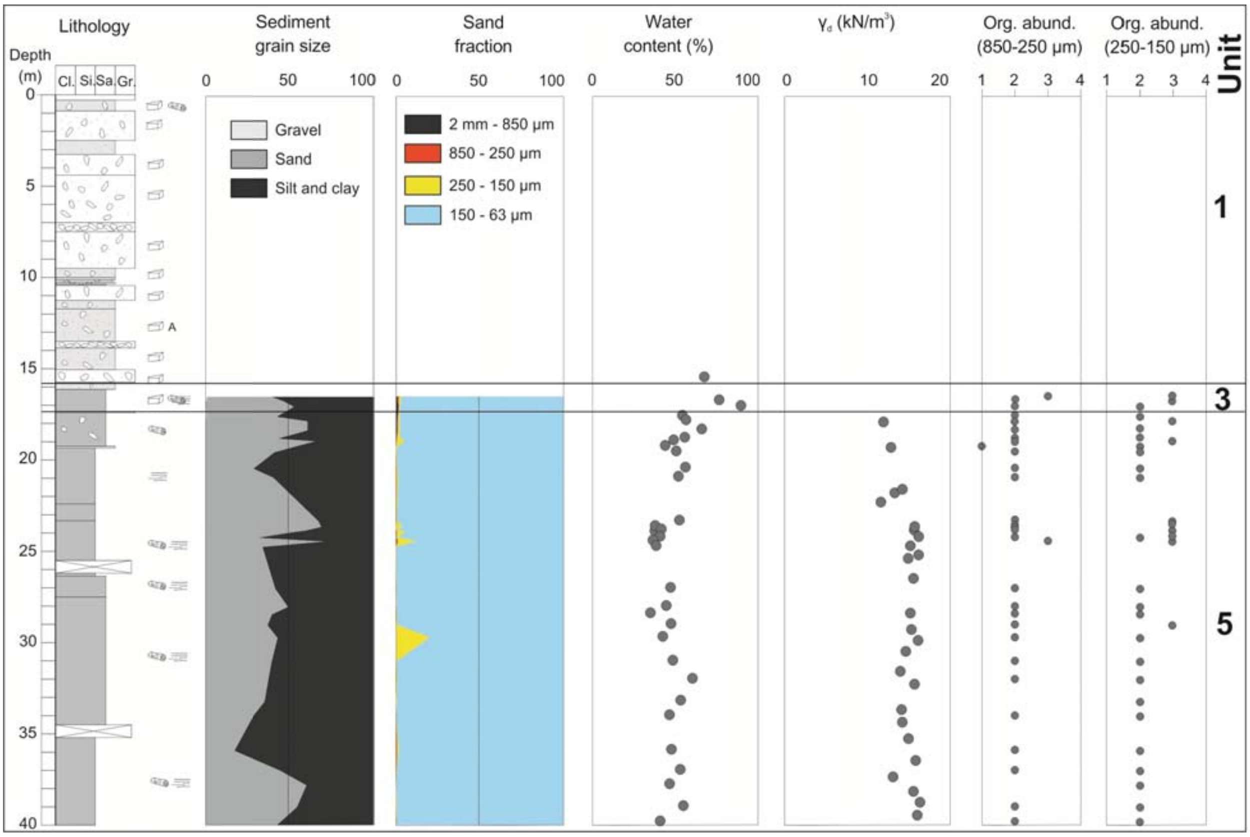

Fig. 6 - Sedimentology and organic abundance of core SI7. Lithological description is based on in situ analysis of the core (cl: clay; si: silt; sa: sand; gr: gravel; symbol legend is shown in Fig. 5), whereas grain size, water content and unit weight derive from laboratory measurements. The abundance of organic material (org. abund., 1: absent; 2: rare; 3: present; 4: abundant) is estimated by means of a stereoscopic microscope.

high (ca. 90%) and unit weight quite low (Ferrario et al., 2015b).

