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## Plio-Quaternary coastal landscape evolution of north-western Sicily (Italy)

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### ABSTRACT

We present and discuss the results of a geomorphological and geological study aimed at reconstructing the Plio-Quaternary evolution of the NW Sicily coastal belt, a low strain rate region in the central Mediterranean Sea.

We performed morphometric and field analysis of Quaternary marine terraces extracting more than 300 shoreline location points subdivided into six orders. The obtained dataset was validated by investigating the morphological changes along topographic profiles and comparing the extracted locations and elevations with the stratigraphic boundaries in the Plio-Quaternary units.

We distinguished two contiguous coastal sectors characterized by different paleo-shoreline elevations and Plio-Quaternary evolution, whose estimated uplift rates fit well with the well-known, regional eastward uplift rate increase along the Northern Sicilian continental margin.

Obtained results, summarized in a geomorphological map and a morpho-evolutionary model, provide new valuable data to characterize the active deformation processes and the seismotectonic setting in this critical sector of the Africa-Europe plate boundary.

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## 1. Introduction

The evolution of the coastal landscape is driven by the continuous interaction between tectonics and climate. Indeed, these forcings indirectly control the development of specific geomorphological processes, inducing migration of the sea level through differential vertical tectonic movements and glacio-eustatic oscillations, resulting in alternating erosional and depositional cycles. Considering the above, the coastal landscape topography can be assumed as the result of the tectonic and climate signals and, thus, an archive recording information about the variation of these two drivers through time.


Some primary markers resulting from the interaction of these two signals are paleoshorelines, marine terrace sequences and unconformity-bounded stratigraphic units (*sensu* Salvador, 2013; Chang, 1975). The joint analyses of these markers allow the reconstruction of the landscape evolution and, in this case, the quantification of the differential vertical movements providing crucial data for tectonic dynamics and seismic hazard assessment (e.g. Ferranti et al., 2021; Garrote et al., 2008; Sulli et al., 2013).

The Northern Sicilian Continental Margin (NSCM) is a low-strain rate region located along the plate boundary of the slowly converging African and European plates (see 'Regional framework sketch' in the

Main Map, Sulli et al., 2021a) and is a puzzling region resulting from the interaction of two different geodynamic processes. The western and central parts of the margin are characterized by processes resulting from the Africa-Europa collision, in which the African-thinned continental crust subducts beneath the European Sardinian and Kabylean-Calabrian units (Sulli et al., 2021b, and reference therein). Differently, its rapidly uplifting eastern portion is controlled by the subduction of the Ionian oceanic lithosphere beneath the European Calabrian Arc (Meschis et al., 2018, 2019). The whole NSCM is characterized by a low seismic moment release, an active shortening with rates close to 1 mm/yr and by elusive active faults not fully identified and characterized yet (Devoti et al., 2017; DISS Working Group, 2021; Parrino et al., 2022; Rovida et al., 2021; Sulli et al., 2021b).

Several studies investigated the differential vertical movements in the eastern sector of the NSCM (Peloritani Mountains), analyzing the Quaternary marine terraces, the drainage network, the offshore morphobathymetric setting, and the sedimentary architecture (Antonioli et al., 2006, 2018; Cosentino & Gliozzi, 1988; Ferranti et al., 2006; Hugonie, 1981; for a review see Cerrone et al., 2021). Conversely, there are still few attempts to investigate the Quaternary uplift history of the central and western sector of the NSCM and, thus,

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its recent landscape evolution is still a matter of debate (Agate et al., 2017; Catalano et al., 2010a, 2010b, 2011, 2013a; Di Maggio et al., 2009, 2017).

We present a review of the most up-to-date literature and a new morphometric dataset extracted from a digital elevation model of the western sector of the central NSCM in order to reconstruct its geomorphological evolution. The proposed dataset could represent a valuable tool for new studies on identifying and characterizing active faults, potential input data for seismic hazard assessment, and landscape evolution forecasting scenarios.

## 2. Study area and geological and geomorphological overview

### 2.1. Study area

The NSCM develops on the northern coast of Sicily and in the southern Tyrrhenian Sea as the southernmost prosecution of the Apennine-Maghrebian fold and thrust belt, a subduction-collisional boundary between Europa, Africa and Ionian plates. The study area includes two low-relief coastal plains in the central western sector of the NSCM between the city of Palermo and Termini Imerese (Figure 1). The area is marked by the NNW-SSE elongated Palermo plain and the WNW-ESE oriented Termini plain. Mountain ranges surround the Palermo plain to the inland and open to the sea, while a hilly landscape, interrupted by an NNW-SSE oriented carbonate ridge in its central portion, borders the Termini plain to the South.

### 2.2. Stratigraphy

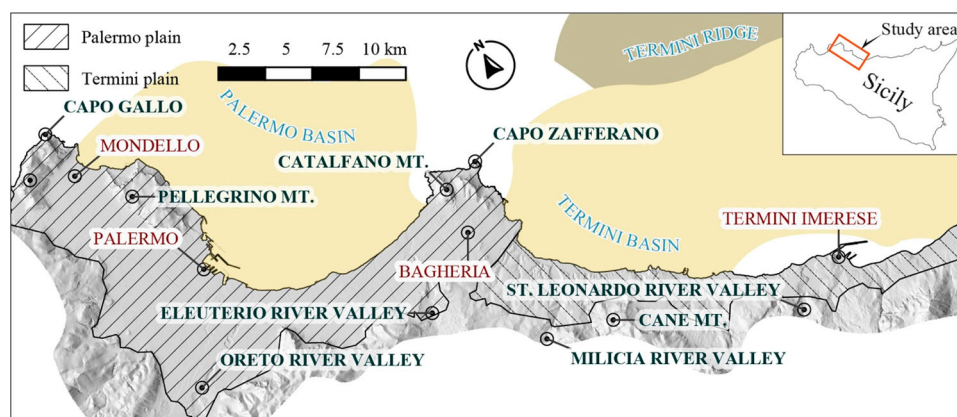
Two different Plio-Quaternary successions crop out in the western and eastern sectors of the study area (Figure 2), representing the infilling of two different sedimentary basins (Figure 1; Agate et al., 2017; Di Maggio et al., 2009; Dominici et al., 2020; Incarbona et al.,

2016; Lo Iacono et al., 2014; Martorana et al., 2018; Milia et al., 2021). Both successions lie unconformably on a deformed substrate that is constituted by rocks that are indicative of shallow to deep water marine environments. Excluding the Messinian crisis, these environments persisted from the Triassic to the early Pliocene, when the Trubi unit (Zanclean) deposition was completed, and the first areas of Sicily began to emerge (Di Maggio et al., 2017).

