Last Interglacial sea-level proxies in the Western Mediterranean

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Abstract. We describe a database of Last Interglacial (Marine Isotopic Stage 5) sea-level proxies for the Western Mediterranean region. The database was compiled reviewing the information reported in 179 published studies and contains 371 sea-level datapoints (sea-level index points and marine or terrestrial limiting points) and 304 associated dated samples. The database follows the standardized WALIS template and is available as Cerrone et al, 2021b (https://doi.org/10.5281/zenodo.4497365).

1 Introduction

This paper describes the Last Interglacial (here broadly defined as Marine Isotopic Stage 5e, MIS 5e) sea-level database for the Western Mediterranean, that was compiled standardizing data contained in published scientific papers. The database was created using the WALIS interface, available at this link: https://warmcoasts.eu/world-atlas. This interface allows standardizing data and metadata on Pleistocene relative sea-level indicators and associated ages. The database described in this study represents the output of a tool embedded within the WALIS interface, that allows exporting all data in spreadsheet format. As a result, the Western Mediterranean database presented in this work is in .xls format, is open access, and available as Cerrone et al, 2021b (https://doi.org/10.5281/zenodo.4497365). Field descriptions are available at the following link: https://doi.org/10.5281/zenodo.3961544 (Rovere et al., 2020).

The data compiled in this manuscript were extracted from 179 studies (Figure 1a), that were reviewed between March 2020 and January 2021 (Figure 1b). Therefore, data contained in papers that appeared after this timeframe are not included in our database. The majority of the studies we reviewed were published within the last 40 years (Figure 1c). The database encompasses the Mediterranean coasts of Spain, France, Italy, Albania, Algeria, and Morocco. The coasts of Tunisia and Lybia, which may be also considered as part of the Western Mediterranean, are the subject of another compilation (Mauz, 2020). On the Eastern Mediterranean side, compilations are available for Israel (Sivan and Galili, 2020) and Cyprus (Zomeni, 2021). Moreover, we did not include in the database cave deposits as sea-level indicators from Mallorca and Croatia, to avoid duplication of data within WALIS. These deposits are part of another compilation (Dumitru et al., 2020). Overall, the Western Mediterranean Last Interglacial database contains 305 sea-level index points, 42 marine limiting

(indicating that sea-level at the time of formation was above the reported facies), and 26 terrestrial limiting points (indicating that sea-level at the time of formation was below the reported facies). Each data point was associated with one or more dated samples or linked to a chronostratigraphic attribution.

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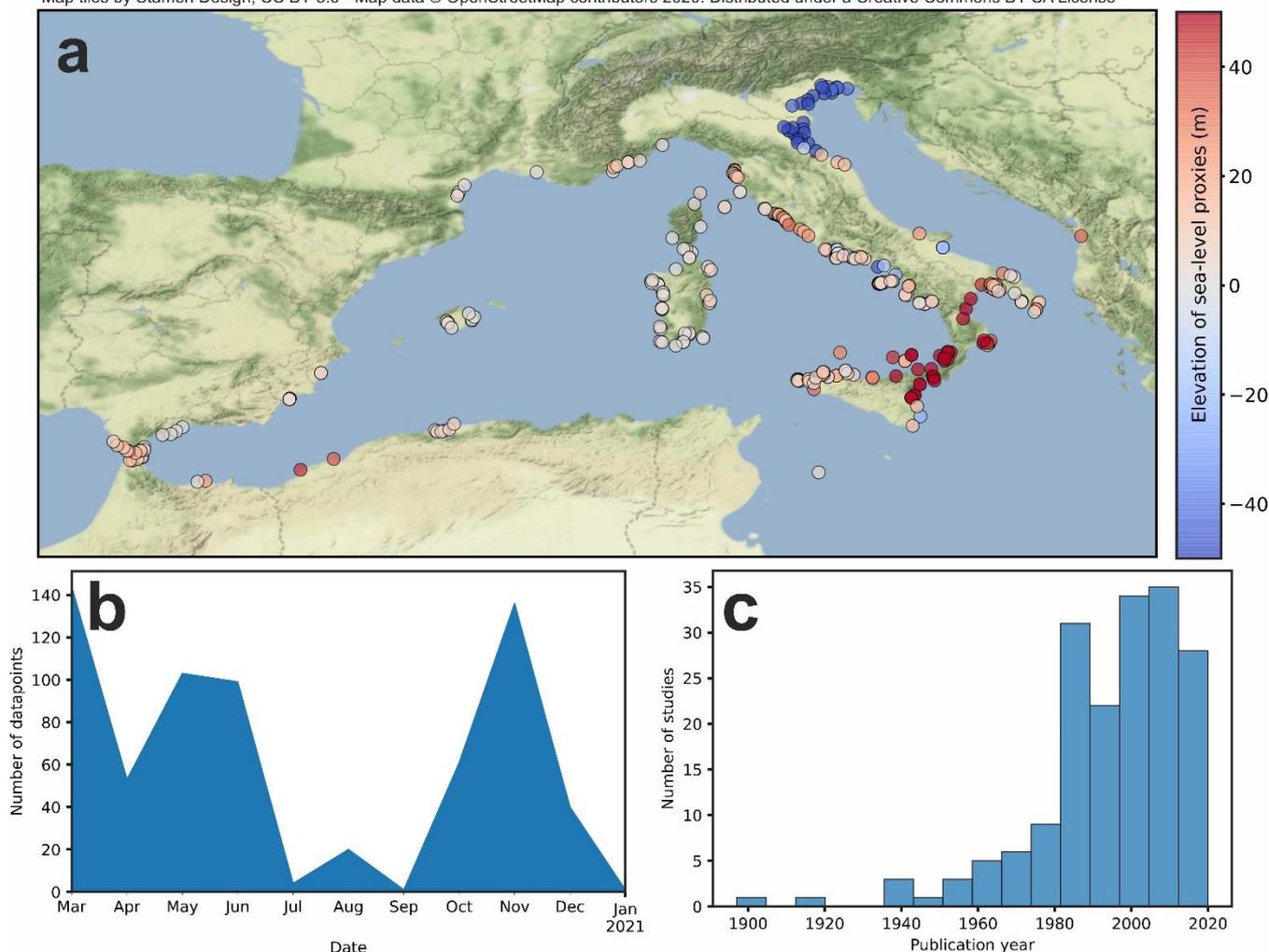
Figure 1: Overview of the Western Mediterranean database. a) Elevation of sites within the reviewed geographic area; b) Data ranges of database creation; c) Year of publication of reviewed studies.

In the following sections, we first give an overview of the classic literature describing the Last Interglacial sites in the Western Mediterranean. While many of these older studies mentioned in this section do not contain all the metadata required

40 by the WALIS interface, they represent the foundations upon which successive studies inserted in our database were developed. Next, we give a brief description of the types of sea-level indicators, elevation measurement techniques, sea level

datums, and dating (or age attribution) techniques contained in our database. We then turn to the description of the sea-level datapoints inserted in the database divided by National / Regional / Provincial boundaries. This part of the MS serves as a supplement to the data, where we provide additional descriptions and/or information on choices made during the compilation.

2 Literature overview

In the Western Mediterranean, the investigation of Quaternary marine and coastal deposits dates back more than one century. At the beginning of the 20th century, several geologists worked on both sides of the basin describing outcrops correlated to the "Tyrrhenian" sea-level highstand (Issel, 1908; de Lamothe, 1911; Gignoux, 1913; Blanc, 1936). This "first wave" of authors was followed by a series of geologists who detailed the first stratigraphic descriptions and uncovered new sites (e.g., Butzer and Cuerda, 1962; Ottmann, 1954; Bonifay and Mars, 1959). This "second wave" was helped by the development of dating techniques such as U-Series (Stearns and Thurber, 1965), which helped to strengthen previous chronological correlations, that were heretofore based almost uniquely on (bio)stratigraphy.

These studies laid the foundation upon which, in the 1980s and 1990s, studies on Western Mediterranean Last Interglacial outcrops flourished. Among the many works done in these two decades, it is worth mentioning the work of (Hearty, 1986), who applied Amino Acid Racemization to a vast number of Mediterranean sites. This work appeared on a Special Issue of the journal "Dating Mediterranean shorelines", edited by Ozer and Vita-Finzi (1986). This volume also contains the first (to our knowledge) Mediterranean-wide synthesis of Last Interglacial data (Flemming and Webb, 1986) and the first application of Electron Spin Resonance dating on Western Mediterranean outcrops (Brückner, 1986).

The renewed interest stirred by the "Dating Mediterranean shorelines" volume reflected in a large number of studies in the late 1990s and 2000s. Our Western Mediterranean database is largely based on these studies (see the detailed regional descriptions below) and on the regional/national data syntheses that were carried out by several authors in the last 20 years (Bordoni and Valensise, 1999; Nisi et al., 2003; Zazo et al., 2003; Ferranti et al., 2006;).

3 Sea-level indicators

Within the Western Mediterranean context, we identified eleven types of sea-level indicators (Table 1). The most widespread sea-level indicators are marine terraces, beach deposits (or beachrocks), and tidal notches (Figure 2). A large percentage of sites are also characterized by the presence of marine or terrestrial limiting points. Whenever mentioned by the original study, we assigned the upper and lower limits of the indicative meaning using modern analog data. When not possible, we

used the IMCalc tool (Lorscheid and Rovere, 2019) to extract ex-situ values for the calculation of reference water level and

70 indicative range (i.e., the relationship between the dated facies and the contemporary mean sea-level, Shennan et al., 2015).

