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ORIGINAL ARTICLE

Beached swords from Marano Lagoon (northern Adriatic) reveal ancient land–sea connections and recent coastal evolution

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Abstract

Depositional and erosional processes, subsidence and sea-level changes have strongly modified the coastal landscape of northern Adriatic lagoons. Such rapid transformations have induced significant consequences on human settlements and, thus, on the archaeological visibility of the area, still largely unexplored. We present here six metal swords fortuitously retrieved by fishermen over the last decades in front of the barrier islands of Marano Lagoon (north-eastern Italy). Multi-analytical analyses carried out on the artefacts (X-ray radiography and computed micro-tomography, radiocarbon dating and typo-chronology) combined with the study of the coastal

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paleo-environment (mainly based on historical cartography and remote sensing) allowed the items' main features to be defined, and highlighted both the historical importance of the area and the significant morphological changes that have occurred there over the last millennium. Data presented indicate that Marano Lagoon was a major hub in the northern Adriatic in the Late Middle Ages, during the crucial period of the Crusades, and in Early Modern times, connecting inland Europe with the Mediterranean Sea. Moreover, the research highlights the onset of coastal erosion that occurred in the last century after a phase of relatively geomorphic stability, possibly deriving from the intensification of human impact and climate change.

KEYWORDS
coastal erosion, geoarchaeology, Grado-Marano Lagoon, historical cartography, Middle Age-Modern Age, Crusades, northern Adriatic, swords

INTRODUCTION

Thanks to its dense network of watercourses, which offer privileged paths to continental inlands, the Italian regions along the northern Adriatic have constituted one of the main gateways between the Mediterranean and Central Europe throughout history (Horden & Purcell, 2000: 166–167; Marriner & Morhange, 2007). This strategic position underlay the extraordinary flourishing of maritime cities in historical times, such as Aquileia, Grado, Altinum and Venice, located in easy-to-reach brackish lagoonal environments. Whilst a long tradition of archaeological and historical studies has focused on these important centres (e.g., Bertacchi, 2003; Gelichi, 2021; Marano, 2022: 47–90; Mozzi et al., 2016), little is known about the occupation of the northern Adriatic coasts in Roman and medieval times. Available written sources report of minor harbours and settlements located east of Venice in the largest lagoon system of the area (the Grado-Marano Lagoon), which acquired considerable economic and political influence during the Middle Ages. Notwithstanding this, with the exception of the city of Grado, the archaeological evidence is scanty and only a few sites have been investigated so far (Auriemma et al., 2013; Auriemma & Maggi, 2013; Capulli & Scarton, 2020; Gaddi, 2001).

Moreover, similar to other lagoonal systems, depositional and erosional processes, subsidence and sea-level changes have strongly modified the landscape of these areas in the last millennia with tangible effects on the geography of the coasts (Chesworth, 2008: 426–427; Galloway & Hobday, 1983; Morhange et al., 2017; Summerfield, 1991: 313–341). Such rapid transformations induced significant consequences on the human settlement and, thus, also on the archaeological visibility of the areas (Giaime et al., 2019; Nunn, 2017: 145–156). In this perspective, the combined analysis of old and fresh archaeological data and other sources of information (e.g., remote sensing and historical cartography) can help reconstruct the evolution of recent landforms in such a dynamic environment.

In this study we present six metal finds (namely 1–6) discovered in Marano Lagoon, that is, the western sector of the Grado-Marano Lagoon system (Figure 1). They were first investigated using a multi-analytical approach in order to define the typology, technology, chronology and state of preservation of the artefacts. Further analyses have considered the metal finds as a proxy for examining the historical, geographical and paleo-environmental context of Marano Lagoon. This second level of analysis shed light on the connectivity of the area during the medieval and modern periods and on the important morphological changes that occurred over the last millennium. With the aim of inserting the

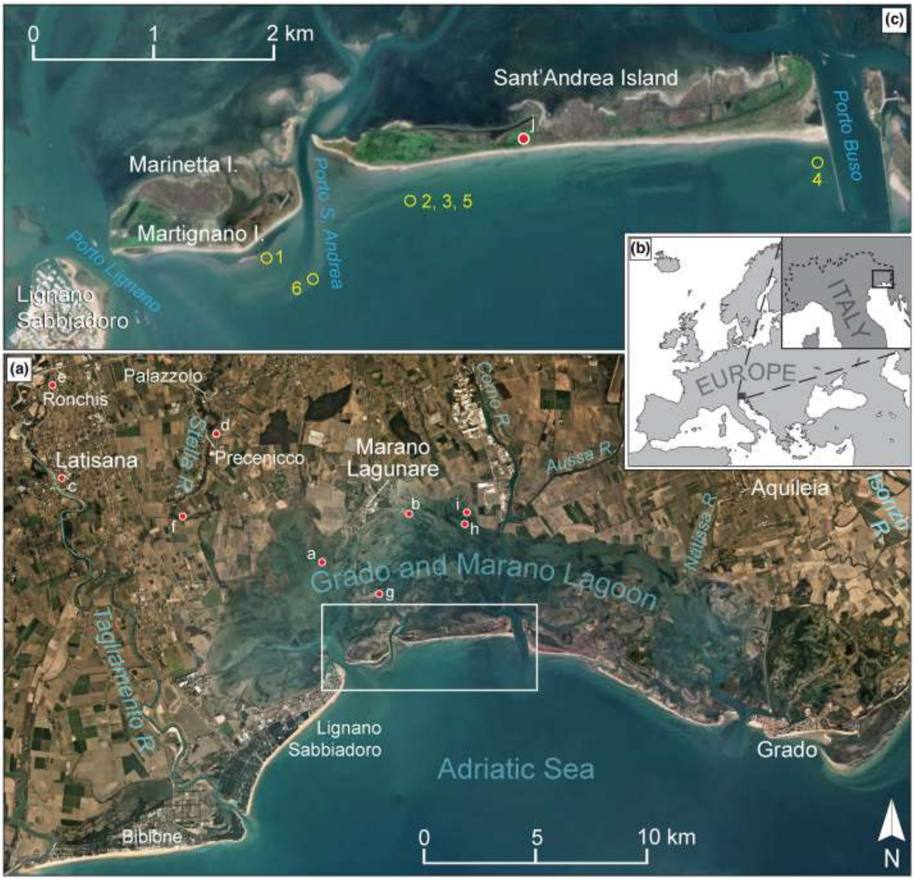

FIGURE 1 (a) Satellite image of Marano Lagoon with the position of the barrier islands of Marinetta and S. Andrea (white box) shown with the main archaeological sites mentioned in the text: Bioni (a); S. Pietro (b); Latisana (c); Precenicco shipwreck (d); Volta di Ronchis (e); Titiano, Madonna della Neve (f); Piere del Tribel (g); Piere del Ficarol (h); and Piere d'Isela (i). (b) Geographical position of the studied area. (c) Location of the retrieved swords 1–6 (yellow circles) and position of the archaeological site at S. Andrea (j) [Color figure can be viewed at wileyonlinelibrary.com]

archaeological findings within the geomorphological framework, the historical cartography depicting the area was analysed by comparing the results with aerial pictures and satellite images. A major aim was to explain why the metal finds (swords) have been found in front of the barrier island and how the landscape of the area has changed from that period to the present.