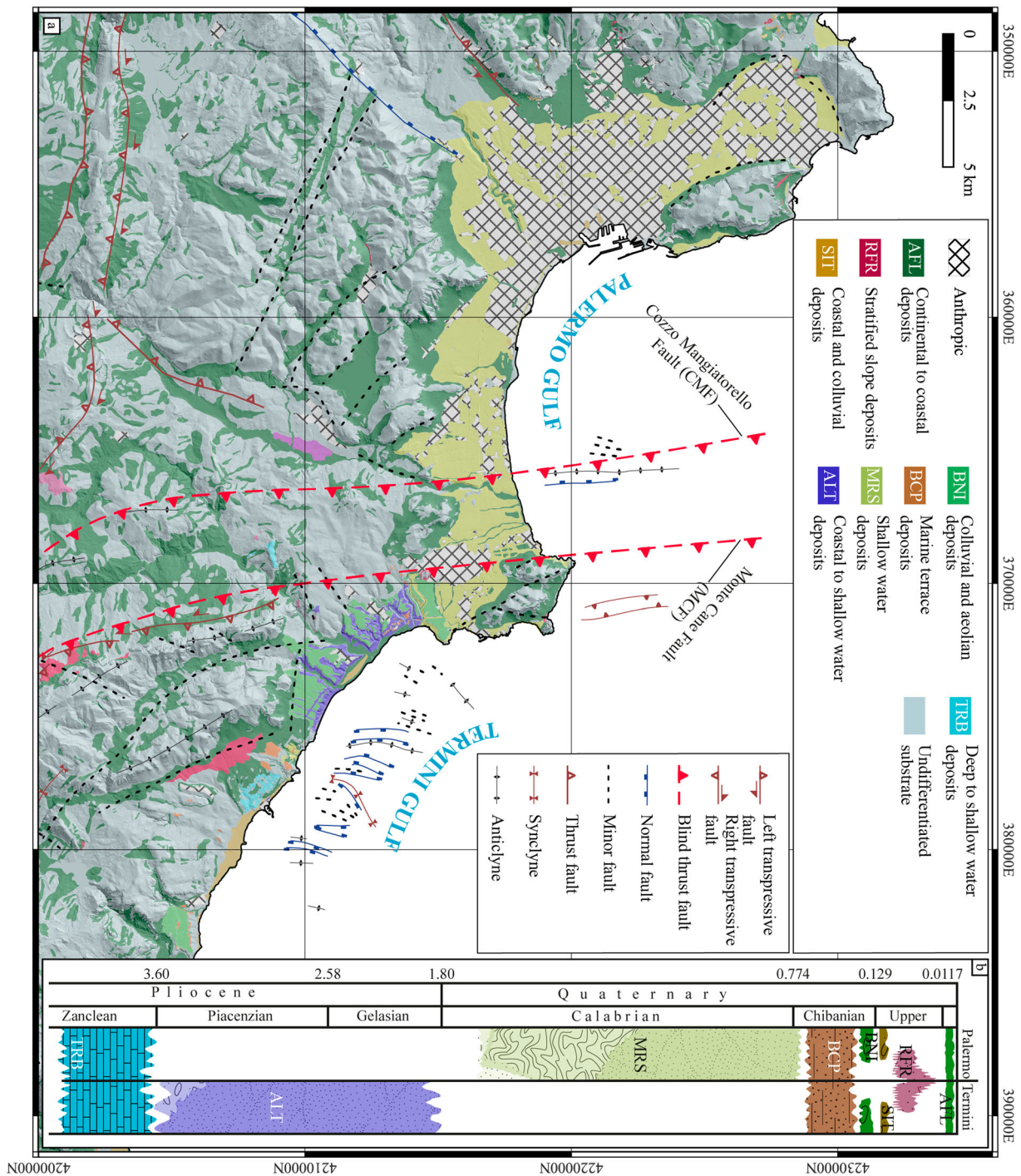
To the west, the Palermo Basin (Figures 1 and 2) is made up of less than 100 m thick deposits, corresponding to the Marsala synthem (MRS; middle-late Calabrian, 1.5–0.77 Ma; Di Maggio et al., 2009 and reference therein).

The base of the succession is made up of a 40–50 m thick package of thin conglomerate beds that upwards and laterally passes to foraminifera bearing bluish clays with interbedded sandy-silty horizons forming the Ficarazzi clays unit (Figure 3). The Ficarazzi clays gradually pass upward to yellowish calcarenites and sands with interbedded microconglomerate horizons, constituting the ca. 20 m thick Palermo calcarenites unit (Catalano et al., 2013a; Figure 3).