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Table 1: Sea-level proxies used in the Western Mediterranean database. Abbreviations as follows. RWL=Reference Water Level; IR=Indicative Range; Ob=Ordinary berm; db=breaking depth; SWSH=Storm Wave Swash Height; MHHW= Mean Higher High Water; MLLW=Mean Lower Low Water; mLd = modern Lagoon depth; HAT=Highest Astronomical Tide; LAT=Lowest Astronomical Tide; MSL=Mean Sea Level;

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RSL indicator	Description	RWL	IR
Beach deposit or beachrock	From Mauz et al., 2015: "*Fossil beach deposits may be composed of loose sediments, sometimes slightly cemented. Beachrocks are lithified coastal deposits that are organized in sequences of slabs with seaward inclination generally between 5° and 15°*" Definition of indicative meaning from Rovere et al. (2016)	(Ob + db)/2	Ob to db
Beach ridge	Otvos,2000 defines beach ridges as "*stabilized, relict intertidal and supratidal, eolian and wave-built shore ridges that may consist of either siliciclastic or calcareous clastic matter of a wide range of clasts dimensions, from fine sand to cobbles and boulders*". Definition of indicative meaning from Rovere et al. (2016)	(SWSH + Ob)/2	SWSH to Ob
Beach swash deposit	Beach face between mean sea level and foredune. Upper Limit (UL) = spring tidal range / 2 or, mean higher high water; Lower Limit (LL) = MSL	(UL + LL) / 2	UL to LL
Foreshore deposits	Beach deposits characterized by a horizontal or gentle seaward-dipping lamination	(MHHW to MLLW)/2	MHHW to MLLW
Lagoonal deposit	Lagoonal deposits consist of silty and clayey sediments, frequently characterized by the presence of brackish or marine water fauna (Rovere et al., 2016). Usually, lagoon sediments are horizontally laminated (Zecchin et al., 2004). Definition of indicative meaning from Rovere et al. (2016).	(MLLW + mLd)/2	MLLW to mLd
Bioerosional and erosional markers on a limestone cliff	Relics of bioerosional (e.g., *L. lithophaga* boreholes) or erosional indicators on a sparse elevation range on a limestone cliff		Distance between MSL and the difference of upper bound of occurrence minus lower bound
Lithophyllum Byssoides algal rims	Upper intertidal fossil algal rim (Sechi et al., 2020)	(HAT-MSL)/2	HAT-MSL
Shallow or intertidal marine fauna	Marine fauna usually associated with very shallow water or intertidal environments		Based on the upper and lower limits of living modern analog faunas
Upper limit of *Lithophaga* boreholes	Boreholes created by mollusks of the Lithophaga genus, forming a well-delineated band on a rocky shoreline around the tidal level (Laborel and Laborel-Deguen, 1994)	(MLLW to LAT)/2	MLLW to LAT
Marine Terrace	From Pirazzoli et al., 2005: "*Any relatively flat surface of marine origin*". Definition of indicative meaning from Rovere et al., 2016	(SWSH+ db) / 2	SWSH to db
Tidal notch	Tidal notches are "*indentations or undercuttings cut into rocky coasts by processes acting in the tidal zone (such as tidal wetting and drying cycles, bioerosion, or mechanical action)*" (Antonioli et al., 2015). Definition of indicative meaning from Rovere et al. (2016)	(MHHW + MLLW)/2	MHHW - MLLW

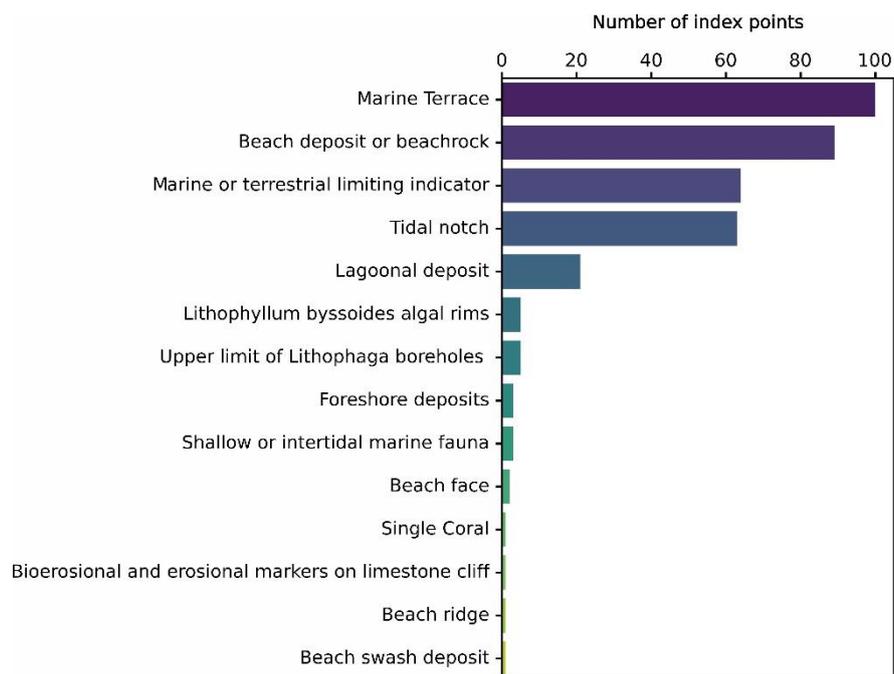



Figure 2: Types of sea-level indicators and number of sites where they are present within the Western Mediterranean database

3 Positioning techniques and vertical datums

The elevation of the large majority of sea-level index points reported in the database was measured with metered tapes or

105   rods and is referred generally to as "mean sea-level", with no additional information provided (Figure 3a,b). Whenever the

elevation measurement technique was not reported, we set the elevation error to 20% of the elevation value. If only the sea-

level datum was not reported, we added 5% to the reported elevation error. Also, we remark that the majority of studies do

not report precise coordinates for the sites investigated. Therefore, we had to reconstruct the geographic location of many

sites with the aid of geolocation services (e.g. Google Earth). This means that the location reported in the database is, for

110   many sites, only indicative (Figure 3c).

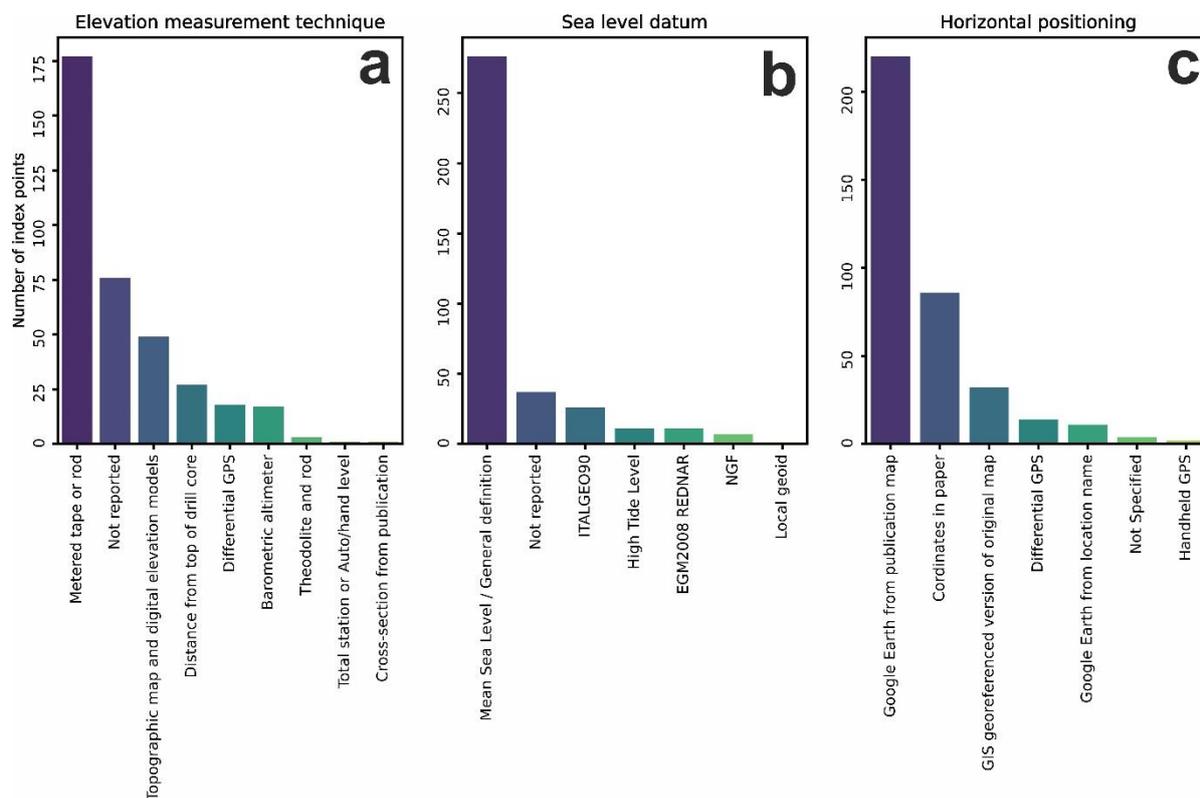



Figure 3: Elevation measurement (a), sea level datums (b) and horizontal positioning (c) associated with sea-level indicators in the Western Mediterranean database.