REGIONAL SETTING

Geological and geomorphological framework

The studied swords were found in the seaward part of Grado-Marano Lagoon, which is protected against the action of marine waves by a system of barrier islands fed by the sediments transported by the Tagliamento and Isonzo rivers. The mouths of these streams also mark the western and eastern limits of the lagoon, respectively, and the shifts of their position over the millennia have strongly influenced the evolution of the brackish area (Marocco, 1989, 1991) (Figure 1a).

The lagoon is connected to the open sea through some tidal mouths that allow water and sediment exchange and are the backbone of a complex network of tidal channels and creeks. The main lagoon channels are connected to the major streams draining within the basin, which consists of rivers originating from a spring belt cropping out in the middle of the alluvial plain and that are characterized by an almost steady water discharge and the almost complete lack of sediment (Fontana et al., 2014, *passim*). The major of these groundwater-fed rivers are the Stella, Muzzanella, Zellina, Aussa and Corno rivers. The tide amplitude reaches maximum values of 1 m and its influence is felt along the rivers for many kilometres upstream of the lagoon inlets (Fontolan et al., 2012), allowing an easy upstream sailing to the inland towns of Latisana, Palazzolo, S. Giorgio and Cervignano.

The formation of the lagoon began *c*.5500 BCE (Fontana et al., 2017) and it experienced an evolution mainly influenced by the shifting of the mouths of the Tagliamento and Isonzo rivers and the relative sea-level rise (RSL) (Marocco, 1989, 1991). However, as documented by stratigraphic investigations and the position of the archaeological sites, the morphologic situation was already almost stable during the Roman period, when the barrier islands were already displaying a position rather similar to the present one (Auriemma & Maggi, 2013; Fontana et al., 2017). In Marano Lagoon the RSL was −1.2 ± 0.3 masl during the first part of the Roman period (Auriemma et al., 2013; Fontana et al., 2017), whereas for the early medieval period detailed estimates are not available. However, significant information for the last 1000 years was published by Marocco (2004) about the city of Grado, by Camuffo (2021) about Venice and by Faivre et al. (2019) about southern Istria; moreover, other data about the northern Adriatic are available in the recent review published by Vacchi et al. (2016). Despite the possible local variations, the available data suggest that the RSL in the study area has been raising rather progressively since the Roman period, until the acceleration of the last century. In the last decades the rising rate increased, also because of human-induced subsidence (Da Lio & Tosi, 2018).

Currently the coastline is prone to a severe erosive trend, which is occurring especially during sea-storm surges and is causing a visible retreat of the barrier island (Bondesan et al., 1995; Fontolan et al., 2012). At some points, wash-over fans have formed in the last years, giving evidence of the landward shifting of the coast.

Historical and archaeological context

Since Roman times, Marano Lagoon was densely occupied along its fringes and constituted an important commercial terminal. Long-distance trades with different Mediterranean regions are demonstrated by amphorae and pottery found on several islands of the lagoon as well as at Aquileia and Grado, dated to a period spanning from around the first to the beginning of the seventh centuries CE (Auriemma et al., 2013; Marano, 2022: 53–54, *passim*). Similar imported materials found in Udine, in the inland of Friuli, point to the existence of a minor road connecting the two areas in Late Antiquity (Arthur, 1990; Buora, 1990). It is therefore highly probable that at least part of the Roman road system crossing the region continued to be in use during the Middle Ages (Capulli & Scarton, 2020: 59, *passim*). Among the Roman sites, structural evidence found at Piere del Tribel, Piere del Ficarol, Piere d'Isela and S. Andrea islands testifies for the strategic occupation during the Imperial period (Auriemma et al., 2013) (Figure 1a, sites g–i; C, site j). The importance of the area is also documented by the choice of Marano as the seat of the episcopal synod in 590 CE.

In the following period between the sixth and the 10th centuries, unlike the inland of Friuli, which was annexed to the Lombard kingdom along with most of the Italian peninsula, the coastal centres of the northern Adriatic remained under the political influence of Byzantium (Cammarosano, 1988). The only available information for this period is provided by a few structures associated with finds recorded at Marano and the surrounding islands of the lagoon. At Bioni Island, recent investigations have discovered an adult man's burial dated to the seventh to eighth centuries (Auriemma et al., 2013). On the same island, as well as at Sant'Andrea some wall structures partly submerged and architectural features demonstrate the existence of places of worships (churches and monasteries), also reported by the 10th–11th-centuries Altinate Chronicle (Auriemma et al., 2013) (Figure 1a, site a; C, site f).

Another building mentioned by the Chronicle was possibly located on the island of S. Pietro, but archaeological evidence is lacking so far (Auriemma et al., 2013) (Figure 1a, site b).

A new historical phase started in 1031 when the entire lagoon fell under the rule of the patriarchate of Aquileia, an ecclesiastical state which was part of the Holy Roman Empire and controlled the area at that time. Patriarch Popone I understood the strategic position of Marano and started the erection of an imposing fortress along the coast. Dockings located in the lagoonal fringes of Veneto and Friuli became the favoured hubs for the exchange of goods between Central Europe and the Republic of Venice. Exchanged goods included timber transported from the mountains of Veneto and Friuli as well as fish and waterfowl caught and manufactured in lagoonal areas (Capulli & Scarton, 2020: 56–57; Rösch, 1985). It must be noted that Marano was one of the few centres of salt production in the northern Adriatic documented at least since the 13th century (Di Manzano, 1876: 87).

Both the documentation of a large commercial settlement dated to the late 12th - early 13th centuries in the city centre of Latisana (Fontana, 2006: 17, 167–169) and a coeval 8 m-long perfectly preserved wooden hull found in the Stella River near Precenicco give strong clues about the importance of this area in late Middle Ages (Capulli & Scarton, 2020: 103–121, *passim*) (Figure 1a, sites c, d). This is further supported by the minting of silver coins, documented by a few items bearing the Gorizia comital symbols and the wording 'Latisana harbour' on the Tagliamento River dated to late 12th–early 13th centuries (Galasso, 1999).

In the early 13th century, this long-distance connection was further strengthened by the Counts of Gorizia, a German family who had obtained from the Patriarchate of Aquileia the control over several centres strategically placed along the left bank of the Tagliamento River. Adding these possessions to those located in Carinthia, Tyrol, and the peri-Alpine area of Friuli, they were able to control the main flows of people and goods between the coast of Friuli and the inland (Degrassi, 2007). Trades with the Serenissima were stimulated by different actions taken by the counts. Among them, documented is the exemption from the payment of duties for goods traded at Latisana port in exchange for the maintenance of the infrastructural network (Altan, 1991: 221; Capulli & Scarton, 2020: 54).

In this historical context, a new stimulus in the development of the area was given by the Crusades and the needs for protection and hospitality of a mass of pilgrims, merchants, armed and religious travellers to/from the Holy Land. Between late 12th and early 13th centuries, different military orders were allowed to erect several reception facilities (the so-called *hospitia–hospitalia*) in the lowlands of Friuli on behalf of the allegiance to the pope (Altan, 1987). Among the others, the order of the Teutonic Knights acquired particular importance in the area. In 1232, they obtained the dominion of Precenicco from the Patriarchate who wanted to contain the expansion of the Counts of Gorizia in the region. At that time, they already controlled some important religious centres of the area, such as the churches–*hospitia* of Volta di Ronchis and Madonna della Neve near Titiano (Capulli & Scarton, 2020: 63–64, *passim*) (Figure 1a, sites e, f).