The Termini basin (Figure 1) is a WNW-ESE partially offshore Plio-Quaternary basin adjacent to the eastern termination of the Palermo basin and limited northward by the intraslope Termini ridge (Figure 1). Within this sedimentary basin, deposits show 80 m thick sedimentary packages of alluvial conglomerates (3.6–3.1 Ma), deltaic sandstones, deltaic-pebbly sandstones, inner-shelf mudstones, colluvium deposits and paleosols of the mid-Piacenzian – early Gelasian (about 3.1–2.5 Ma) Altavilla Sands (ALT) unit (Dominici et al., 2020; Figure 2). The lower part of the succession shows an arrangement from alluvial fans to delta front to open shelf paleoenvironment, reflecting deepening environmental conditions; evidence of subaerial, flood-dominated fluvio-deltaic deposition suggests high slope values of sediment



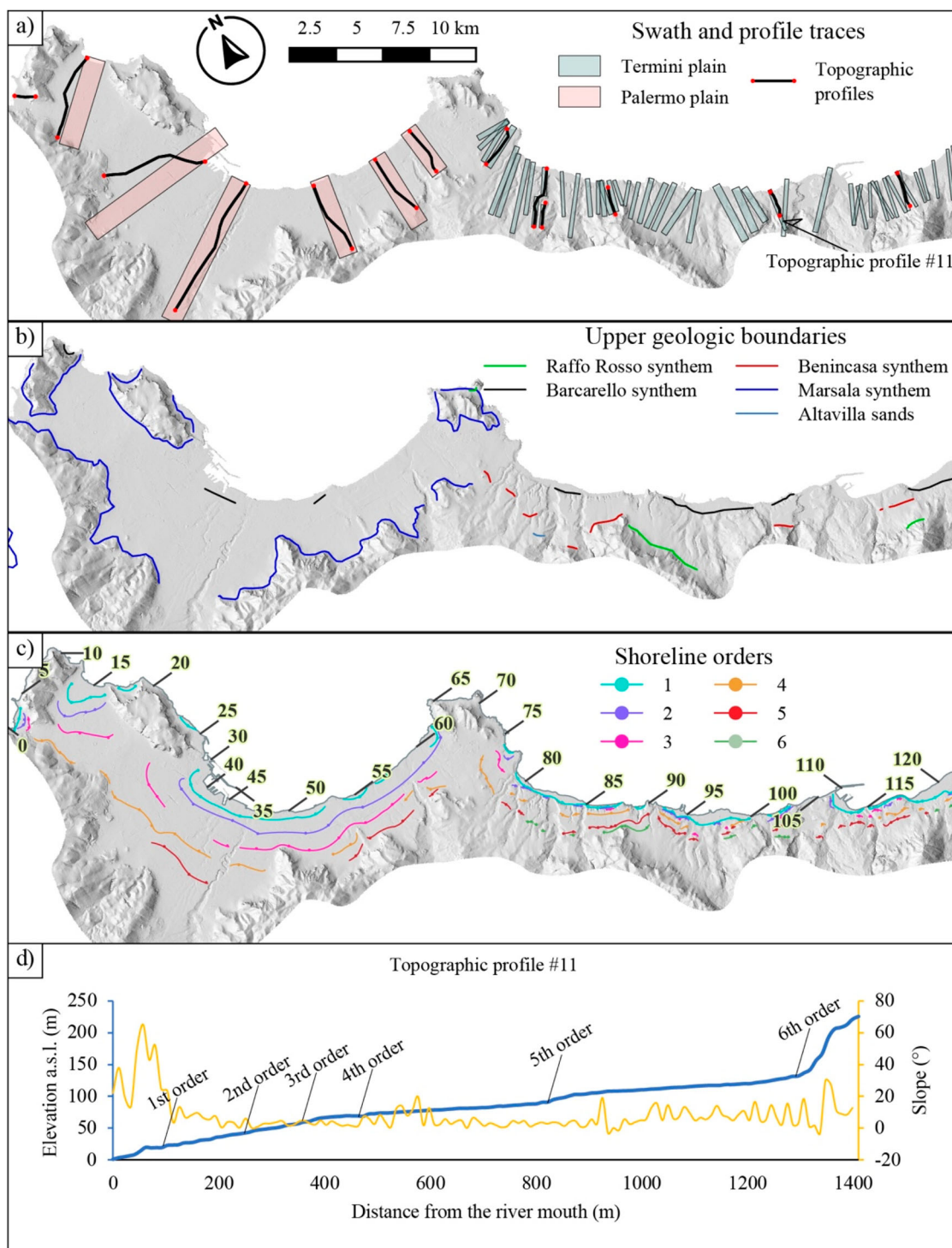
**Figure 1.** Map of the western portion of the central Northern Sicily Continental Margin. The yellow-shaded areas represent the offshore extent of the Palermo and Termini basins. The polygons with different patterns represent the inland extent of the two basins (Palermo plain and Termini plain, respectively). Please check, in the main map, the ‘Regional structural sketch’ and the ‘location of the investigated area in the central Mediterranean region’ for a broader geographical setting.



**Figure 2.** Geological map of the study area, where stratigraphic units and main tectonic structures of the Plio-Quaternary are detailed; on the right, the stratigraphic log of the Palermo and Termini basins. AFL – Capo Plaia synthem; RFR – Raffo Rosso synthem; SIT – Barcarello synthem; BNI – Benincasa synthem; BCP – Buonfornello-Campofelice synthem; MRS – Marsala synthem; ALT – Altavilla Sands unit; TRB – Trubi unit (see text for the description of the stratigraphic units).

source areas like the modern topography. Thin mudstone intervals, proximal delta coarse-grained sediments, paleosoils, and alluvial fan deposits in the upper part of the succession highlight an initial sediment bypass to deeper marine settings followed by an accommodation space decrease. The top of the succession is truncated by an erosive surface that has erased the most recent layers (Dominici et al., 2020). Along the areas close to the coastline, MRS deposits cover the ALT unit (Catalano et al., 2013a).

Above the ALT and MRS deposits, the middle-late Pleistocene sedimentary succession develops upwards in the Palermo and Termini basins (Figure 2). Few meters thick lens-shaped sedimentary bodies, consisting of continental to coastal/marine deposits enclosed between unconformity surfaces of regional extent, occur along the emerged areas of the plains of Palermo and Termini. These bodies have been organized in unconformity-bounded stratigraphic units (syntems) and correlated to Marine Isotope Stages (MISs) by Di



**Figure 3.** (a) Map of the swath profile boxes and topographic profile traces, oriented towards the maximum slope direction, in the Palermo and Termini plains; (b) map of the upper geologic boundaries of RFR, SIT, BNI, MRS, and ALT; (c) map of the detected shoreline angles orders in the study area; the numbers highlighted in yellow represent the distances (in km) along the coastline starting at the westernmost location on the map; the succession is complete in the Termini plain; the sixth order is missing in the Palermo plain; (d) topographic profile #11; the thick blue line represents the elevations, the thin orange line represents the slope value, the black arrows indicate the location of the six detected shoreline angles orders.