Archaeological evidence based on chronology of masonries and materials (Jorio, 2004) suggests that Unit 3 begun to settle during the Roman age, when the town was founded. Before that period, the strong sedimentary supply of the streams resulted in an higher energy of the local environment. Man-made interventions on the river courses promoted alluvial deposition on the western side of the plain, whereas in the central sector a low-energy environment with shallow waters developed enabling the deposition of Unit 3. Here, anoxic conditions are present and sediments are saturated with water, thus otherwise perishable biological and archaeological materials (leather, wood, peat, seeds) can be preserved. Plastic silts and clays contain a coarser fraction made up by biological remains and artifacts (Fig. 4).

During Roman age, the harbor environment was first located close to the present-day Piazza Mazzini (see Fig. 2 for location), then moved towards the north-east (Fig. 7) due to silting of the basin. Harbor clays settled atop older sediments constituted by Unit 4 or Unit 5; a sequence of alternating strata of Unit 4 and 3 is locally recorded in the western sector of the urban area, attesting for both lacustrine and alluvial floods.

On the lake shore, the age of the unit has been bracketed between VIII and XV century AD (SI3; Ferrario et al., 2013). A particular situation was encountered in SI1, located on the eastern part of the lake shore (see Fig. 3): here, a 70-cm thick layer belonging to Unit 3 is intercalated within anthropic materials of Unit 1 (Fig. 4a). The lower part of Unit 1 has been interpreted as a man-made filling built in order to protect a coastal infrastructure; Unit 3 refers to a quiet environment developed for a short time and then covered by another phase of man-made filling accumulation, presumably related to the land reclamations occurred since XVIII century.

5.3. Post-harbor environment and the most recent evolution

The upper limit of Unit 3 can be defined as the Harbor Abandonment Surface (HAS, *sensu* Marriner & Morhange, 2007). The abrupt boundary between fine silts of Unit 3 and overlying coarser materials represents coastline progradation of both natural or man-made origin, which caused a silting of the harbor basin and its loss of functionality. In the southern and western sectors of the town, Unit 3 is overlaid by the coarse sediments of Unit 2: during historical times, alluvial floods promoted coastline progradation, culminated in the landlocking of the harbor basin. However, in the central and northern parts of the town, Unit 1 lies in unconformity over Unit 3, attesting to anthropic modification of the coastline.