This political situation lasted until *c.*1420, when the whole area, together with all the Patriarchate possessions, fell under the Republic of Venice (Menis, 1964). Favoured by this new political setting, the area still appears to maintain its role of an important hub along the Adriatic seaway, as made evident by the historical cartography of the period.

MATERIALS AND METHODS

Here we present six metal finds (namely 1–6) from this area, at times fortuitously recovered by fishermen in the last four decades. Apart from item 4, which was found at close distance from the Porto Buso tidal inlet, all the other artefacts were found a few hundred metres offshore from the islands of Martignano and S. Andrea at less than 5 m of depth on the sandy sea bottom (Figure 1) (see Material S1 in the additional supporting information for the items' coordinates).

The finds, immediately recognized as swords by their shape, are embedded in up to 5 cm-thick concretion mainly consisting of fine sand made of clasts of limestone and dolomite and with concretioned lagoonal shells (in particular *Chamalea*, *Glycimeris* and *Bittium* sp.). Of these, two finds (swords 4 and 6) were extracted from the cap and restored by the Soprintendenza Archeologia, Belle Arti e Paesaggio del Friuli Venezia Giulia. Results obtained from the preliminary study of sword 6 encouraged to set a programme of multidisciplinary scientific analyses carried out through the fruitful collaboration of different institutions. Further investigations on the context allowed a deepening of understanding of the coastal geomorphological processes underlying the discovery of the swords.

X-ray radiography and conventional computed micro-tomography (microCT)

X-ray radiography and conventional microCT were carried out at the at the Multidisciplinary Laboratory of the 'Abdus Salam' International Centre for Theoretical Physics of Trieste using a system specifically designed for the study of archaeological and paleoanthropological materials (Tuniz et al., 2013) (see Material S2 in the additional supporting information). Part of sword 5 was scanned using a sealed X-ray source (Hamamatsu L8121-03) at a voltage of 140 kV, a current of 200 µA and with focal spot size of 20 µm. The X-ray beam was filtered by a 1 mm-thick copper absorber.

A set of 1800 projections of the sample were recorded by a flat panel detector (Hamamatsu C7942SK-25) over a total scan angle of 360°, with an exposure time/projection of 1.5 s. The resulting microCT slices were reconstructed in 32-bit format and an isotropic voxel size of 39 µm using the commercial software DigiXCT (DIGISENS). The radiographs of the other swords with a variable pixel size between 45 and 50 µm were acquired using the same system, a voltage of 140 kV, a current of 500 µA and a focal spot size of 50 µm.

Synchrotron microCT and radiocarbon dating

A sample of about 2 × 3 × 1 mm taken from the wooden sheath of sword 5 was analysed by high-resolution synchrotron X-ray microCT at the SYRMEP beamline (Tromba et al., 2010) of the Elettra synchrotron facility in Basovizza (Trieste, Italy) using phase-contrast imaging based on a free-space propagation (Cloetens et al., 1996). This analysis, allowing fine morphological features in the wood to be visualized, was carried out in order to determine the wooden species (Dreossi et al., 2009; Rigon et al., 2010).

Experiments were performed with a filtered white beam (filters: 1.5 mm Si + 0.025 mm Mo) corresponding to a mean energy of about 20 keV.

A set of 1800 projections of the sample were recorded by a 16-bit, water-cooled, 2048 × 2048 pixels sCMOS macroscope camera (Hamamatsu Orca Flash 4.0) coupled by a high numerical aperture optics to a 17 µm-thick GGG:Eu scintillator screen, over a total scan angle of 180°, with an exposure time/projection of 1.0 s. The sample-to-detector distance was set to 150 mm. The tomographic reconstruction was performed by using the SYRMEP Tomo Project 4.0 software, custom-developed at Elettra (Brun et al., 2015) allowing axial slices to be obtained in 32-bit format with an isotropic voxel size of 1.5 µm.

The same wooden sample from sword 5 previously analysed by the synchrotron microCT was chemically pretreated at the 'iCONa Laboratory' of the Department of Environmental, Biological, and Pharmaceutical Sciences and Technologies (DiSTABiF), University of Campania 'Luigi Vanvitelli' (Italy). The radiocarbon content was quantified via accelerator mass spectrometry (AMS) using the dedicated beam line of the HVEE 3 MV Tandem accelerator installed at the INFN-LABEC Laboratory (Laboratory of Nuclear Techniques for Cultural Heritage) of Florence (Chiari et al., 2021; Fedi et al., 2007). Calibration of the dating was obtained by using OXCAL software v.4.4-IntCal20 (Bronk Ramsey, 2009; Bronk Ramsey et al., 2020; Reimer et al., 2020).

Typo-chronology of swords

In this study, the description and analysis of swords follow the terminology and the typological system first designed by Oakeshott (1964), later adopted with minor changes by other authors (e.g., Aleksić, 2007; Geibig, 1991). Morphometric parameters of single-sword typological features were measured on both the artefacts and the X-ray-derived images. The morphological features of sword components were described using the terminology reported in Material S3 in the additional supporting information.

Historical cartography and remote sensing

The north-western Adriatic coast is represented in a large number of historical maps with variable scales, generally dating between the 14th and 18th centuries. These documents were mainly checked in the Archivio di Stato in Venice, but some belong to private collections. Ancient maps dating to the 19th and first half of 20th centuries are also available at the Istituto Geografico Militare in Florence (IGMI www.igm.it).

The recent evolution of the coastal area was studied through the analyses of aerial photographs and satellite images (see Material S2 in the additional supporting information).

RESULTS

X-ray radiography and conventional microCT

X-ray radiography and following restoration works carried out on sword 6 revealed that the iron was highly corroded, whereas the organic components were quite well-preserved (Capulli & Milocco, 2018). The sword has a single-hand grip consisting of a so-called ‘clove’ iron pommel, a flat and wide tang with a rectangular section, tapered at the end. On the tang, the pommel and two wooden valves covered with a fabric cord poorly preserved are fixed. The two arms of the cross-guard are asymmetrical and slightly enlarged at the ends, with a square section. Only a thin layer of the iron blade, strongly oxidized and mineralized, is preserved. The double-edged blade is straight with a lenticular section and a nearly rounded point. A fuller of about 1.5 cm in width is visible and ends up almost to the point. The sword sheath consists of a wooden core covered with leather on both sides. Traces of an iron reinforcement are visible on the point. Part of the sheath is also constituted by a sword-guard, that is, a leather feature adhering to the cross-guard to protect the sword from rain (Figure 2, sword 6).

Along with sword 6, the fragmentary sword 4 was almost completely extracted from the concretion shell and restored. The state of preservation of the metal is scanty. However, the main morpho-typological traits can be distinguished. The item has a short curved cross-guard with a circular section. The blade is around 81 cm in length and between 2.5 and 7.0 cm in width with a tapering and sharp end (Figure 2, sword 4).