Maggio et al. (2009). The Piana di Partinico synthem (locally Buonfornello-Campofelice synthem – BCP) consists of several cycles of marine terrace deposits related to sea-level high stands (MISs 17–7) lying on wave-cut platforms. The Polisano synthem (locally Benincasa synthem – BNI) is constituted by aeolian and colluvial deposits related to MIS 6, lying on a

non-depositional or subaerial erosion surface. The Barcarello synthem (SIT) is composed of marine terrace deposits related to MIS 5.5, bearing a warm-temperate fauna including *Thetystrombus latus* (commonly known as *Strombus bubonius*) and lying on a wave-cut platform; laterally and vertically, these deposits pass into welded colluvial deposits related

to MIS 5, lying on a continental erosion surface. Raffo Rosso synthem (RFR) encompasses thick stratified slope deposits of the last glacial climate (MISs 4-2), lying on a non-depositional surface.

The top of the successions consists of Holocene marine (submerged areas) or coastal, fluvial, colluvial, aeolian and gravity (emerged areas) deposits. Coastal and continental deposits (Capo Plaia synthem – AFL) up to 20 m thick (Martorana et al., 2018) lie on subaerial erosion or non-depositional surfaces.

The sea-level fluctuations significantly controlled the depositional history of the Palermo basin, reflecting discontinuous and repeated episodes of coastal to shelf sedimentation bounded by unconformities. From the Holocene highstand (from 7.0–8.0 ka), the coastal plain recorded continental and transitional sedimentation that persisted until historical times (Incarbona et al., 2016 and reference therein).

The syn-depositional tectonic activity in the Termini basin is supported by significant unconformities and the difference in dip direction values between the lower and upper parts of the succession of the ALT unit of N345E and N10E, respectively. The latter also highlights the tectonic forcing on the fluvial drainage geometry through which a fluvial system flowing towards the NW during Pliocene times was deflected to NE during the early Pleistocene (Dominici et al., 2020).

### 2.3. Tectonics

The study area belongs to the western sector of the central NSCM (see ‘Regional framework sketch’ in the Main Map), where two different geodynamic processes coexist, such as the Ionian oceanic slab hinge retreat and the continental collision between the Sardinia-Corsica microplate and north African margin (Catalano et al., 2013b; Di Stefano et al., 2015; Facenna et al., 2004; Sulli et al., 2021b). The collisional system developed since the early Miocene through two thin- and thick-skinned thrusting phases. Such shortening phases involved the Meso-Cenozoic silico-carbonate succession developed on the African passive continental margin and locally re-activated Mesozoic extensional structures (Avellone et al., 2010; Catalano et al., 2013b; Gasparo Morticelli et al., 2015; Gugliotta & Gasparo Morticelli, 2012; Gugliotta et al., 2014; Parrino et al., 2019). Fault-controlled structural highs, due to the late Miocene–early Pliocene shortening (the second shortening phase), bounded a series of intraslope basins formed in response to the progressive SE retreat of the Ionian slab (Kastens et al., 1988; Lo Iacono et al., 2014). About 0.8 Ma ago, a tectonic reorganization of the convergent Nubia-Eurasia margin occurred in the central Mediterranean. This reorganization triggered the ongoing shortening process and the regional uplift driven by the Africa-Eurasia lithospheric collision (Di

Maggio et al., 2017; Goes et al., 2004; Sulli et al., 2021b; Zitellini et al., 2020). The computed GNSS velocity fields, together with coastal erosional features, provide information highlighting a slow NNW-SSE oriented convergence with a velocity ranging around 1 mm/yr and a slow regional uplift of about 0–24 mm/kyr in the area (Devoti et al., 2017; Ferranti et al., 2006). In the study area, the crustal shortening is taken up by the NNW-SSE trending, transpressional Monte Cane and Cozzo Mangiatorello faults (Parrino et al., 2022; Figure 2).

### 2.4. Geomorphology

The study area shows a landscape marked by significant and discontinuous topographic lows consisting of a seaward flat bottom (coastal plain) and bounded inland by wide, over 100m-high, tectonically controlled abandoned coastal cliffs. The present-day topography results from the interaction between differential uplift, river incision, and eustatic changes. Such processes influenced by the formerly originated structural and stratigraphic features drove the landscape evolution of this area (Di Maggio et al., 2017). The result of such evolution consists of a staircase of marine terraces alternated with broad polycyclic marine surfaces near the coast and mountain ranges to the inland (Di Maggio et al., 2017; Hugonie, 1981; Mauz et al., 1997). The landforms in the inland portion highlight that river incision, karst phenomena, differential erosion and planation processes characterize the active morphotectonic processes within the investigated area (Agnesi et al., 2000; Di Maggio, 2000; Di Maggio et al., 2012, 2014). Uplifted Middle-Upper Pleistocene marine terraces are carved into Calabrian (1.8 Ma to 0.77 Ma) coastal to neritic deposits (MRS) forming the coastal plains or older rocks and develop from the sea level up to about 100–300 m a.s.l. (Catalano et al., 2010a, 2010b; Di Maggio, 2000).

## 3. Methods

The map presented here is the result of the review of recent literature (Agate et al., 2017; Catalano et al., 2010a, 2010b, 2011, 2013a; Di Maggio et al., 2009; Dominici et al., 2020 and reference therein), field survey and morphometric analyses performed on a LiDAR-derived digital elevation model provided by the Regione Siciliana over the whole Sicilian territory (Regione Siciliana, 2010).

Morphometric analyses were performed following the TerraceM approach (Jara-Muñoz et al., 2019) to detect the shoreline angle locations through 52 swath profiles roughly perpendicular to the coastline and covering almost the entire study area.