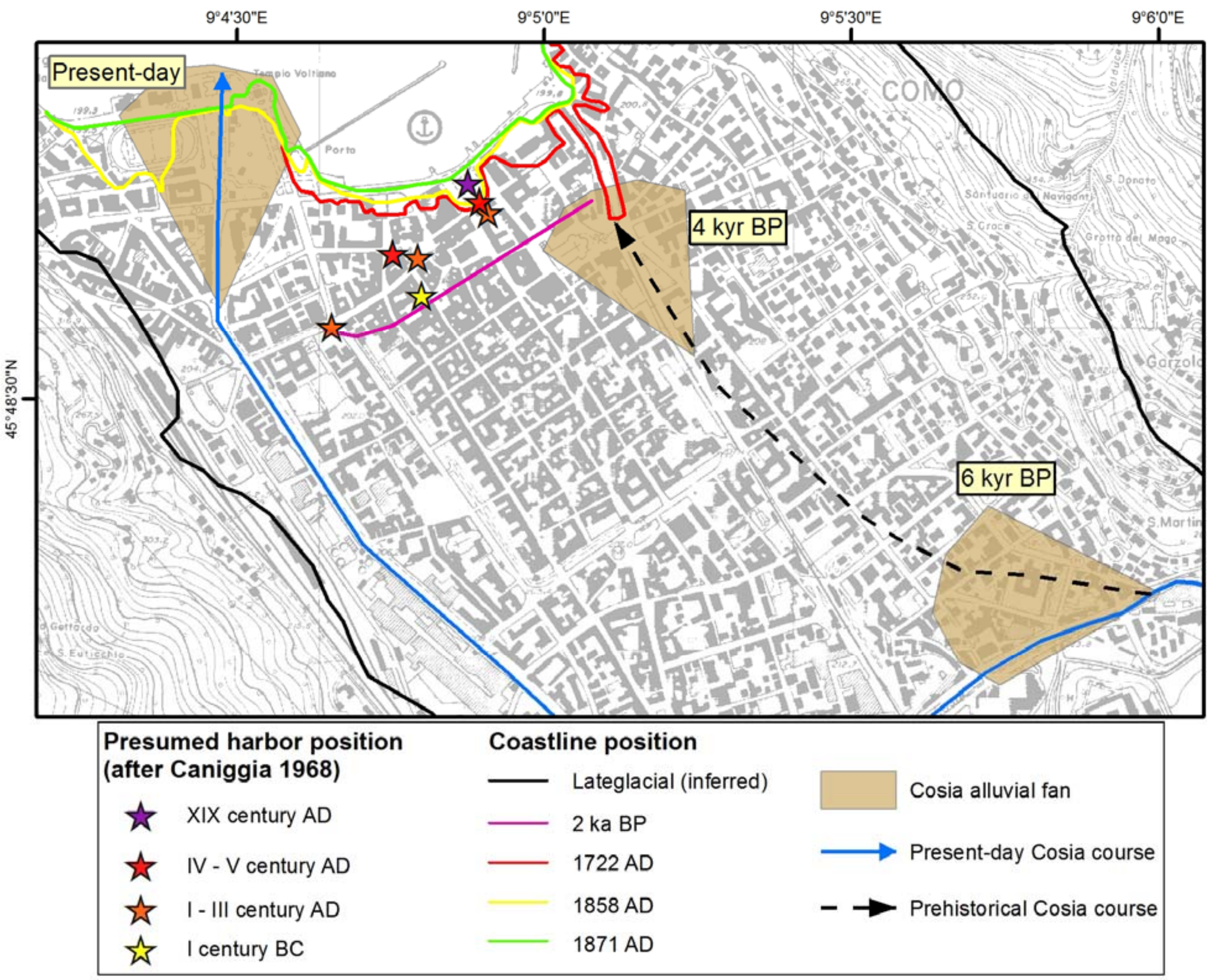

Fig. 7 - Map of the Como urban area, showing the Holocene position of the Cosia alluvial fan and the evolution in coastline and harbor position. Modified after Ferrario et al., 2013.

Man-made fillings are constituted by medium-to-coarse sands and fine gravels with silty matrix; accumulation of blocks, mainly made of limestone, is recorded on the coastal area.

On the lake shore area, Unit 1 is typically younger than 200 years and reaches a maximum thickness of ca. 15 meters. The coastline evolution in the last centuries is constrained by old city maps (Gianoncelli, 1975): at least three phases of land reclamation were realized in XVIII-XIX century. Present-day Piazza Cavour was the dock of the town till 1870, when a notable reorganization of the coastline took place and the last marshy areas were reclaimed. Coastal changes show a progressive regularization, obtained through the filling of natural coves.

5.4. Geologic cross-sections

Stratigraphic data were arranged in two different cross-sections, illustrated in Fig. 8. Vertical and lateral facies changes are common and reflect the paleogeographic evolution of the area driven by natural as well as human-induced factors. Unit thickness varies notably in limited planar extents, especially along the N-S direction. Instead, on the W-E direction, lithological units can be depicted along their extension along the lake shore. Fig. 8b shows the main stratigraphic characteristics of Unit 3: in the western part it overlies Unit 4, whereas to the east it overlies Unit 5. Locally, a more complex setting is present, such as in correspondence with core SI1: the interpretation drawn here suggests a lateral facies contact between Unit 4 and Unit 1, both passing to the top to Unit 3 and finally to Unit 1. In core SI1 anthropic fills are present down to 13 m depth; the lower part is interpreted as a protective filling for coastal infrastructures, including a staircase. It was then submerged for a short period, testified by a 70-cm thick layer belonging to Unit 3 at 6.70 – 7.30 m depth and then covered by another phase of man-made deposits (Fig. 4a).