X-ray radiographs on swords 1–3 allowed some diagnostic morpho-typological features to be identified. Sword 1 shows a profiled disc cut into an octagonal shape by faceting the profile. The cross-guard presents thin and rectilinear arms with knobbed terminals and a circular cross-section (Figure 2, sword 1). Sword 2 shows a rounded and embossed pommel, a flat and wide tang with a rectangular section, slightly rounded at the end (Figure 2, sword 2). Sword 3 presents a pommel with chamfers cut into octagonal facets. The cross-guard is featured by rectilinear hands with sharp ends (Figure 2, sword 3).

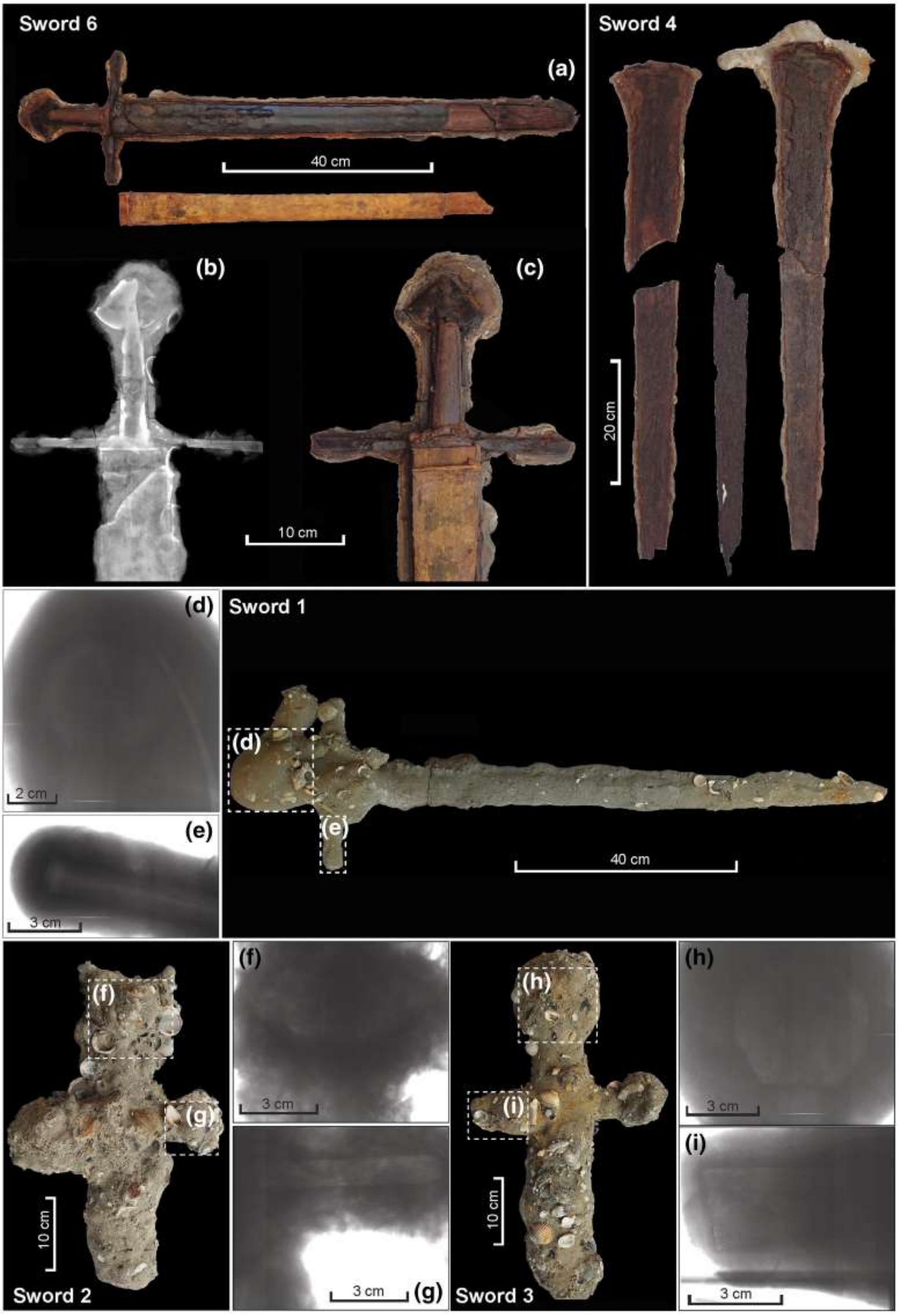

FIGURE 2 Swords 6 and its associated wooden sheath after restoration (a); X-ray radiography of the pommel, grip, cross-guards, sheath and part of the blade before (b) and after (c) restoration. Sword 4 after restoration. Swords 1–3 and X-ray radiography of pommels (d, f, h) and cross-guards (e, g, i) [Color figure can be viewed at wileyonlinelibrary.com]