The obtained dataset was validated by investigating the altitude and slope variations along topographic

profiles oriented towards the maximum slope direction. Furthermore, an additional dataset validation was performed by comparing the extracted shoreline angle locations and elevations with the highest lithological boundaries of the Plio-Quaternary succession outcropping in the study area, such as the upper limits of the MRS, ALT, BNI, and SIT and manually checking the locations of these points through satellite imagery (Google Earth imagery, freely accessible at: <https://earth.google.com/web/>).

We analyzed the elevation of the validated shoreline angle dataset into a distribution along the coastline vs elevation chart to check the data reliability and exclude remaining outliers. Through an in-house developed semi-automatic geospatial model, to minimize the perspective distortion in the distribution along the coastline vs elevation chart, we projected shoreline angle points along the coastline extracting the line describing the minimum distance between each point and the coastline. Then we computed the distance between the intersection of each minimum distance line and the coastline, starting from a point selected along the coastline at the western boundary of the study area. The distribution along the coastline vs elevation chart allowed us to validate the paleoshore elevation outliers, checking if a reliable lateral continuity characterized the detected orders along at least one of the two studied plains.

Detailed field surveys were performed using published topographic base maps (1:10,000 scale maps of the Carta Tecnica Regionale, CTR, provided by the Regione Siciliana and accessible at: <https://www.sitr.regione.sicilia.it/cartografia/carta-tecnica-regionale/>) aiming at the validation of the shoreline elevation and collecting in the field both lithological and geomorphic evidence of paleo-sea levels into critical sectors of the study area. Moreover, the field survey allowed the discrimination of paleo-sea level orders in sectors not characterized by easily recognizable morphometric signatures of relatively uplifted shoreline angles.

Satellite imagery interpretation and geomorphological field surveys allowed the recognition of the prominent landforms in the study area, which have been arranged based on the process responsible for their origin and represented in the geomorphological map (see the Main Map) using polygons and ‘full coverage’ techniques, where the whole topographic surface is ‘interpreted’ seamlessly (Bufalini et al., 2021 and reference therein).

#### 4. Results

The geomorphological surveys carried out in the study area are summarized in a geomorphological map (see the Main Map) showing: (1) a large polycyclic marine terrace surface along the Palermo

plain, which develops between about 10–125 m a.s.l. carved in the MRS deposits; (2) a large polycyclic marine terrace surface along the western Termini plain, which develops between 25–200 m a.s.l. carved in the deposits of ALT; (3) a staircase of at least six orders of marine terraces in the eastern Termini plain (Termini Imerese area), which develops between about 20–300 m a.s.l. carved in the pre-Pliocene rocks, with abrasion surfaces covered by the BCP deposits; (4) SIT deposits on an abrasion surface that develops in the areas closest to the coast, which is discontinuous in the Palermo plain (where its inner margin is about 10 m a.s.l., at the foot of small cliffs 1–2 m high) and continues in the Termini plain (where its inner margin is about 15 m, at the foot of large cliffs about 10 m high); (5) wide abandoned cliffs tens of meters high, which internally delimit the succession of marine terraces; (6) a relief dissected by deep river valleys, indicative of prevailing incision processes.

The overall unfiltered data allowed us to recognize eight shoreline elevation orders; however, only six are characterized by a reliable continuity along the investigated area (Figure 3(c)). According to average elevations of the ground surface determined by analyzing the shoreline angle points, the first order shoreline angle located at c. 10 m a.s.l., the second order at c. 24 m a.s.l., the third order at c. 40 m a.s.l., the fourth at c. 68 m a.s.l., the fifth at c. 100 m a.s.l. and the sixth at c. 119 m a.s.l.

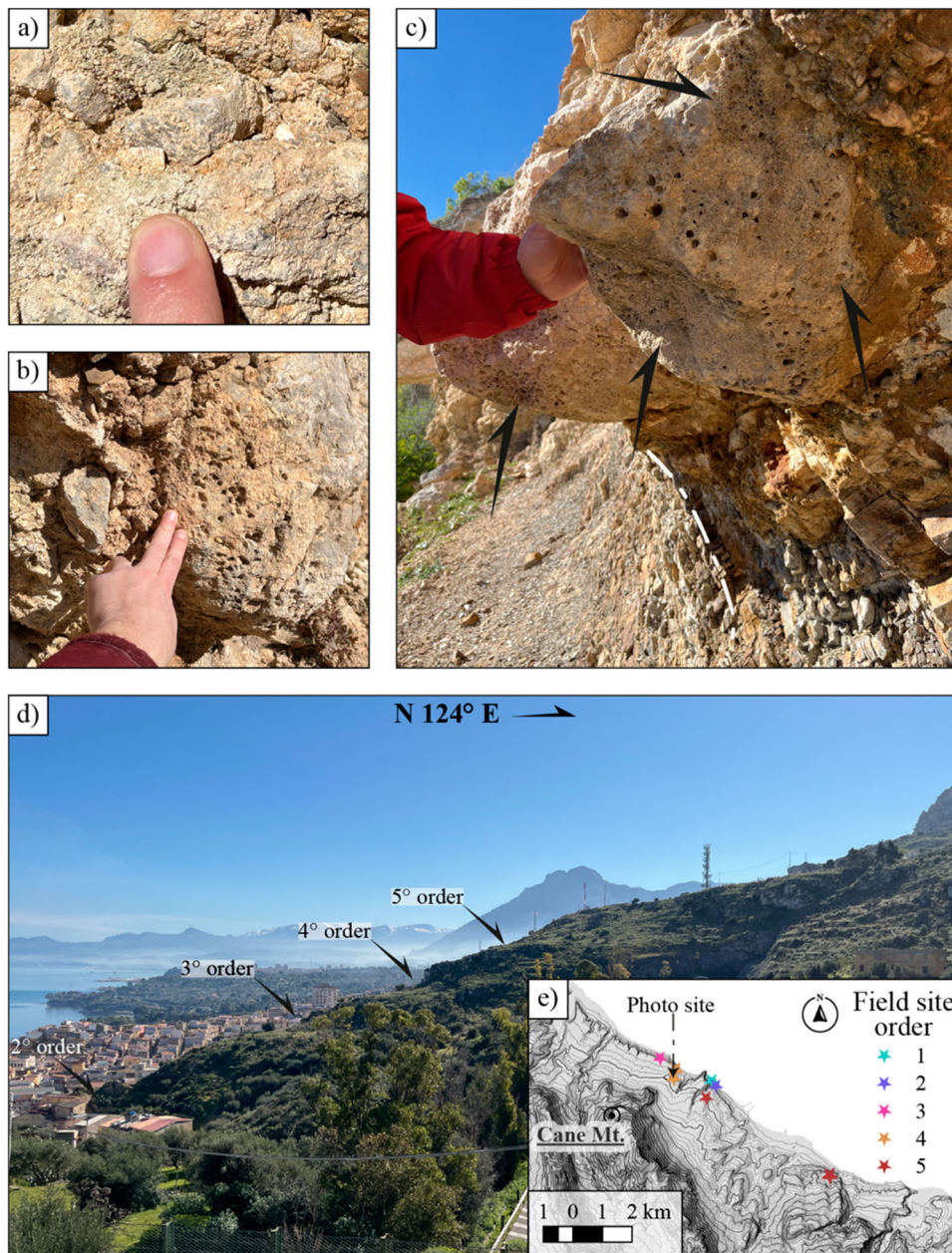
The overall statistical parameters of the detected shoreline angle elevation dataset are summarized in Table 1.