4 Age attribution

115 In the Western Mediterranean, Last Interglacial sea-level indicators have been assigned an age through a large array of techniques (Figure 4). U-Series was used to date corals preserved at several locations (Figure 4a). The vast majority of dated corals are specimens or fragments of *Cladocora caespitosa* (Linnaeus, 1767). Nearly two-thirds of the corals were dated with Mass Spectrometry, while one third was dated via the older alpha-counting technique. We also included in the database 33 U-Series ages on mollusks or corallineaceous algae (Figure 4b). We remark that, due to issues with the open-system

120 behavior of mollusks and corallinaceous algae, WALIS only allows the attribution of a general Marine Isotopic Stage to each sample, which we based on the reported ages and, if present, correlated discussions in the original manuscripts. While we did not include in our compilations the cave deposits from Mallorca and Croatia (that were, as remarked in the introduction, already compiled in WALIS by Dumitru et al. (2020), we inserted several speleothems that were dated in Southern Italy and Morocco to support the chronological attribution of sea-level indicators in these areas (Figure 4c).

125 Optically Stimulated Luminescence (OSL), Thermo Luminescence (TL), Infrared stimulated Luminescence (IRSL) and Electron Spin Resonance (EER) techniques were used to date coastal deposits at several locations, mostly in Italy (Figure 4d,f). Much more widespread is the use of Amino Acid Racemization (AAR) on mollusks (Figure 4e). This technique was used to strengthen biostratigraphic correlations among sites. In general, mollusks falling into "Aminozone E" were correlated to MIS 5e thanks to *Cladocora* corals dated with U-Series at sites where mollusks and corals were found in the

130 same deposit (Hearty et al., 1986a).

Chronostratigraphic and bio-stratigraphic correlations among sites are common in the Western Mediterranean (Figure 4g). Among these, one of the most widespread is related to the presence, embedded within Pleistocene deposits, of Senegalese fauna (for a detailed description, see Benjamin et al., 2017). The "Senegalese fauna" term is used to identify an assemblage composed of the following species: *Persististrombus latus (Gmelin, 1791), Conus testudinarius, Cantharus viverrata,*

135 *Tritonium ficoides, Natica lactea, N. turtoni, Mytilus senegalensis, Arca Geissei, Cardita senegalensis,* and some other minor species (Gignoux, 1913). The designation of this kind of fauna derives from the fact that the most representative species of the Senegalese fauna, *P. latus* (Figure 5, currently lives along the Atlantic coasts of western Africa at warm low-latitudes, from Angola to Senegal. Deposits with Senegalese fauna are encountered throughout the Western Mediterranean, excluding the coasts of the northern part of the Adriatic Sea.

140 The presence, within a Western Mediterranean Pleistocene deposit, of Senegalese fauna or *P. latus* is often used to denote an MIS 5e age of the deposit itself. But this chronological attribution has been challenged, at least for the Mediterranean coasts of Spain, by the fact that *P. latus* was found on marine terraces dated to MIS 5, MIS 7, and MIS 9 (Zazo et al., 2003). Details on the arguments for and against the attribution of *P. latus*-bearing deposits to MIS 5e are summarized in a series of comments-replies to Bardají et al., 2009a by Mauz and Antonioli, 2009 and Bardají et al., 2009b. In our compilation, we

145 assigned deposits bearing Senegalese fauna a general MIS 5 age, meaning that we deem it possible that this faunal assemblage was present in the Western Mediterranean at least throughout the different warm peaks of this Marine Isotopic Stage. We also remark that, at many sites where Senegalese fauna was described, independent datings (e.g., AAR, Luminescence, U-Series) confirmed the MIS 5e age of the deposit. Moreover, we highlight that, in Western Mediterranean Pleistocene sea-level studies, the species name *Strombus bubonius* (Lamarck, 1822) is widely used to indicate the

150 gasteropods of the Strombidae family, instead of the more appropriate *Persistrombus latus* (Gmelin, 1791) as recently established by Kronenberg and Lee (2006) and Harzhauser and Kronenberg (2008). Throughout our database, we, therefore, used *P. latus* even when the original authors used *Strombus bubonius*.

A second particular type of chronostratigraphic attribution is the one related to tidal notches (Antonioli et al., 2018). Tidal notches (Figure 6) are sea-level indicators that have a very narrow indicative range, but that cannot be dated directly due to

155   their erosive nature. In general, tidal notches have been dated indirectly by association with nearby deposits of known age. In our compilation, we, therefore, assigned to each tidal notch an age corresponding to the nearest deposit for which a chronological constraint is available, similarly to the approach followed by Antonioli et al. (2018).

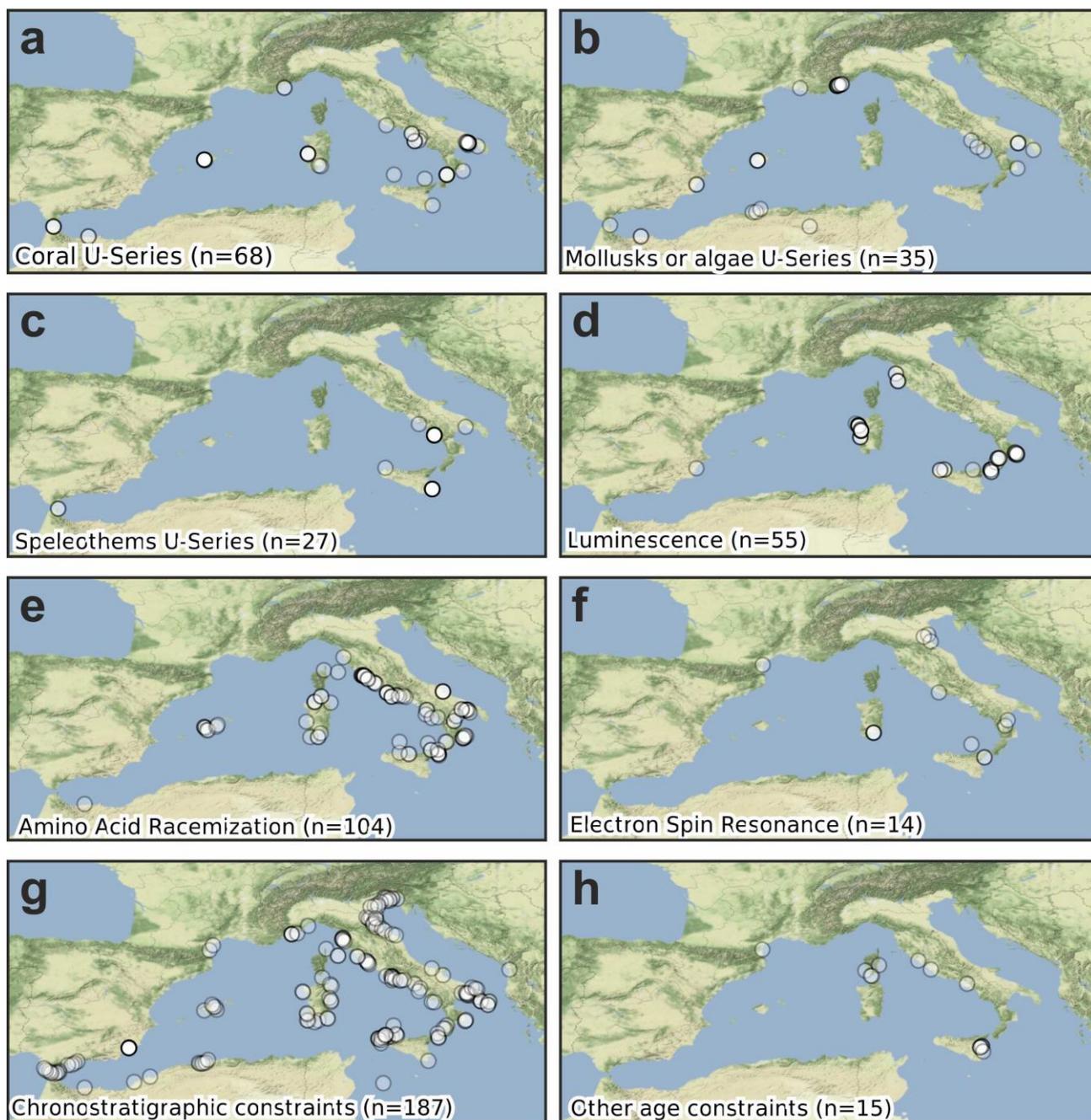
In the database, we inserted also a small number of "Other" age constraints (Figure 4h), e.g., limiting radiocarbon dates or Argon / Argon ages for which there is no standard template within WALIS.

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Figure 4: Geographic location of dated samples (or chronostratigraphic attributions), divided by type of analysis.

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Figure 5: Bioclastic calcarenite bearing *Persistrombus latus* (reported in many publications with its former name, *Strombus bubonius*) at Il Fronte site, Taranto, Puglia, Italy. Photo C. Cerrone

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Figure 6: Tidal notch on the Orosei cliffs, Sardinia, Italy. Note the modern notch carved at present sea level. Photo by A. Rovere.