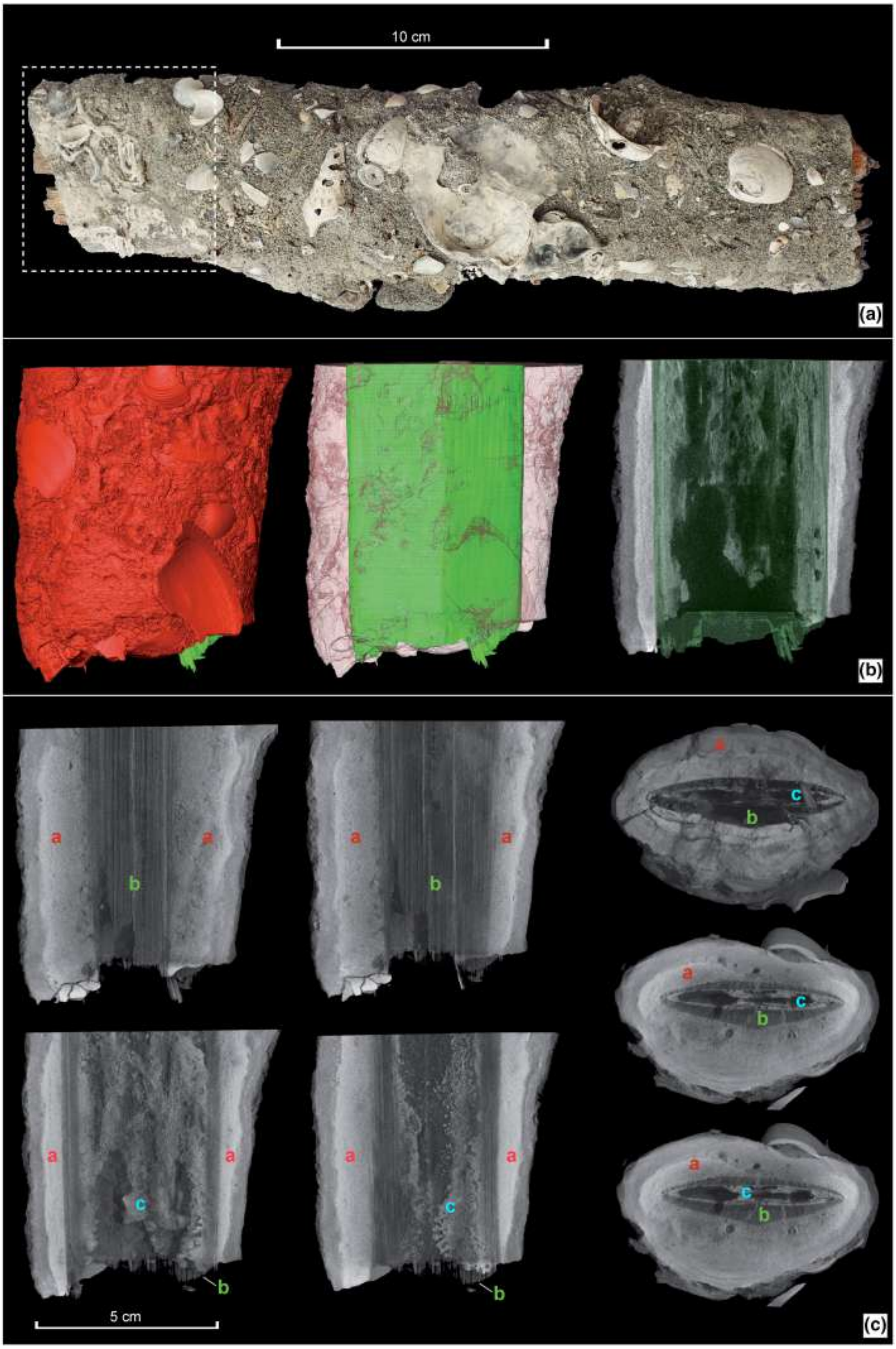

FIGURE 3 (a) Sword 5 with the position of the microCT acquisition (white dotted box); (b) microCT renderings showing the cap (red), the wooden sheath (green) with the cap in transparency, and a longitudinal section of the highly corroded metal blade with the sheath in transparency; (c) microCT longitudinal and transversal sections showing the cap (a), the wooden sheath (b) and the metal blade (c). [Color figure can be viewed at wileyonlinelibrary.com]

MicroCT analyses on the fragmentary blade of sword 5 enlightened the presence of a well-preserved wooden sheath. Like sword 6, the shape of both the blade and the sheath is lenticular. The iron blade is poorly preserved (Figure 3) (see Material S4 in the additional supporting information for measures of the typological features).

Synchrotron microCT and radiocarbon dating

High-resolution microCT allowed the wood species to be determined as belonging to *Fagus sylvatica* (Ruffinatto & Crivellaro, 2019: 197) (see Material S5 in the additional supporting information). The radiocarbon age obtained from a fragment of the sheath (930 ± 60 BP) was calibrated using the OxCal v 4.4 and IntCal20 calibration curve (Bronk Ramsey, 2009; Bronk Ramsey et al., 2020; Reimer et al., 2020), giving a range spanning between 1016 CE and 1225 cal. BCE (2σ) (see Material S6 in the additional supporting information).

Typo-chronology of swords

According to the typological system adopted in this study, the best-preserved sword 6 fits well Oakeshott's blade type X (Oakeshott, 1964, 1991, 2002) corresponding to Geibig's type 10 (Geibig, 1991). With the necessary caution in the chronological attribution of these finds due to the rarity of weapons recovered from archaeological excavations and to the wide variability in the individual traits, this type can be dated to a period spanning between *c*.950 and 1250 CE (Aleksić, 2007; Geibig, 1991; Oakeshott, 1964, 1991, 2002) (for other comparisons, see Material S2 in the additional supporting information).

As for the visible morphological features, it is possible to note high similarities between the microCT scans of swords 2, 3 and 6 in the shape and dimension of the pommel, grip and cross-guard. The pommel is one of the traits that is more sensitive to changes through time. In swords 2 and 6, pommels belong to variants of the so-called ‘Brazil-nut’ type, typical in swords dated to *c*.950–1250 (Oakeshott, 1964, styles E and B), while sword 3 has a faceted disk pommel that reaches its peak of popularity in the 15th–16th centuries, but is also occasionally associated to finds earlier than 1300 (Oakeshott, 1964: 103, type I1).

Coeval artistic representations of similar swords are also well-attested across Central and Southern Europe. Swords similar to sword 6 with a glove pommel rectilinear cross-guard and a broad blade appear in a miniature of the 11th century Gospel of Otto III preserved in the Bayerische Staatsbibliothek in Munich (Oakeshott, 2002: 30, fig. 8) and on the fresco of the late 12th–early 13th centuries relating to the scene of the martyrdom of St Thomas Becket in the presbytery of the church of SS. Giovanni and Paolo of Spoleto (Iovenitti, 2006: 428). Significant for dating is also the presence of the sword-guard in sword 6, which appears not to be attested in iconographic sources before the 13th century (Oakeshott, 1980: 135). Swords with an embossed Brazil nut pommel similar to sword 2 are common in manuscript illustration, such as Cod. Lat. 4456, a sacramentary from the Cathedral Treasury at Bamberg, made for Emperor Henry II between 1002 and 1024 (Oakeshott, 1964: 30, fig. 9) and decorated metalwork such as an engraved copper gilt altar representing S. Sulpicius dated to *c*.1100 CE (Oakeshott, 1964: 30, fig. 10). Other generic but significant comparisons of swords in vogue during the Third Crusade are depicted in an early 13th-century stained glass window from the Louvre Museum, Paris (Nicolle, 2005: 8, fig.) and in a relief of S. Donnino Cathedral in Fidenza, northern Italy (Nicolle, 2005: 30, fig.).

Finally, in sword 1 the disk pommel cut in octagonal facets (see above), the presence of the knuckle and the shape of the cross-guard lead the sword are comparable with Oakeshott's type XVIIIa (Oakeshott, 1964: 67–79). This model was in vogue in the 15th–16th centuries (Iovenitti, 2006: 428–429, figs. 4 and 17; Oakeshott, 1964: 68–69). Whilst less information is available for sword 4, based on similarities with sword 1, including blade length and width and the shape of the preserved part of the cross-guard, a similar chronology is likely.

Historical cartography and remote sensing

The geomorphological research led to an analysis of a historical map that was published (Bianco et al., 2006: 449) and is analysed here for the first time with respect to its geomorphological content. It is a document drawn by the famous Venetian cartographer and hydraulic engineer Cristoforo Sabbadino, or a copy of his original drawing, and it depicts the topography of the coastal sector between the Tagliamento River and Duino in the first part of the 16th century. The map describes the position of the tidal mouths and documents the slightly different position of some of them compared with the present setting. Moreover, several coastal breaches (‘*rota*’) are depicted. In the seaward sector the map highlights the occurrence of large shoals (‘*scano*’) and the very shallow waters existing along the islands, indicating the insidious zones around the tidal mouths and the possible difficulties for the sailors in entering the lagoon. The feature described only in this historical map is a lighthouse (‘*faro*’) located at the boundary of the submerged beach between the mouths named S. Andrea and Lignano.

The age of the map is confirmed by the name of the author (b. 1487, d. 1560), and the presence of the town of Villa Vicentina, which had been founded in 1466.

DISCUSSION

Swords’ typo-chronology, state of preservation and botanical data

The multi-analytical study carried out on six swords found in Marano Lagoon allowed the morpho-typological features, state of conservation of the items and their chronology to be specified.