We detected five orders of shoreline angles elevation points, and the fourth and fifth orders roughly correspond to the lateral, pinch-out termination of the MRS deposits (the most elevated mapped limit of Quaternary deposits, dated to 1.5–0.77 Ma, see Figure 3) in the Palermo plain. Differently, in the Termini plain, we detected six orders of shoreline angle points and the fifth and sixth order locate in the surrounding of the BNI (late Chibanian – MIS 6) upper elevation outcrops (Figure 3). Elevation points of the first order lie near the upper elevation outcrops of the SIT (Upper Pleistocene – MIS 5.5), along the whole coastline of the study area (Figure 3).

Field surveys allowed the detection of 29 paleo-sea level marks from 7 locations in a rocky coastal sector of Termini plain, whose topographic features do not show enough constraints to be interpreted solely by morphometric techniques. Such evidence consists of tidal notches, marine sedimentary bodies, marine fossils, and marine fossil traces (Figures 4 and 5), as recognized by previous investigations within the Mediterranean realm (e.g. Armijo et al., 1996; De Santis et al., 2021; Ferranti et al., 2006; Robertson et al.,

**Table 1.** Statistical parameters of the shoreline angles elevation dataset. Most parameters refer to the overall linear regression of the shoreline angle points detected in both plains. The last two columns highlight the difference in the regression slope lines computed for the two plains separately.

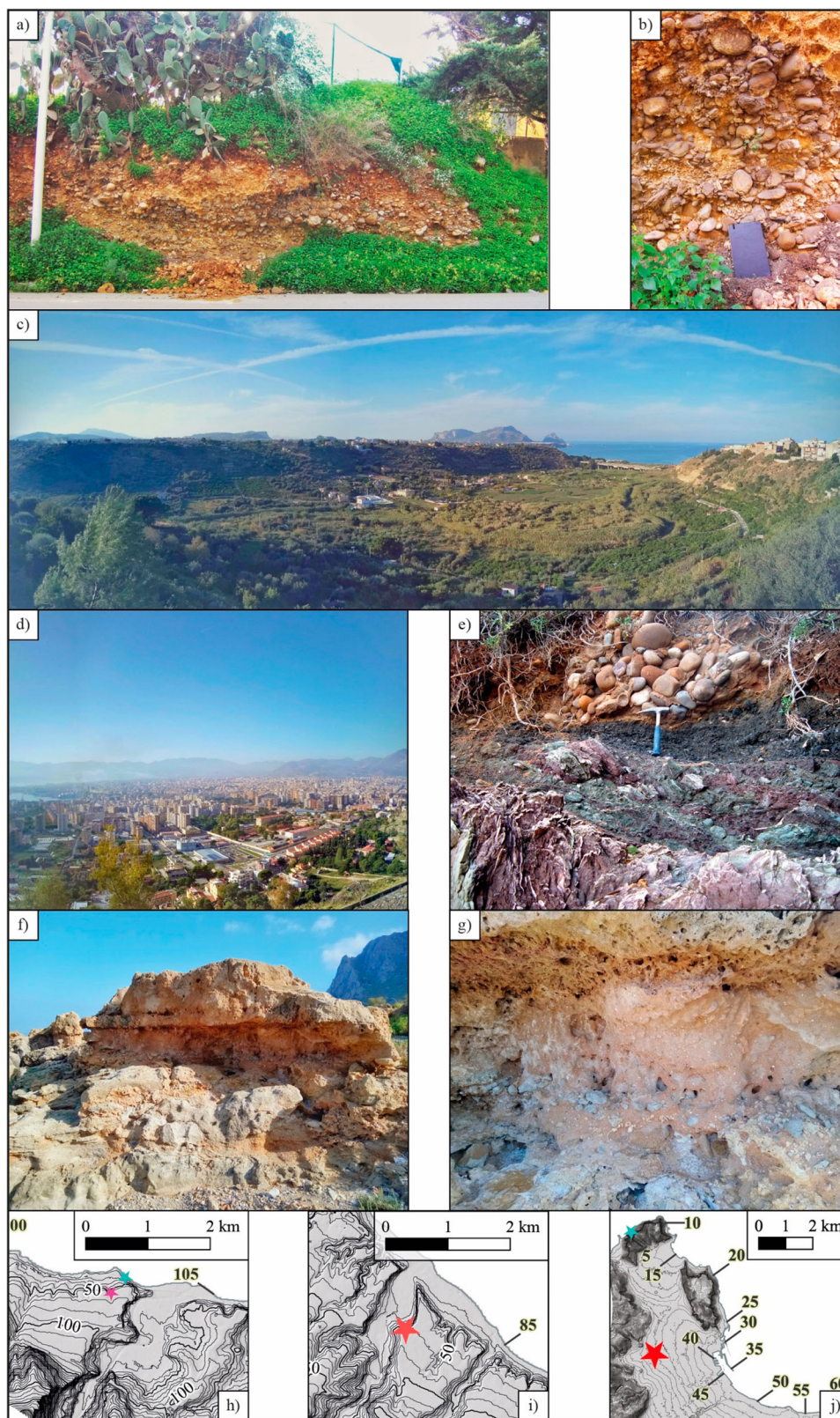
Paleoshoreline order (#)	Nu-mber of data (#)	Shoreline elevation			St. Dev. (#)	Linear regression eq.	R <sup>2</sup> (#)	Linear regression slope (°)			Distance to coastline		
		Avg	Min	Max				All	Pa	Te	All	Pa	Te
		(m asl)											
1.0	57.0	10.2	5.0	23.0	4.6	$y = 0.0301x + 7.929$	0.1	1.7	1.3	6.5	0.3	0.4	0.2
2.0	30.0	24.2	14.0	35.8	7.8	$y = 0.2119x + 10.201$	0.9	12.0	9.3	8.8	0.7	1	0.3
3.0	26.0	39.8	23.0	53.7	8.6	$y = 0.2232x + 24.92$	0.9	12.6	8.1	4.7	1.3	2	0.4
4.0	41.0	67.2	50.0	86.5	12.3	$y = 0.3208x + 42.654$	0.8	17.8	12.6	18.5	1.6	3.1	0.7
5.0	40.0	99.5	80.0	116.0	10.0	$y = 0.4027x + 62.969$	0.8	21.9	27.6	17.1	1.5	3.3	1.1
6.0	16.0	118.7	108.5	133.9	7.5	$y = 0.5719x + 64.913$	0.9	29.8	\	29.8	1.4	\	1.4