5 Quality of sea level and age determinations

Within WALIS, it is possible to insert a quality score for age and RSL information associated with each sea-level indicator. The ranking follows a simple score (from 0 to 5), that is codified following the general guidelines given in the WALIS
170   documentation (Rovere et al., 2020) and reported verbatim in Table 2.

In general, if a site was dated only with one among U-Series on mollusks, AAR, or chronostratigraphic constraints, it was given an "Average" score. Sites where several dating techniques were used concurrently, giving coherent results, received a higher score. Tidal notches are a particular case, as they can be dated only indirectly. For these indicators, the age information quality was systematically set to "Poor". We remark that this is a conservative choice, as the quality of the
175   indirect age attribution for notches might be higher if the dated deposits are close to the notch. In our compilation, we followed whenever possible the WALIS guidelines. In case our quality assessment deviated from the guidelines, the reasons for the scoring choice were detailed in the "Quality notes" field.

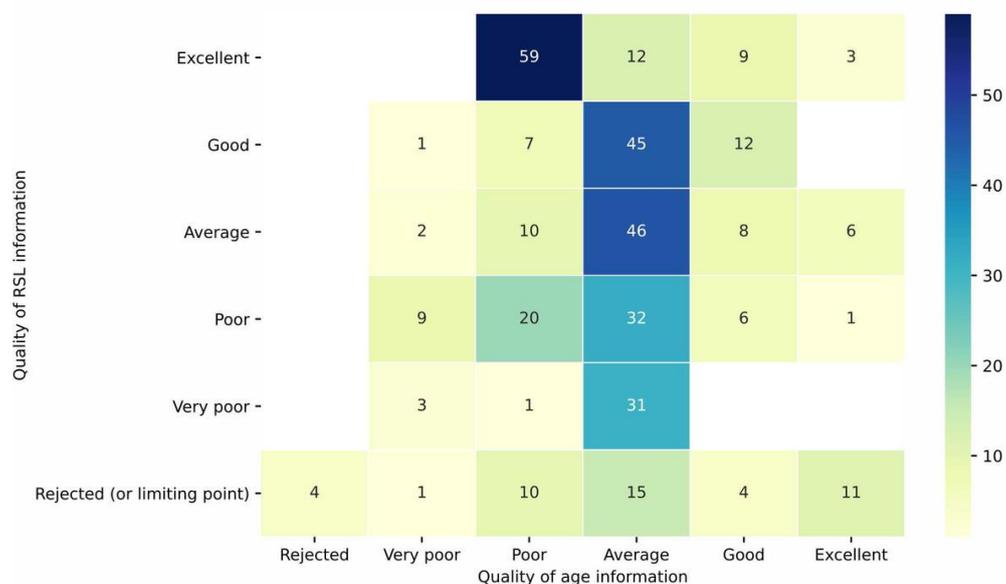
Overall, nearly 40% of points in the database have above average quality for both age and RSL information, with only three sites reaching an excellent score in both categories (Figure 7).

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Figure 7: Heatmap summarizing the quality of age and RSL information as estimated within the Western Mediterranean database. Numbers in each cell detail the number of sites with the corresponding RSL/age quality ranking.

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Table 2: Quality ranking as suggested by the WALIS guidelines (verbatim from Rovere et al. (2020), originally published under CC-BY 2.0 license)

RSL indicators quality ranking	
5 (excellent)	Elevation precisely measured, referred to a clear datum and RSL indicator with a very narrow indicative range. Final RSL uncertainty is sub-metric.
4 (good)	Elevation precisely measured, referred to a clear datum and RSL indicator with a narrow indicative range. Final RSL uncertainty is between one and two meters.
3 (average)	Uncertainties in elevation, datum, or indicative range sum up to a value between two and three meters.
2 (poor)	Final paleo RSL uncertainty is higher than three meters
1 (very poor)	Elevation and/or indicative range must be regarded as very uncertain due to poor measurement/description / RSL indicator quality
0 (rejected)	There is not enough information to accept the record as a valid RSL indicator (e.g. marine or terrestrial limiting)
Age information quality ranking	
5 (excellent)	Very narrow age range, e.g. few ka, that allows the attribution to a specific timing within a substage of MIS 5 (e.g. 117±2 ka)
4 (good)	Narrow age range, allowing the attribution to a specific substage of MIS 5 (e.g., MIS 5e)
3 (average)	The RSL data point can be attributed only to a generic interglacial (e.g. MIS 5)
2 (poor)	Only partial information or minimum age constraints are available
1 (very poor)	Different age constraints point to different interglacials
0 (rejected)	Not enough information to attribute the RSL data point to any Pleistocene interglacial.

6 Relative sea-level data

In the following sections, we describe the datapoints inserted in the Western Mediterranean database, starting from the coasts
190 of Spain and proceeding clockwise across the basin. In the text, we refer to the elevation of sea-level indicators as "*a.s.l.*"
(above present mean sea level) or "*b.s.l.*" (below present mean sea level). These represent the elevations we derived from the
original studies. For regions where sea-level indicators span a significant latitudinal or longitudinal gradient, we present
maps and paleo RSL elevation/distance graphs. Site names inserted in WALIS are reported in italics whenever they do not

refer to towns or toponyms that can be easily retrieved on topographic maps and/or geolocalization services (e.g., Google
195   maps). Wherever possible, we kept location names in the original language, or as reported in the reviewed papers. Sites
inserted in WALIS are always associated with their corresponding unique RSL ID in parenthesis. Whenever mentioned,
dated samples are also listed with their unique WALIS ID, e.g. AAR ID, USeries ID, etc.

6.1 Spain (Mediterranean Coasts and Gibraltar Strait)

Along the Mediterranean coasts of Spain, Last Interglacial sea-level proxies have been preserved mostly as relic beach or
200   subtidal deposits, containing remnants of Senegalese fauna. While some sites preserved fossil specimens of the coral
Cladocora sp., dated to MIS 5e with U-Series (e.g. Muhs et al., 2015), many other sites rely on chronological constraints
given by Amino Acid Racemization (e.g. Hearty, 1987), U-Series on mollusk shells (e.g., Hillaire-Marcel et al., 1996) and
biostratigraphy (e.g., Bardají et al., 2015). Along the Mediterranean and Strait of Gibraltar coasts of Spain, the Last
Interglacial sea-level indicators are concentrated in four regions: Islas Baleares (Mallorca), the southern tip of the Comunitat
205   Valenciana (Alicante province), Murcia, and Andalucía. Zazo and Goy, 1989 also report overlapping marine levels near the
Ebro Delta, in Catalonia, located slightly above sea level, dated with ESR by Brückner and Radtke (1986). As we were not
able to retrieve the original papers in this area, these data points were not included in WALIS.