Swords 2, 3 and 6 fit into the production of the 12th–early 13th centuries double-edged swords, with rather precise formal comparisons with regard to pommels, cross-guard and blade. This chronology is strongly confirmed by a calibrated radiocarbon dating on a wooden sample taken from the sheath of sword 5, resulting therefore coeval to the aforementioned swords. Noticeable differences in typological traits and significant comparisons encourage swords 1 and 4 to be attributed to the Modern Age, probably to the 15th–16th centuries (Figure 4).

The microCT-based 3D reconstruction of sword 5 has shown the poor preservation of the metal embedded in the cap, providing useful indications for the conservation of the embedded artefacts and possible restoring interventions. Based on these results, the preservation of metal in swords 1–3 is likely to be similarly poor.

Synchrotron microCT allowed the wood species of the sheath of sword 5 to be determined as belonging to the European beech (*F. sylvatica*), which corresponds to the same species used for the grip of sword 6 (Capulli & Milocco, 2018). Relevant comparisons can be established only with Early Middle Age swords, much better studied than those belonging to the following period. The use of beech for sheaths of Early Middle Age swords is widely attested in Central/Northern Europe and also sporadically documented in northern Italy. Instead, harder wood types (in particular oak) or other materials (animal horn and bone) are generally preferred for handles of cutting/stabbing weapons (Haneca & Deforce, 2020; Rottoli & Castiglioni, 2014).

The presence of a *faro* in the sea to indicate the entrance to Marano Lagoon is an extraordinary proof of the importance of the maritime route towards Marano or other towns in the mainland of the lagoon. As experienced in the sea-storm surges of the last decades, the waves can reach over 4 m of height as regards the position of the lighthouse, so this construction was prone to such events. Moreover, the functionality of the lighthouse needed the presence of some people taking care of the fire at

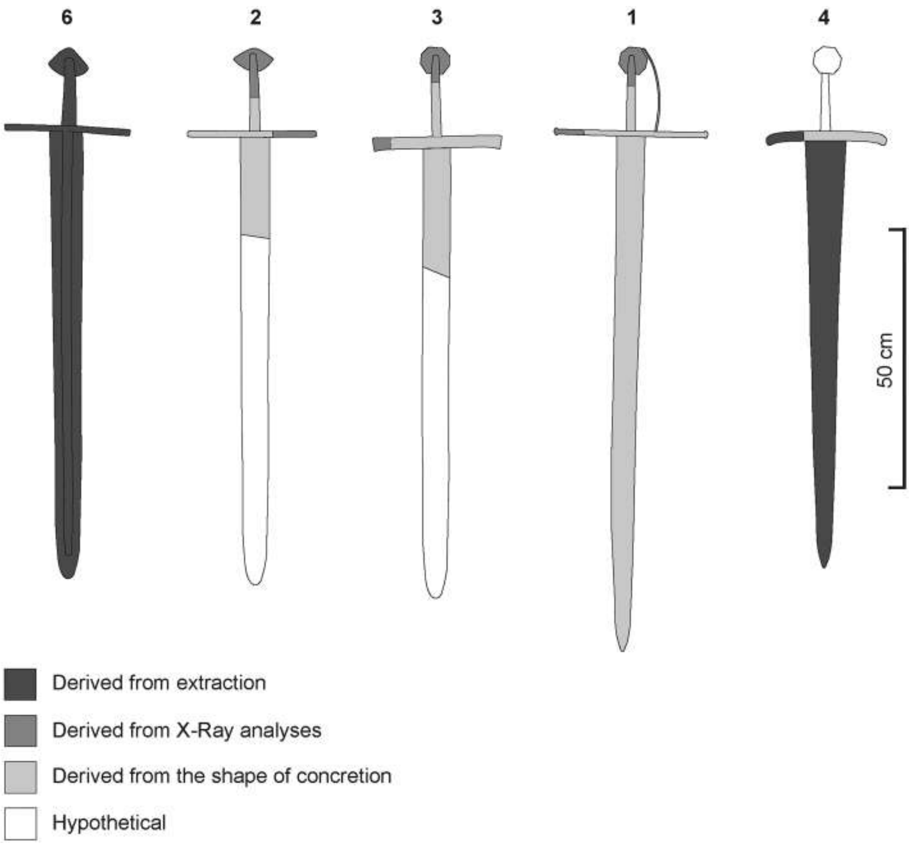

FIGURE 4 Sketch of the swords analysed with hypothetical reconstructions of their entire shapes.

night and eventually of soldiers protecting this outpost, which served both as a route signal for sailors and also as a lookout against possible enemy raids. Considering these aspects, the existence of the lighthouse in the sea and its management implied tremendous economical and logistic efforts for the local community.

The presence of lighthouses along the low-lying coast of the north-western Adriatic is documented only in the main tidal mouths of Venice Lagoon (i.e., Lido and Malamocco), where fortified structures constructed of stone or brick are attested since the 19th century, as depicted in the map Kriegskarte and in the Austro-Hungarian map of the Second Military Survey (www.maps.arcanum.com). Instead, symbols comparable with those depicted in the map of Grado-Marano Lagoon are first documented in 18th-century historical maps of Venice Lagoon which described this structure, apparently made of wood, as '*lanterna*' (maps of Archivio di Stato of Venice SEA Lidi disegni n. 67 and n. 05-IV). If the occurrence of these constructions near Venice is not surprising according to the importance of the place, it appears completely unexpected in front of the Lagoon of Grado-Marano.

The *faro* is documented only in the two described maps of the 16th century and its position matches the area where most of the swords have been found. The age and position of the cartographic documents' evidence highlight the continuous importance of the area between the 13th and 16th centuries. On the contrary, the lack of younger structures and findings testifies that after the mid-16th century the area experienced some major changes, probably related to environmental variations that transformed the tidal mouth of S. Andrea (Figure 5a-b).