**Figure 4.** Field evidence of fourth-order paleoshorelines, detected in the eastern sector of the study area, and panoramic view of the different order marine terraces in the Termini plain: (a) fragmented marine fossils within a coastal deposit of BCP; (b) evidence of Lithophaga holes; (c) the black arrows point to traces of Cliona vastifera orange sponges, which are also interested by Lithophaga holes; the white dashed line highlights the morphology of the studied smoothed tidal notch (sensu Antoniolli et al., 2018); (d) panoramic view of the 2° up to the 5° shoreline angles orders; (e) map view of surveyed sites, shown as stars; the Colour code highlights the five shoreline angle orders in the inset (e).

2019, 2020) and allowed us to validate the first 5 of the 6 shoreline angle orders morphometrically recognized in the whole study area.

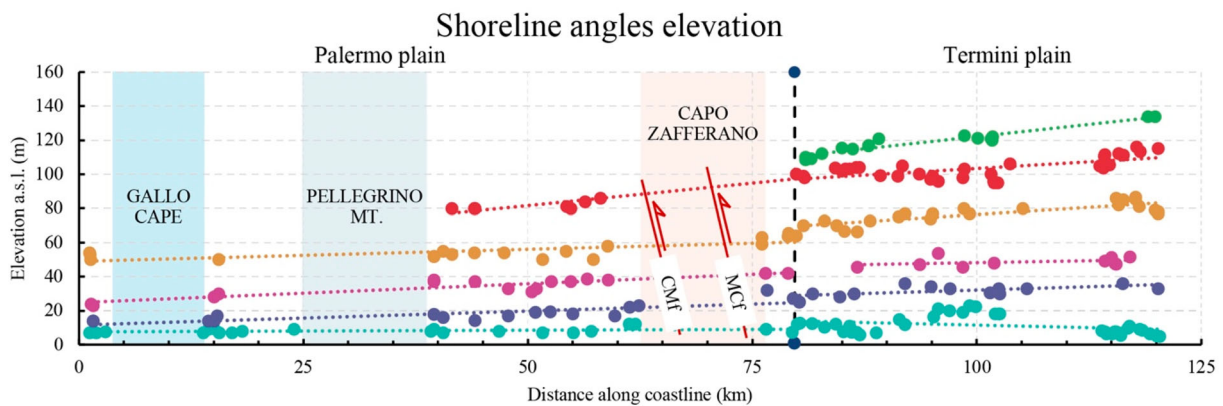
The elevation of the detected shoreline angle orders highlight that almost all the identified shoreline orders are located at higher elevations in the



**Figure 5.** (a) and (b) Marine terrace deposits (BCP) of third order paleoshorelines detected in the Termini plain (for location see box h, magenta star); (c) the wide polycycle marine terrace surface cut into the ALT deposits by the Milicia River, in the Altavilla area – Termini plain (see box i, red star); (d) the wide polycycle marine terrace surface carved on MRS deposits, on which the city of Palermo stands – Palermo plain (see box j, red star); (e) coastal deposits (SIT) on a MIS5.5 wave-cut platform carved in pre-Pliocene rocks, along the Termini plain (see box h, light green star); (f) coastal and colluvial deposits (SIT) on a MIS5.5 wave-cut platform carved in MRS deposits (see box j, light green star); (g) detail of Fig. 5f, with interdigitated colluvial deposits, marked by a stone line structure, among coastal deposits.

**Table 2.** Summary of the coastal evolution of the Palermo and Termini plains (please, see the evolution model in the Main Map for the graphical representation).

Age	Palermo plain	Termini plain	
		Western sector	Eastern sector
Chibanian–Holocene (0.77–0 Ma)		Emersion – Uplift – Fault activation From coastal to continental deposition (BCP, BNI, SIT, RFR, AFL) Relative downward migration of sea level – Shoreline advancement to E, NE Marine terrace carving – River incision	
Mid–Late Calabrian (1.5–0.77 Ma)		Submersion – Subsidence MRS deposition	Coastal area – Uplift Wave-cut processes Submerged area – Subsidence MRS deposition
Late Piacenzian–Early Calabrian (3.1–1.5 Ma)	Uplift River incision	Post 1.8 Ma? Emersion and erosion? Sedimentary gap? Up to 1.8 Ma Submersion – Subsidence	Uplift River incision
Late Zanclean? – Early Piacenzian (3.6? – 3.1 Ma) Zanclean (5.33–3.6? Ma)	Emersion – Uplift River incision	River incision – Continental deposition in alluvial/coastal plain Submerged area – Foredeep basin Trubi unit deposition	Emersion – Uplift River incision



**Figure 6.** Shoreline angles order distribution along coastline vs elevation along the coastline (see Figure 3 for the map view of these data). The thin red lines represent the locations of two actively deforming faults crossing the investigated coastline and are labelled Cozzo Mangiatorello fault (CMf) and Monte Cane fault (MCf), respectively (Parrino et al., 2022).