6.1.1 Andalucía

The Andalucía region includes sites that are located both in the Mediterranean and on the Atlantic coast, west of the
210   Gibraltar Strait (Figure 8). In this region, studies on Pleistocene shorelines date back to the late 1980s /1990s (Zazo, 1980;
Zazo and Goy, 1990). Several sites were reviewed in this area by Zazo et al., 1999, and were inserted in WALIS with RSL
IDs from 752 to 765 (Figure 8). Ages were assigned based on chronostratigraphic correlation within sites, some of which
were dated using U-Series on mollusks. In general, MIS 5e deposits in this area are described as MIS 5e marine remains. As
most of the geological sketches in the original paper show that they are located on a flat surface, we inserted these data
215   points in WALIS as marine terraces, with a broader indicative range than beach deposits.
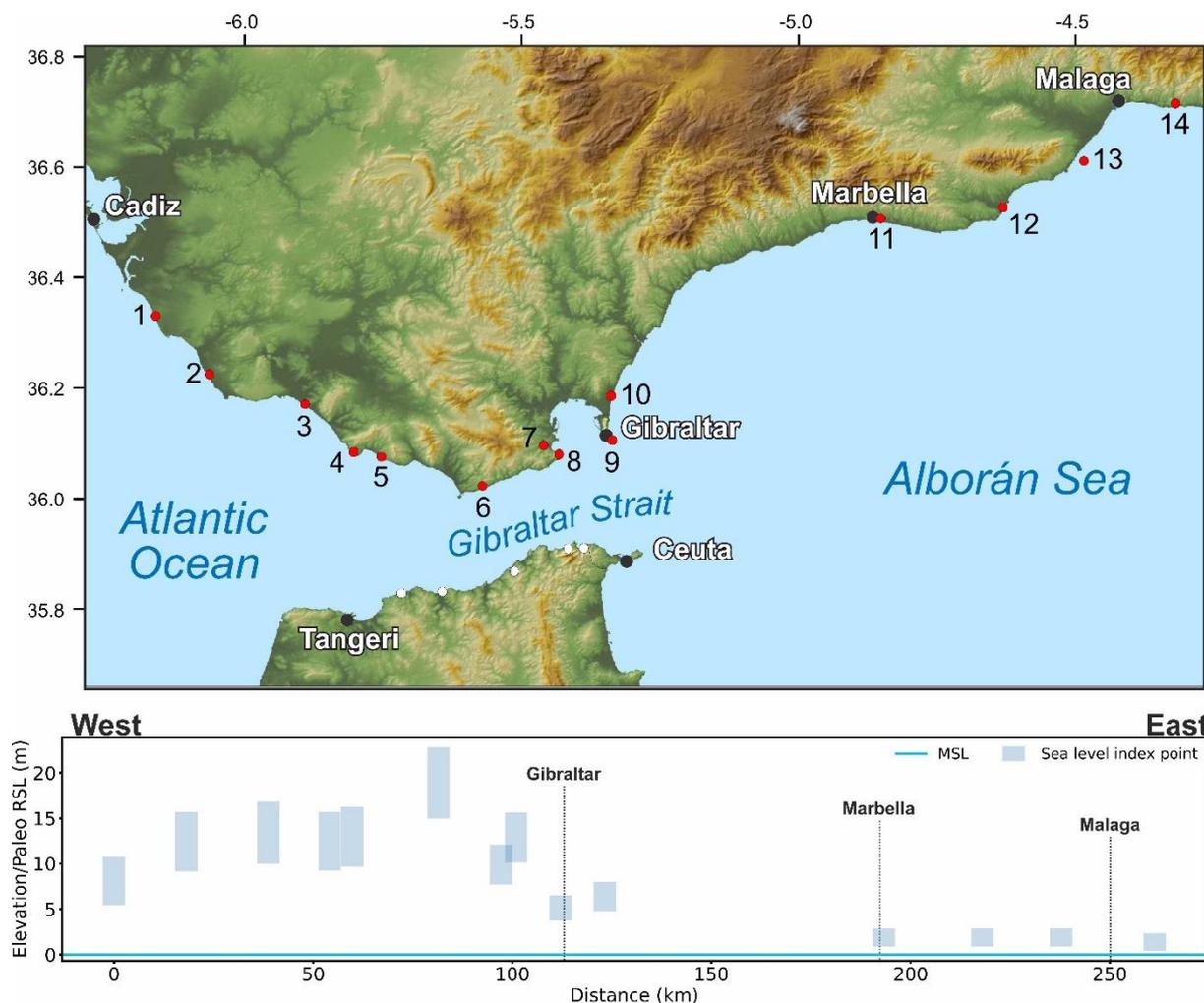
Figure 8: Last Interglacial sea level data for Andalucía (Spain). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from West (left) to the East (right). Sites list: 1: Torre del Puerco (RSL ID 765). 2: Conil-Trafalgar (RSL ID 764). 3: Zahara (RSL ID 763). 4: Cabo Gracia (RSL ID 762). 5: Bolonia - Punta Paloma (RSL ID 761). 6: Tarifa (RSL ID 760). 7: Algeciras 1 (RSL ID 758). 8: Algeciras 2 (RSL ID 759). 9: Gibraltar (RSL ID 757). 10: La Linea (RSL ID 756). 11: Marbella (RSL ID 755). 12: Fuengirola (RSL ID 754). 13: Torremolinos (RSL ID 753). 14: El Candado (RSL ID 752). The topography has been obtained from the Shuttle Radar Topography Mission void-filled DEM (Farr et al., 2007), free NASA dataset.

6.1.2 Murcia

In Murcia, north of Cape Cope, several terraces attributed to different interglacials were reported by studies in the late 1980s / early 1990s (Dabrio et al., 1991; Bardají et al., 1986). The sites were later re-described by Zazo et al. (2003), who clarified that paleomagnetic data and chronostratigraphic correlations with other sites in Almeria and Alicante were used to give an age to these deposits. Within the sites in the so-called Cope Basin, the most complete was reported from a location called *Casa de Renco* (RSL ID 750), where marine conglomerates outcrop up to 5.2m a.s.l. Bardají et al. (2015) describe the lowermost sedimentological units in 11 outcrops along the Cope Basin (RSL IDs 740-750). In particular, they assign the shell-rich conglomerate of Unit D to MIS 5e, identifying different sea-level oscillations within it. The authors do not rule out a possible MIS 5a or 5c age for this unit, as its age attribution is based solely on the presence of *P. latus* and other warm-water faunas. In WALIS, we reported the 11 sites described by Bardají et al., 2015 where Unit D is reported and assigned them a general MIS 5 age.

6.1.3 Comunitat Valenciana (Alicante province)

One of the most studied Last Interglacial outcrops in continental Spain is located in the Comunitat Valenciana, within the Alicante Province, 100 km south of the city of Valencia. Here, studies on the stratigraphy of the *La Marina - El Pinet* site date back to the 1980s (Bernat et al., 1982; Hearty et al., 1987; Goy and Zazo, 1988; Goy and Zazo, 1989). More recently, Goy et al. (2006) analyzed the stratigraphy of two sections within this site (A and B, RSL IDs respectively 751 and 738), where they found evidence for an MIS 7 terrace (dated using U-Series on *Cladocora* corals). Immediately above this terrace, U-Series on mollusks (*P. latus*) yielded ages consistent with MIS 5, which were later assigned to MIS 5e by an OSL age on oolitic sands of 114 ± 15 ka (Mauz et al., 2012). It is noteworthy that the entire area shows tectonic instability, and even between the MIS 5 terrace at the two sections (separated by less than 300 meters) there is an offset of 2-3 m.

6.1.4 Islas Baleares (Mallorca)

The island of Mallorca (Figure 9) has arguably preserved some of the most prominent Last Interglacial sea-level proxies for the Western Mediterranean, which have been studied since at least the late 1950s (Butzer and Cuerda, 1962; Cuerda, 1957). Stearns and Thurber, 1965 reported U-Series (obtained with alpha counting) ages on mollusk shells for 10 samples at different sites across the island. In particular, they concentrated on the *Camp de Tir* site (RSL ID 357), which is also referred to as "Es Carnatge". This outcrop, located close to the Palma airport, is a Pleistocene beachrock deposit, composed of different units that were described in several studies (Butzer and Cuerda, 1962; Cuerda, 1957; Hearty, 1987; Zazo et al., 2003; Bardají et al., 2009a). Several authors concentrated on establishing chronological constraints for the different units

within the beach deposit at *Camp de Tir* (Figure 10), with U-Series (Hillaire-Marcel et al., 1996; Muhs et al., 2015; Zazo et

255   al., 2003) or Amino Acid Racemization (Hearty et al., 1986a; Hearty, 1987).

An account of the history of investigations of the *Camp de Tir* outcrop (among others) is given in Vicens et al., 2012. Until very recently, the outcrop was divided into different units, which were assigned to "Neotyrrhenian" (ca. 2 m a.s.l., MIS 5a) and "Eutyrrenian" (ca. 3 m a.s.l., MIS 5e) based on faunal content, U-Series on mollusks and Amino Acid Racemization. This apparent age difference has been recently ruled out by Muhs et al., 2015, who dated nine *Cladocora sp.* coral samples

260   from the (supposed) MIS 5a unit at Camp de Tir, and obtained ages spanning the range 119-126 ka. Based on these, the authors argued that the entire *Camp de Tir* outcrop was deposited in MIS 5e. Lorscheid et al., 2017 measured the elevation of a bioconstructed rim of vermetids close to the location where *Cladocora* corals were dated, gathering a paleo RSL elevation at *Camp de Tir* of 2.10 ± 0.71 m a.s.l.

Camp de Tir is surely the most widely described MIS 5e outcrop in Mallorca but is not the only one. Re-assessing sites

265   reported in previous studies, Lorscheid et al., 2017 surveyed with differential GPS other 10 sites scattered across the island. Overall, the fixed biological indicators and beach deposits at these sites show a coherent picture of paleo RSL located 2.9 ± 0.8 m a.s.l. This estimate is in very good agreement with the indications of phreatic overgrowth on speleothems (Tuccimei et al., 2006, 2012). The most recent MIS 5e datum for these indicators in Mallorca is 2.15 ± 0.75 m a.s.l. (Polyak et al., 2018).

In WALIS, we inserted data for 11 sites (Figure 9) in Mallorca as reported in Lorscheid et al., 2017, associating them with