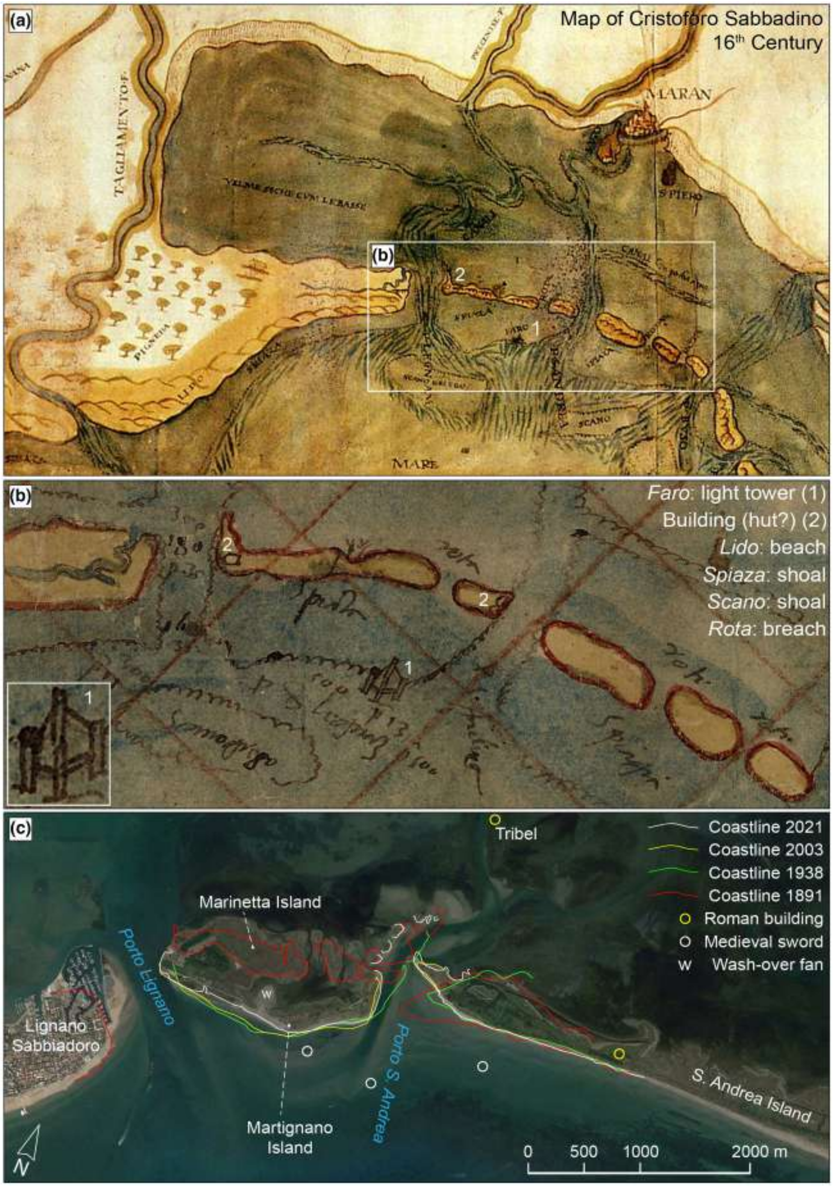

FIGURE 5 (a) Detail of the 16th-century map by Cristoforo Sabbadino (private collection in Fanzolo of Vedelago; cf. Bianco et al., 2006); (b) map obtained as a probable copy of the original drawing by Sabbadino (Archivio di Stato di Venezia, ASVE_Disegni_40); and (c) coastline reconstruction (1891–2021) and the main archaeological features and landforms identified superimposed onto a satellite image [Color figure can be viewed at wileyonlinelibrary.com]

Coastal geomorphological processes

The swords have been found over the last decades and this period has been characterized by a marked erosive trend in the beach barriers between Lignano and Porto Buso, where the coast retreated of some tens of metres with major changes in the tidal mouth of Sant'Andrea. This erosive tendency is in contrast to the seaward progradation that affected this stretch of coast between 1891 and *c*.1990, as documented by the Tavolette maps of IGMI and the aerial pictures. In particular, between 1891 and 1937 the formation of some new barrier islands occurred in front of the previous one, and this phase brought about the creation of Martignano Island in front of the Marinetta. The recent topographic surveys and satellite images document the ongoing erosive processes, which probably started in some spots at the end of the 1960s (cf. Bondesan et al., 1995), but assumed a severe trend since the 1990s (Figure 5c). As documented along many tracts of the Mediterranean coast (Anthony et al., 2014), also in the study area the erosive processes could have been boosted by the sedimentary starvation induced by the anthropogenic disturbances that have recently occurred to the main rivers. In particular, the hydroelectric dam of Solkan, near the Slovenian–Italian boundary, has been interrupting the transport of coarse sediment along the Isonzo River since the second half of the 20th century (Siché & Arnaud-Fassetta, 2014). In the same period, the gravelly beds of the Torre Torrent and Tagliamento River have been affected by diffuse gravel-mining, inducing a severe limitation of the available material for coastal deposition (Surian et al., 2009; Ziliani & Surian, 2012).

The presence of some *in-situ* Roman and Early Middle Age sites along the island of Sant'Andrea and in some islets within Marano Lagoon seems to confirm the general stability of the coast for a rather long period (cf. Auriemma et al., 2013; Fontana et al., 2017), which contrasts with the present situation. According to these remote-sensed and field data, it is likely that the sea-surges brought to light an old stretch of beach that until a few decades ago was sealed by younger sediments and could have preserved the archaeological remains for some centuries. At the moment it is not possible to discriminate if the swords had been originally buried along the beach or if they had been lost because of shipwrecks or in relation to activity near the tidal mouth, as near the site of the *faro* reported in the map.

Archaeological and historical interpretation of the context

The integration of swords analysis with the available information from the literature, geomorphological setting and historical cartography allowed the historical role of Marano in the Late Middle Ages and the Early Modern period to be detailed. Quite obviously, the presence itself of prestigious goods such as swords, together with the minting activity in Latisana and the Precenicco shipwreck, clearly demonstrate both the economic development and the strategic importance of the area since the late 12th century, as shown by the commercial agreements between Venice and the Counts of Gorizia.

This is further supported by the presence of a quadrangular lighthouse recorded in an early 16th-century Venetian map located offshore of the island of S. Andrea (at short distance from the finding of swords 2, 3 and 5), which can be compared, as for the north-western Adriatic coast, with a lighthouse structure documented in the 18th-century cartography and located near one of the main tidal mouths of the Lagoon of Venice (e.g., map in the Archivio di Stato di Venezia, SEA lidi ds 64). Considering the attractiveness of the area in earlier centuries, it is likely that the *faro*, presumably made of wood, was in use even before in the Late Middle Ages.

While swords 1 and 4 cannot be related to a precise event, the rarity of late medieval sword findings (2, 3, 5 and 6) in settlement and funerary contexts, their similarities in manufacture and, finally, the short distance between the locations where they were retrieved point to a single depositional event. Given the mass movement of people driven from Northern/Central Europe to the Levant in that period, the hypothesis that this group of items is related to the passage of Crusader ships in Marano Lagoon is tempting.

What do we know about the itineraries towards the Holy Land in that period? A pedestrian continental one, crossing Central and Eastern Europe, and Anatolia to the Levant route was taken by Frederick I in 1187. Other two routes are documented by medieval chronicles. One stemmed from the north-western ports of the Mediterranean and followed the Tyrrhenian Sea towards the Eastern Mediterranean, while the second traversed the Adriatic Sea, starting in the major ports of Venice, Zadar and Brindisi. As for Richard I of England and Philippus II of France during the Second Crusade, routes could be used alternatively in opposite directions. A third route (taken by the Venetians in 1202) run alongside the Adriatic and the Aegean coasts to reach Constantinople (Figure 6a).