Termini plain than in the Palermo plain (Table 1), indicating differential uplift rates between the two sectors (see chapter 5).

Such results agree with the fault-related deformation detected in this area by Parrino et al. (2022), which is also supported by the different slope values of the regression lines computed in the two plains separately.

### 5. Discussion and conclusions

Our results show that the two investigated contiguous Palermo and Termini plains have been affected by differential tectonic uplift and subsidence, controlling the coastal landscape evolution in the Plio-Quaternary. Geomorphological evolution has been reconstructed from the Zanclean to the Holocene and summarized in Table 2 for the investigated area.

The Calabrian deposits of the MRS post-date the succession of marine terraces; the marine terrace deposits of BCP and SIT confirm that the succession occurred during sea-level highstands of the

Chibanian–late Pleistocene, similarly to other areas of northern Sicily (e.g. Mauz et al., 1997; Di Maggio et al., 2017 and references therein). The horizontal distance between the shorelines in the Palermo plain is, on average, longer than the corresponding distance in the Termini plain (Table 1, Figure 5). This characteristic is recognizable in all the marine terrace orders even if it is particularly evident for the shorelines of the first three orders. This observation could be due to different pre-existing morphologies. Based on the interpretation of the geometry of these shorelines and considering its known structural pattern, the Palermo plain paleo-landscape can be interpreted as a partially submerged flat area whose basin fill could be associated with the filling processes of a hinterland basin as documented in surrounding areas (Pepe et al., 2003). In a completely different way, the interpretation of the geometry of the paleoshorelines and its sedimentary record highlight that significantly large steep slopes overlooking the sea, structurally controlled, characterized the ancient topography of the Termini plain as in the

present (Figure 3(c) and Figure 6, and Table 1). Such high slope values could probably be related to a higher regional uplift of this coastal sector that was superposed to short wavelength uplift patterns due to compressional active faults. Such an interpretation fits the landscape evolution proposed by Parrino et al. (2022) and provides new clues about the recent tectonic activity of this coastal sector.

In the Palermo plain, numerous authors identify the MIS5.5 (roughly 125 ka) in correspondence to the first order of the shoreline elevation we mapped at roughly 10 m a.s.l. (see Figure 5 and Figure 7; Hugonie, 1981 and references therein; Di Maggio et al., 2009; Di Maggio et al., 2017 and references therein). The morpho-stratigraphic evidence of MIS5.5-related paleoshorelines was detected in the vicinity of the localities of Capo Gallo and Capo Zafferano (see Figure 5; Cerrone et al., 2021; Di Maggio et al., 2009 and reference therein). Di Maggio et al. (2009 and reference therein) indicate the existence of SIT coastal deposits on the MIS5.5 marine terrace also in the Termini plain (shoreline elevation is on average 15 m a.s.l.). Considering a sea level value of ca. + 4 m with respect to the present for MIS5.5 (Rohling et al., 2009) and based on the elevation of our first order paleoshoreline, an uplift of about 6m and 11m in 125 ky occurs for the plain of Palermo and Termini, respectively. As a result, the post MIS5.5 average uplift rate ranges from 0.048 mm/yr, in the Palermo plain, to 0,088 mm/yr in the Termini plain. These rates are slightly higher than those proposed in the literature for the Palermo plain, which varies from  $-0.03$  mm/yr to  $0.01$  mm/yr (Antonoli et al., 2006, 2018; Ferranti et al., 2006). Similarly, the uplift rate for the Termini plain, which is almost two times larger than those calculated for the Palermo plain, well fit with the regional increase in uplift rates recorded from W to E along the coast of the NSCM (Cosentino & Gliozzi, 1988). In agreement with Roberts et al. (2013), Meschis et al. (2018) and Robertson et al. (2019), the higher values of uplift rate of the Termini plain are compatible with the higher number of uplifted palaeoshorelines preserved in this plain.

This study may represent the basis for future works where ages for un-dated palaeoshorelines are assigned, and better-refined uplift rates are estimated by applying a synchronous correlation approach to study crustal deformation and active faults (e.g. De Santis et al., 2021; Meschis et al., 2022; Roberts et al., 2013; Robertson et al., 2019). This approach would allow us to overcome the overprinting or re-occupation problem that often affects regions such as the one investigated in this paper. Finally, the flawless fault-controlled uplift rate may likely be used to derive refined throw rates through time for the active thrust faults deforming our mapped paleoshorelines herein.

Considering the above, the two areas of the investigated NSCM coastal sector were characterized by

different paleo-morphologies and slightly different uplift rates, which, together with the Quaternary eustatic oscillations, drove two significantly different landscape evolutions in adjacent sectors. The presented dataset and uplift rates are consistent with the previous studies in the Palermo plain area and provide new information regarding the Termini plain area. Moreover, the overall vision allowed by the carried-out review work made it possible to reconstruct for the first time the coastal landscape evolution of this coastal sector of the NSCM. The achieved results are helpful insights that fill the knowledge gap about the recent landscape evolution and related tectonic forcings and represent a critical tool for parametrizing active geological structures in the area.

### Software

QGIS 3.22.1-Białowieża, MATLAB, TopoToolbox (Schwanghart & Scherler, 2014) and TerraceM-2 were used for the morphometric analyses; Adobe Illustrator (Adobe Inc., 2019) was used for the vector-based production of the Map.

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No potential conflict of interest was reported by the author(s).

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### Declaration of interest

The authors reported no potential competing interests.

### Data availability statement


The authors confirm that the data supporting the findings of this study within the article and its supplementary materials are freely available.

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