270   different ages as estimated at each site by previous authors. We did not include a second dataset reported by Lorscheid et al., 2017, namely shore platforms measured at higher elevations than the fossil beach deposits, due to the lack of age constraints on these features. As mentioned above, the MIS 5e in Mallorca was studied both on the open coasts and coastal caves, in the form of phreatic overgrowth on speleothems. The details of these latter indicators are reported in another WALIS compilation focussing on U-Series on cave deposits (Dumitru et al., 2020).
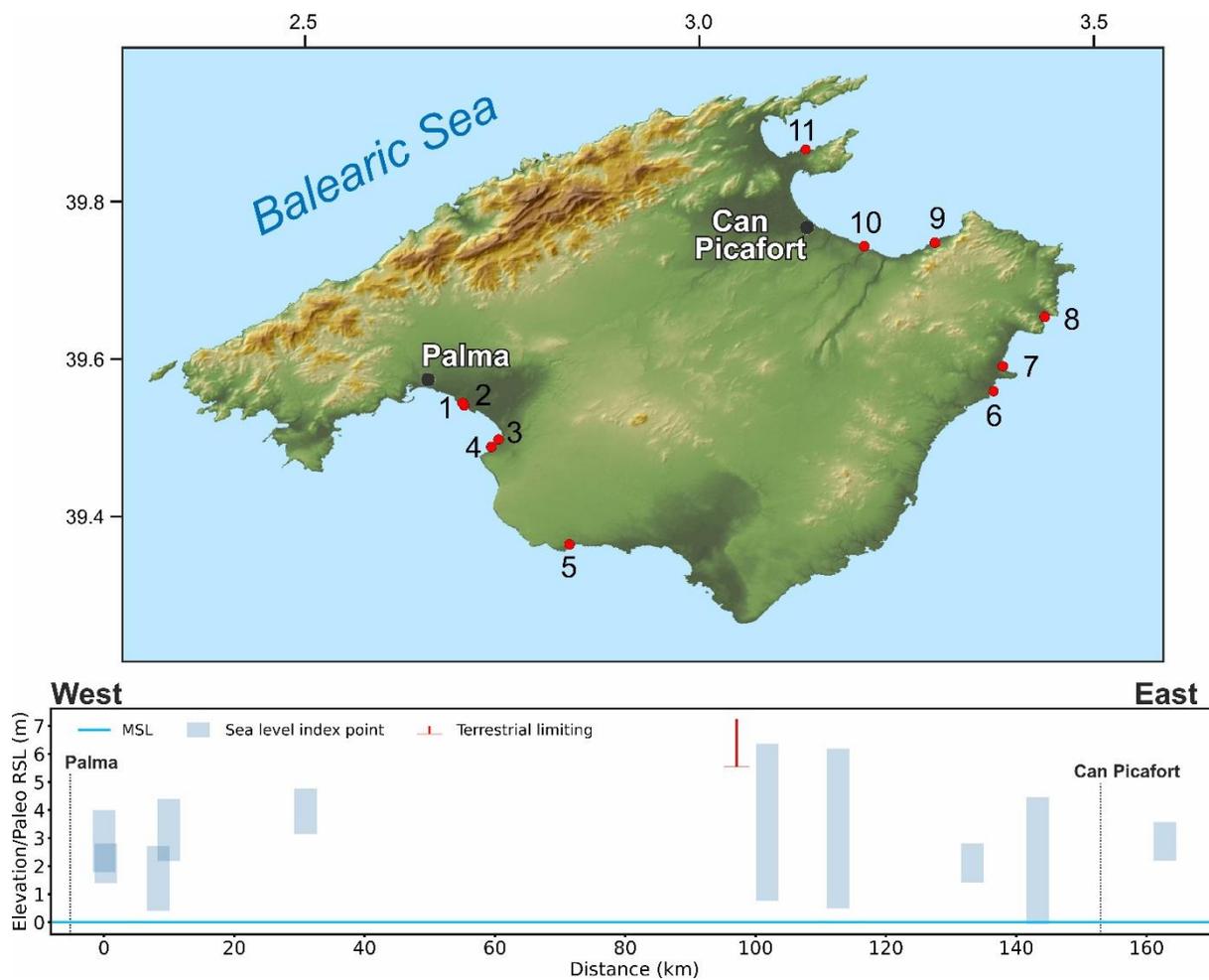
Figure 9: Last Interglacial sea-level data for Mallorca (Baleares, Spain). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, counterclockwise from West (left) to the East (right). Sites list: 1: Cala Pudent (RSL ID 779). 2: Camp de Tir Unit U4 (RSL ID 357). 3: Cova Baixa (Son Grauet) (RSL ID 780). 4: Cala Blava (RSL ID 781). 5: Cala Pi (RSL ID 782). 6: S'Illot (RSL ID 784). 7: Cala Millor (RSL ID 785). 8: Canyamel (RSL ID 786). 9: Caló des Camps (RSL ID 787). 10: Torrent de Son Real (RSL ID 788). 11: Platja de Sant Joan (RSL ID 789).

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280

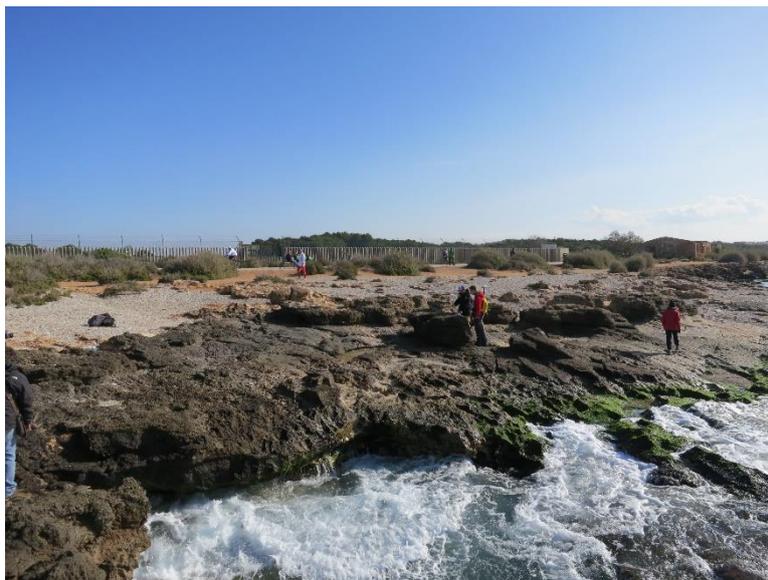



Figure 10: General overview of the Camp de Tir outcrop in Mallorca (RSL ID 357), Balearic Islands, Spain. The upper part of the outcrop is composed by shallow water beach sands of Last Interglacial age. Photo by A. Rovere.

285   6.2 Mainland France

The study of the marine Pleistocene deposits along the Mediterranean coast of France dates back to the 1950s (Masurel, 1953, Ottmann, 1954; Bonifay and Mars, 1959). The large majority of the literature is in French (Barrière, 1966; Ambert, 1999; Lumley et al., 2001; Provansal et al., 1995) while fewer studies were published in English (Dubar et al., 2008; Stearns and Thurber, 1965). In general, the overall quality of the French data is significantly lowered by the dating constraints

290   available. A large part of the marine deposits was dated using radiocarbon techniques in search of a mid-Holocene highstand that was not present in this portion of the Mediterranean (Vacchi et al., 2016). These ages (generally >20,000 years) and the stratigraphic context of the outcrops suggest that the attribution to MIS 5 is reasonable but further analysis with updated techniques is strongly needed, because only a few studies reported ages based on AAR or U/Th dating.

6.2.1 Languedoc-Roussilion

295   The Languedoc-Roussilion coast extends from the border with Spain to the Rhone Delta (Figure 11). Ambert (1999) compiled the most recent review of the Last Interglacial shorelines in this region. These are generally represented by beach deposits (sometimes cemented) found at different elevations, not exceeding ~8 m a.s.l. The beach deposits found near the towns of Narbonne (RSL ID 386), Leucate (RSL ID 385 and 1316), and Port la Nouvelle (RSL ID 384) are characterized by abundant faunal remains rich in *Tapes dianae,* which is considered the key species for the local "Euthyrrenian" stage. The

300   single chronological constrain is provided by an ESR age on a shell collected at Port la Nouvelle (ESR ID 99) which yielded
an age of 128 ± 15 ka (Yokoyama et al., 1987). Our re-analysis indicates that the maximal sea-level highstand in this portion
of the French Mediterranean coast was placed at 6.4 ± 2.5 m a.s.l. Ambert (1999) also reports a possible lower sea-level
highstand which has been the result of a regressive phase following the maximal highstand. This was found near Leucate and
is characterized by beach deposits (RSL ID 1316) which placed the RSL at 3 ± 2.5 m a.s.l. This deposit was dated with both

305   radiocarbon and U/Th techniques but both ages were not considered reliable (Ambert, 1999). The faunal assemblage is also
not very peculiar, with the sole presence of *Spondylus gaederopus*.