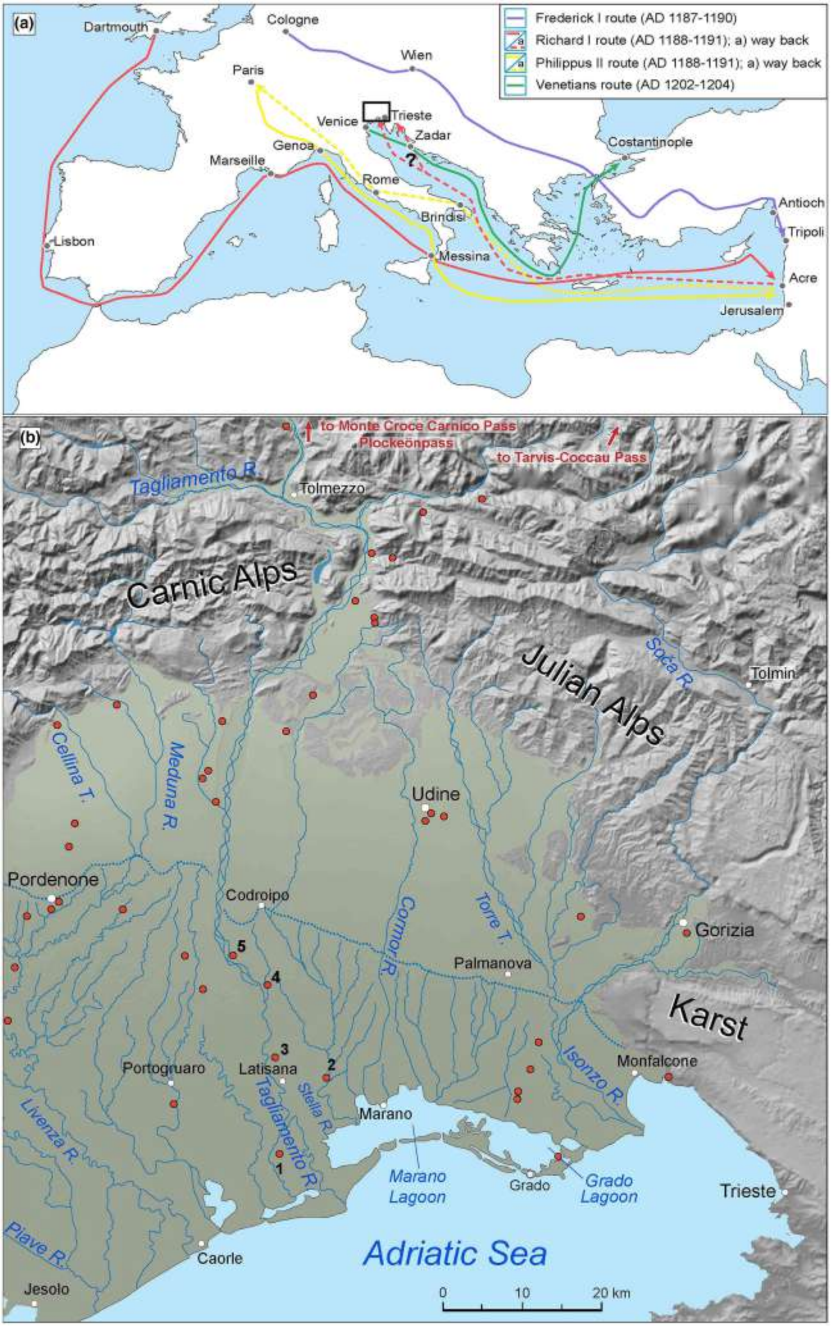

FIGURE 6 (a) Main known routes of the Third and Fourth Crusades with the position of the Friuli region (black rectangle). (b) Map of the Friuli region with the position of the *hospitia hospitalia* dated to 1200–1400 and structures located on the left bank of the Tagliamento River (red circles): 1, S. Michele al Tagliamento; 2, Precenicco; 3, Volta di Ronchis; 4, Varmo; and 5, Pieve di Rosa. Data source: Altan (1991)

Of particular interest for this study is the mysterious and debated return journey of Richard I. According to some chroniclers of the time, the king would have reached the north Adriatic coast somewhere between Zadar and Venice before being captured by Duke Leopold V close to Vienna shortly before Christmas 1192. It is not clear if the fleet intentionally headed to the Adriatic or was shipwrecked, nor what was the exact location of the landing. According to some historians, the king and his company would have shipwrecked around Latisana, crossed the Friuli region northwards, passed the Alps and reached today's Austria (Capulli & Scarton, 2020: 11, n. 1). Whether only partly true, this story tells us about the routes across the Friuli region at that time. Indeed, documented pedestrian routes along the channels of major watercourses mirrored the ancient Roman route to Norico and were known in the Middle Ages as Via Ungarica. These paths were flanked by several hospitals, monasteries and churches, which offered hospitality to travellers. As for the period between the 12th and 14th centuries, many of these structures are attested in the Friuli area and a number of them are located in the lowlands/lagoon where travellers finally embarked (Altan, 1987, 1991) (Figure 6b).

Based on all these considerations, we can conclude that between the Late Middle Ages and the Early Modern period Marano constituted one of the major hubs of the northern Adriatic, only comparable with the Serenissima. It is likely that the importance of this terminal, which connected inland Europe with the Mediterranean along the Adriatic seaway, increased dramatically at the time of the Crusades. With this respect, though further investigations are necessary, it cannot be ruled out that swords 2, 3, 5 and 6 are to be related to the cargo of a Crusader ship that had most likely shipwrecked offshore Marano at the time of the Second or the Third Crusades.

CONCLUSIONS

The combination of multi-analytical analyses carried out on a group of swords recovered in front of the Lagoon of Marano and the study of the coastal paleo-environment yielded significant results for both archaeological and geomorphological reconstructions. Methodologically, this study demonstrates both the potential of paleo-environmental data to support archaeological–historical interpretations and the importance of archaeological data for the reconstruction of coastal morphodynamics, yielding the following main results:

- Based on typo-chronology and radiocarbon dating, swords can be attributed to a long span of time, most probably between the mid-12th and the end of the 16th centuries.
- The ancient artefacts probably derive from the exhumation of archaeological deposits related to barrier islands or shoals that now are under wave erosive action. However, consistent is also the hypothesis that some of the swords resulted from shipwreck.
- The significant number of recovered swords, coupled with the exceptional evidence recorded by historical cartography of offshore archaeological structure, demonstrate that the area was important at least between the Late Middle Age and Early Modern periods, when it constituted one of the main gateways from the Adriatic Sea to the mainland routes towards Central and Northern Europe. This demonstrates the expanding political and commercial importance of the lagoon harbour of Marano and of the other nearby inland ports during the Crusader era, in a context increasingly dominated by the Venetian Republic.
- Our case study suggests that crossing points located between the sea and the lagoon were marked by different types of structures (e.g., lighthouses, docks, poles or other possible signs), which eased the passage of ships in shallow waters where shoals constituted the main danger. This archaeological evidence is generally rather unknown or unreported, but is likely present in similar low-lying coasts around the Mediterranean.
- Our paleo-environmental data, based on the analysis of remote sensing and aerial pictures, support the onset of coastal erosion that occurred in the last century after a phase of relatively geomorphic stability (over the last 2000 years). This possibly derives from the intensification in the last decades of human impact and severe meteo-climatic events affecting the coastal dynamic.

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CONFLICTS OF INTEREST

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AUTHOR CONTRIBUTIONS

Conceptualization and research design: G.V.; Methodology: G.V., F.B., A.F., L.M., C.L., L.L.; Investigation: G.V., A.F., G.M., F.B.; Data curation, G.V., A.F., F.B.; Writing—original draft preparation, G.V., F.B., A.F., C.L., L.M., L.L.; Writing—review and editing, all authors; Supervision, F.B.; Funding acquisition, G.V., F.B.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in the additional supporting information. Additional data are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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