6. CONCLUSIONS

This paper illustrates geoarchaeological research that we performed on the Como coastal area, essentially

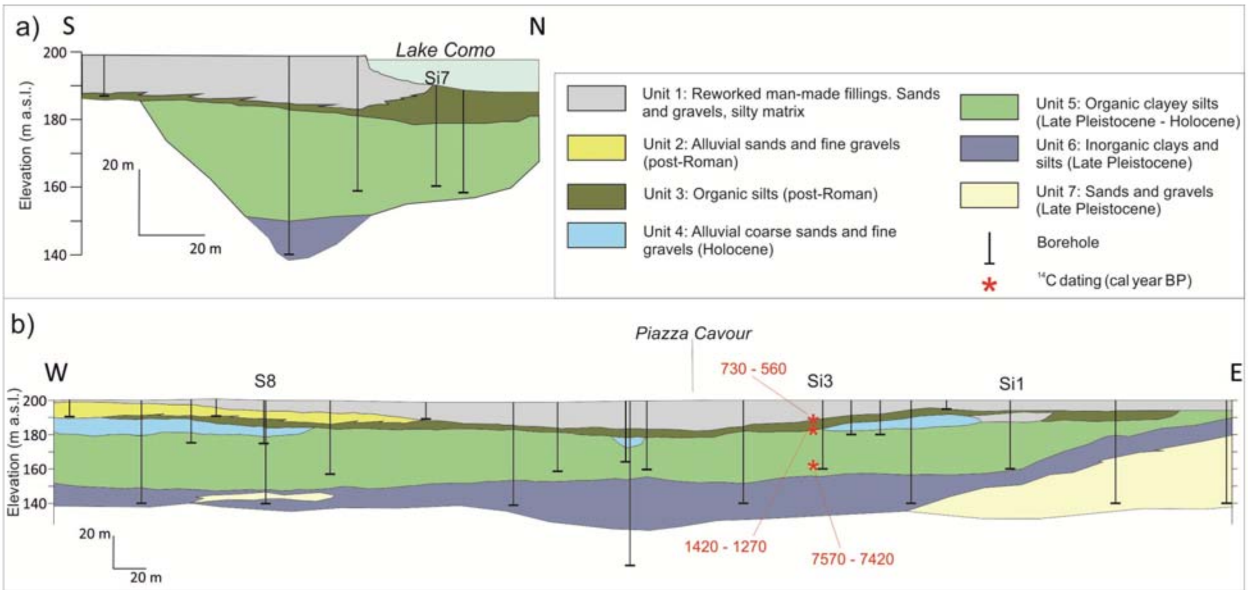

Fig. 8 - a) Geological cross-section N-S oriented, located on the coastal area; b) Geological cross-section W-E oriented, located on the lake shore. Trace sections are visible in Fig. 3. ^{14}C dating performed on SI3 are expressed in cal years BP with two standard deviation ranges.

based on the detailed analysis of sedimentary sequences sampled through extensive coring. Our preliminary results allow to draw some conclusion, as summarized below:

- The comprehensive characterization of the area at the interface between land and the lake clearly shows the strong relationship existing between harbor evolution, natural events and human occupation;
- Sedimentological analyses corroborate available stratigraphic and archaeological data and allow to draw geological cross-sections, aimed at reconstructing the local landscape evolution in the last millennia;
- The adopted methods, based on the integration of stratigraphic, sedimentological, geotechnical and archaeological proxies, document that a cross-disciplinary approach is the best strategy of investigation when natural and anthropic processes are superimposed within each other, as typically occur in the coastal settings of regions with ancient civilization;
- The model of the landscape evolution, if properly integrated in urban planning, is suitable for reaching a better management of the cultural heritage and for revealing possible risk for the local infrastructures and assets;
- Geological techniques are an interesting option when it is not possible to perform archaeological excavations, due to technical difficulties (submerged environments, groundwater) or economic costs; the possibility offered by geoscience to use non-destructive methods is a valuable tool for the protection of very sensitive environments and heritages;
- Obtained results provide guidance for future research involving the integration of the conspicuous geological and archaeological data available for the study area; the Como case is one of the first lacustrine settings studied on a geoarchaeological basis.

The main conclusions arising from the study therefore include not only the specific results achieved so far, but also interesting methodological opportunities for future research at Como or in other similar lacustrine coastal sites.

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