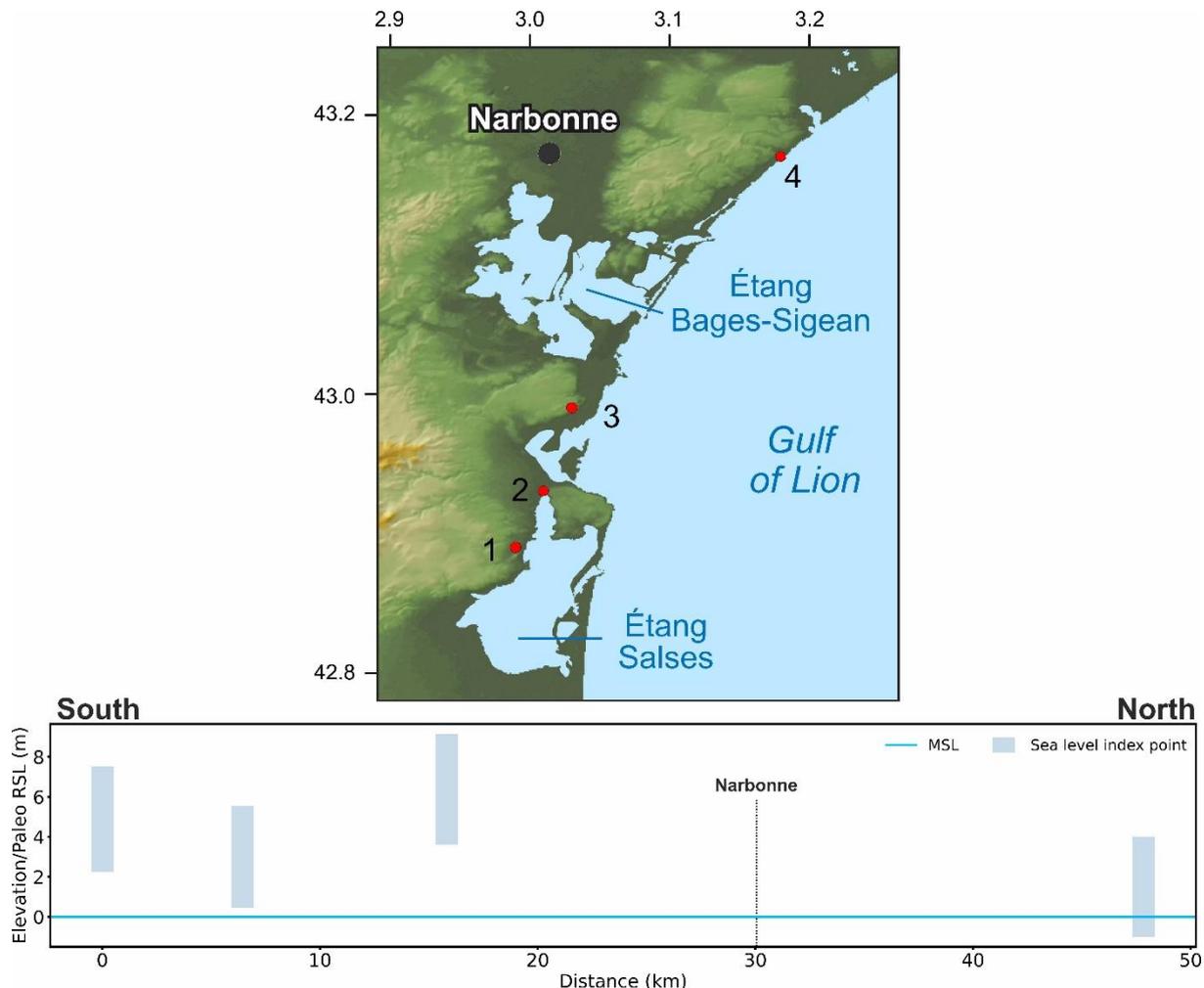



Figure 11: Last Interglacial sea-level data for Languedoc-Roussilion (France). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.

310   **Lower panel: Distance/Elevation graph, from South (left) to the North (right). Sites list: 1: Leucate Le Malpas (RSL ID 385). 2: Leucate La Franqui (RSL ID 1316). 3: Port la Nouvelle Ramandils (RSL ID 384). 4: Narbonne Saint Pierre (RSL ID 386).**

6.2.2 Provence-Cote d'Azur

This portion of the Mediterranean French coast extends from the Rhone Delta to the border with Italy (Figure 12). In his review, Ambert (1999) reports a large elevation variability of the Last Interglacial shorelines which ranges from ~3 to ~22 m

315   a.s.l. The lowest elevations of these shorelines are reported in the Marseille area. Here, the most robust indicator is represented by a lagoonal deposit sampled near the Étang de Berre (Provansal et al., 1995) which was used to reconstruct a paleo sea-level placed at 3 ± 1.4 m a.s.l. (RSL ID 387). The late Pleistocene age of this deposit was provided by U/Th dating on algae (U-Series ID 795) which yielded ages comprised between 129 and 139 ka.

The majority of the data in the Provence-Cote d'Azur province were collected near the cities of Nice and Antibes (Dubar et

320   al., 2008; Hearty et al., 1986a; Gilli, 2018). Stearns and Thurber (1965) firstly attempted to date the paleo-shorelines found in this area. The U/Th dating (U-Series ID 2341) on mollusks found in beach deposits at ~20 m a.s.l. in the *Grotte de Lazaret* yielded an age of 110 ± 10 ka, while other two dates performed near Monaco on beach deposits found at very different elevations (U-Series IDs 2342 at ~33.5 m a.s.l. and U-Series ID 2343, ~1.8 m a.s.l.) yielded ages between 75 and 82 ka. This variability is likely related to issues of dating mixed shell remains with U-Series (Stearns and Thurber, 1965).

325   More recently, Dubar et al. (2008) performed some U/Th dating (U-Series ID 1719 to 1725) on marine shells found in beach face deposits, which yielded MIS 5 ages. These deposits allowed reconstructing a paleo sea-level placed at 14 ± 1.1 m a.s.l. (RSL ID 449) and at 10.3 ± 1.3 m a.s.l. (RSL ID 451). The variability of the last-interglacial shoreline in this area elevation was explained by differential tectonic uplift (Dubar et al., 2008). Gilli (2018) performed a U/Th dating (U-Series ID 1987) on a *Cladocora cespitosa* sample found in living position at Cap d'Antibes. The coral, which yielded an age of 125 ± 5 ka,

330   constrains the paleo seal-level above ca. 6 m a.s.l. during MIS 5e.

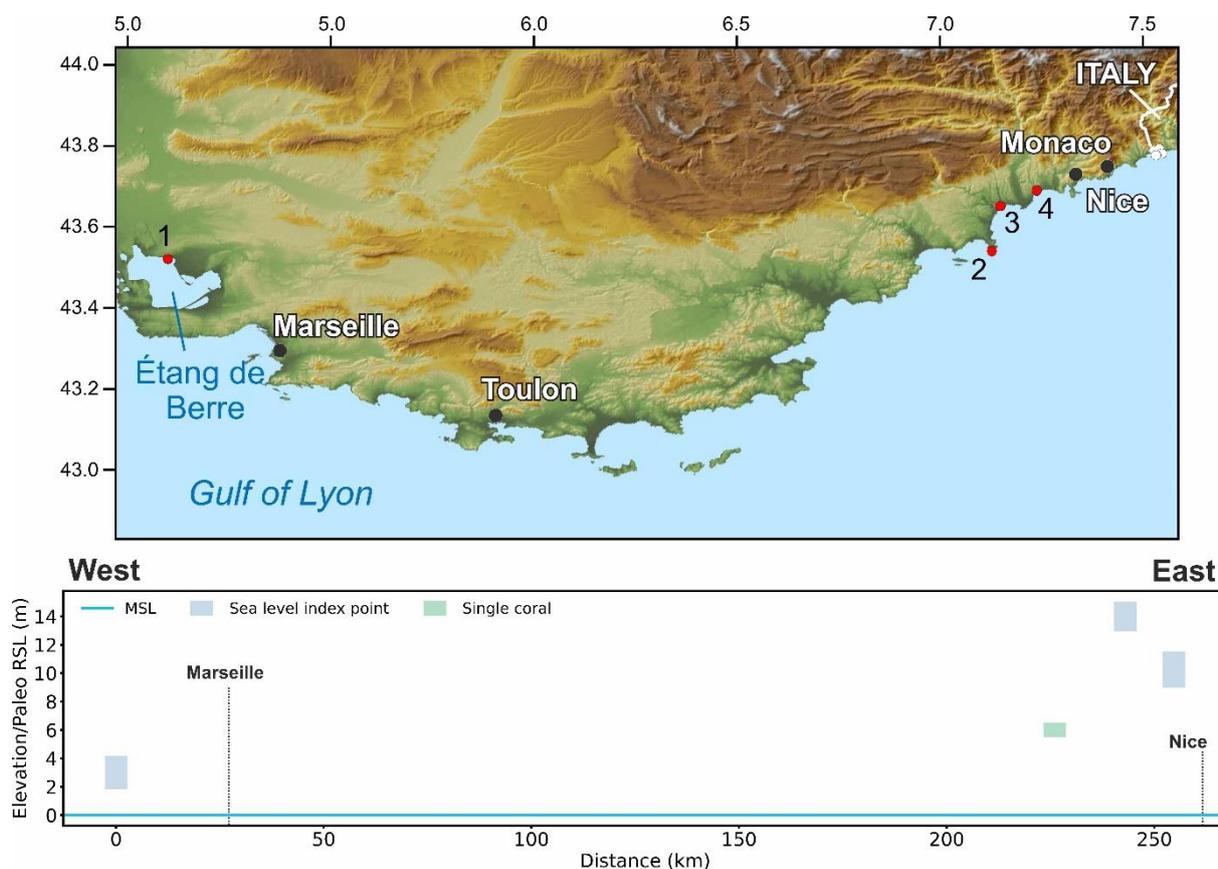



Figure 12: Last Interglacial sea-level data for Provence-Cote Azur (France). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from West (left) to the East (right). Sites list: 1: Étang de Berre (RSL ID 387). 2: Cap d'Antibes (USeries_1988). 3: Nice Le Bosquet (RSL ID 449). 4: Nice Les Amandier (RSL ID 451).

6.3 Mainland Italy

6.3.1 Liguria

East of the French border, Quaternary shorelines (in particular the Last Interglacial ones) are preserved at few locations along the coast of Liguria (Figure 13), mostly on limestone rocky coasts, and in caves. The most recent review on MIS 5e shorelines in this region was written by Federici and Pappalardo, 2006, who analyzed several studies reporting RSL indicators. A few hundred meters from the French border, several sea-level indicators are present inside caves in an area called *Balzi Rossi* (RSL IDs 233, 237, 239, 240) and, further to the East, in the *Madonna dell'Arma* cave (RSL ID 242) (Vicino, 1974; De Lumley, 1969; Isetti et al., 1962). This cluster of data was attributed to the Last Interglacial due to the

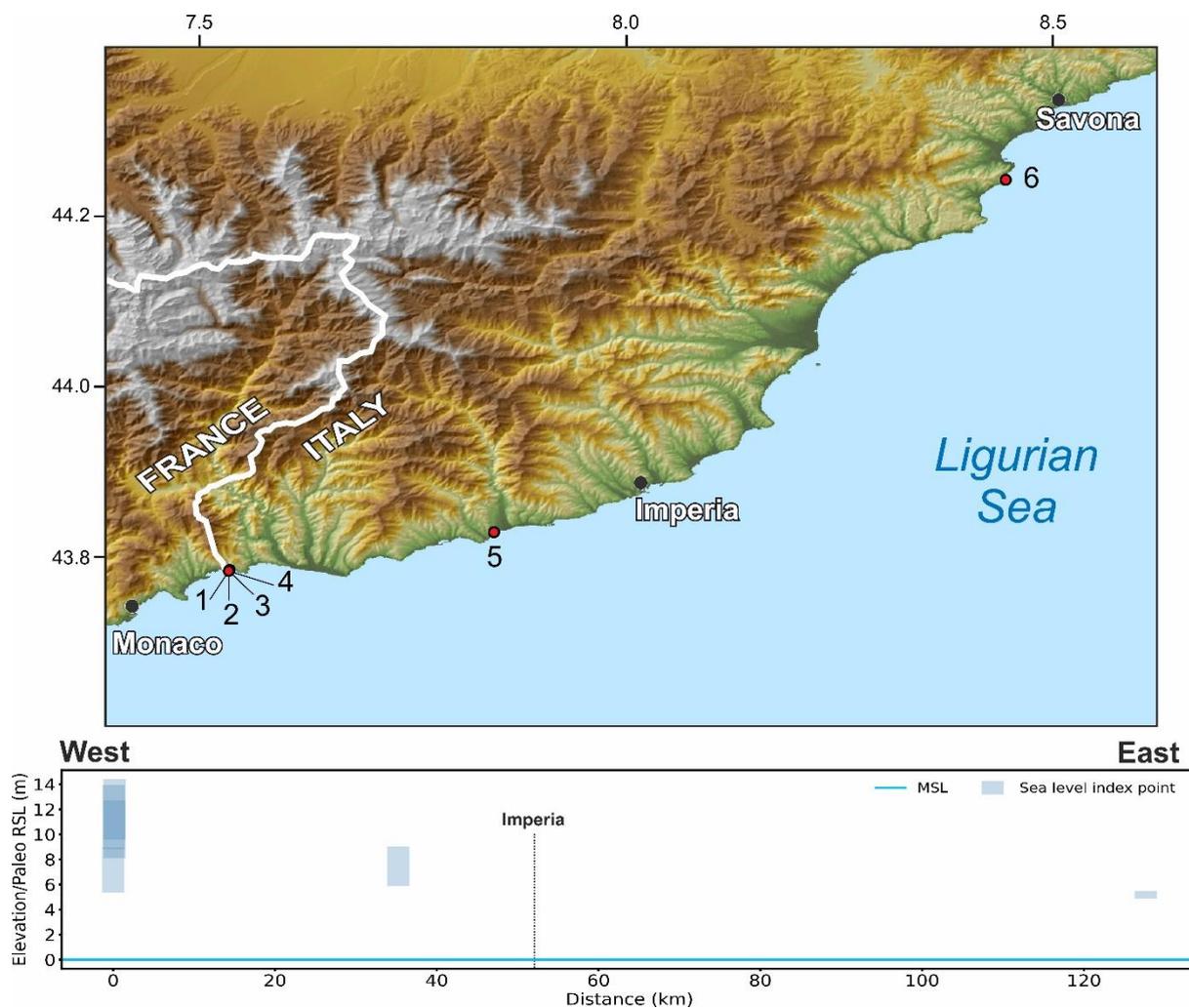
345 presence of *P. latus* and Senegalese fauna and defines paleo RSL at an elevation of 7-12 m a.s.l. Similar deposits found in another marine cave (*Grotta Marina di Bergeggi*, RSL ID 246) give a chronologic constraint to a well-preserved upper band of *L. lithophaga* (date mussel) boreholes (Figure 14) at ca. 6m a.s.l. (Carobene, 2015). East of the city of Genova there is only one outcrop that was attributed to the Last Interglacial by Federici and Pappalardo, 2006, near the town of Lavagna. Here, a marine terrace at 28m a.s.l. was dated with OSL at 139±11 ka. More recent ages confirmed that this deposit is older than MIS 5e (Marta Pappalardo, Pers. Comm. 04.02.2021). Therefore, this data point has not been included in WALIS.

350

Figure 13: Last Interglacial sea-level data for Liguria (Italy). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from West (left) to the East (right). Sites list: 1: Ex Casino (RSL ID 240). 2: Barma Grande (RSL ID

233). 3: Bausu da Ture (RSL ID 239). 4: Grotta del Principe (RSL ID 237). 5: Madonna dell'Arma (RSL ID 242). 6: Grotta
355 **Marina di Bergeggi (RSL ID 246).**

Figure 14: Close-up of *L. lithophaga* boreholes at ca.6m above modern sea level in the Grotta Marina di Bergeggi, Liguria, Italy (RSL ID 246). Each borehole has a diameter of approximately 2-3 cm. Photo by A. Rovere.

6.3.2 Toscana

360 In Toscana (Tuscany), a relatively recent review of the Last Interglacial sea-level record was compiled by Nisi et al. (2003) starting from the compilation of Bordoni and Valensise (1999), which was later summarized and implemented with new information by Ferranti et al. (2006). As a result, many of the sites in our database were already included in Ferranti et al. (2006). In WALIS, we standardize the calculation of the indicative range for many of the previously reported sites, also re-analyzing original works (Figure 15). We report, where available, also details on their dating. Starting from the North of

365 Tuscany, we remark that here we do not include in our database a core in the Versilia Plain. Within this core, coastal deposits found at 60 m b.s.l. were previously attributed to MIS 5e (Antonioli et al., 1999a), but more recently U/Th dating on a *Cladocora sp* coral collected from the same unit yielded an age of 195.7±1.6 ka (Carboni et al., 2010).

In the area of Livorno, Nisi et al. (2003) associated the Last Interglacial with the inner margin of a broadly developed marine terrace at elevations of 14 to 20 m a.s.l. referred to as Terrazzo di Livorno (Livorno Terrace). A topographic sketch of the

370 terrace of the site named *Quercianella* (RSL ID 255, terrace elevation from Nisi et al., 2003 = 17 m a.s.l) published by Boschian et al. (2006) shows that coastal deposits on the same terrace are found several meters below the inner margin (elevation of the "fossil beach" at *Quercianella* = ca.10 m a.s.l.) and that the elevation of the inner margin of the terrace is

covered by fossil dunes and soils. For this reason, unless independent constraints were available on the elevation of coastal deposits, the inner margin of the terraces reported by Nisi et al. (2003) was considered in WALIS as a terrestrial limiting.

375 Zanchetta et al. (2004) describe several boreholes in the Livorno Terrace where coastal marine cemented sands with shells are found at 5-10 m a.s.l. Summarizing previous studies, Ciampalini et al. (2006) clarify that these deposits are attributed to MIS 5e mostly based on Senegalese fauna.

The Livorno Terrace becomes narrower towards the south of Livorno (Boschian et al., 2006), where vertical or sub-vertical outcrops containing MIS 5e deposits were found. Mauz (1999) used OSL to date two sections, *Buca dei Corvi* (RSL IDs 325

380 and 326) and *Baratti* (RSL ID 327 and 328), albeit obtaining only limiting ages (*Buca dei Corvi* >10ka, *Baratti* >100ka). These sections were already described and correlated with Aminozone E (assigned to MIS 5e) with Amino Acid Racemization by Hearty et al. (1986a) and Hearty and Dai Pra (1987). The *Buca dei Corvi* outcrop is reported to contain Senegalese fauna and *P. latus*.

The same authors reported similar deposits (with *P. latus* and assigned to Aminozone E) also on Pianosa Island (RSL ID

385 330, Figure 16), later also described by Antonioli et al. (2011). Here, the Aminozone E beach deposits (at 1.7 m a.s.l.) are in close relationship to remnants of *L.lithophaga* boreholes and marine erosion at higher elevations (ca. 6 to 9 m a.s.l., RSL ID 331) on the cliff. Stocchi et al. (2018) provide differential GPS measurements of these two units at Pianosa Island. These are reported in WALIS as separate entries, as it is not clear if they were formed by one or two highstands, given the impossibility to give an age constraint to the *L. lithophaga* and erosional features on the cliff. The same issue applies to a

390 tidal notch at *Talamone* (RSL ID 335), which was recently measured by Antonioli et al. (2018) at 4.8 m a.s.l. The notch itself cannot be dated directly, but it was associated with closeby (2.7 km) deposits containing warm water fauna at *Campo Regio* (RSL ID 336, 6 m a.s.l., Hearty and Dai Pra 1987). Unfortunately, no AAR constraints are available at this site. South of the Orbetello lagoon, the Last Interglacial beach deposits were mapped by Hearty and Dai Pra (1987) at 10-13m a.s.l.

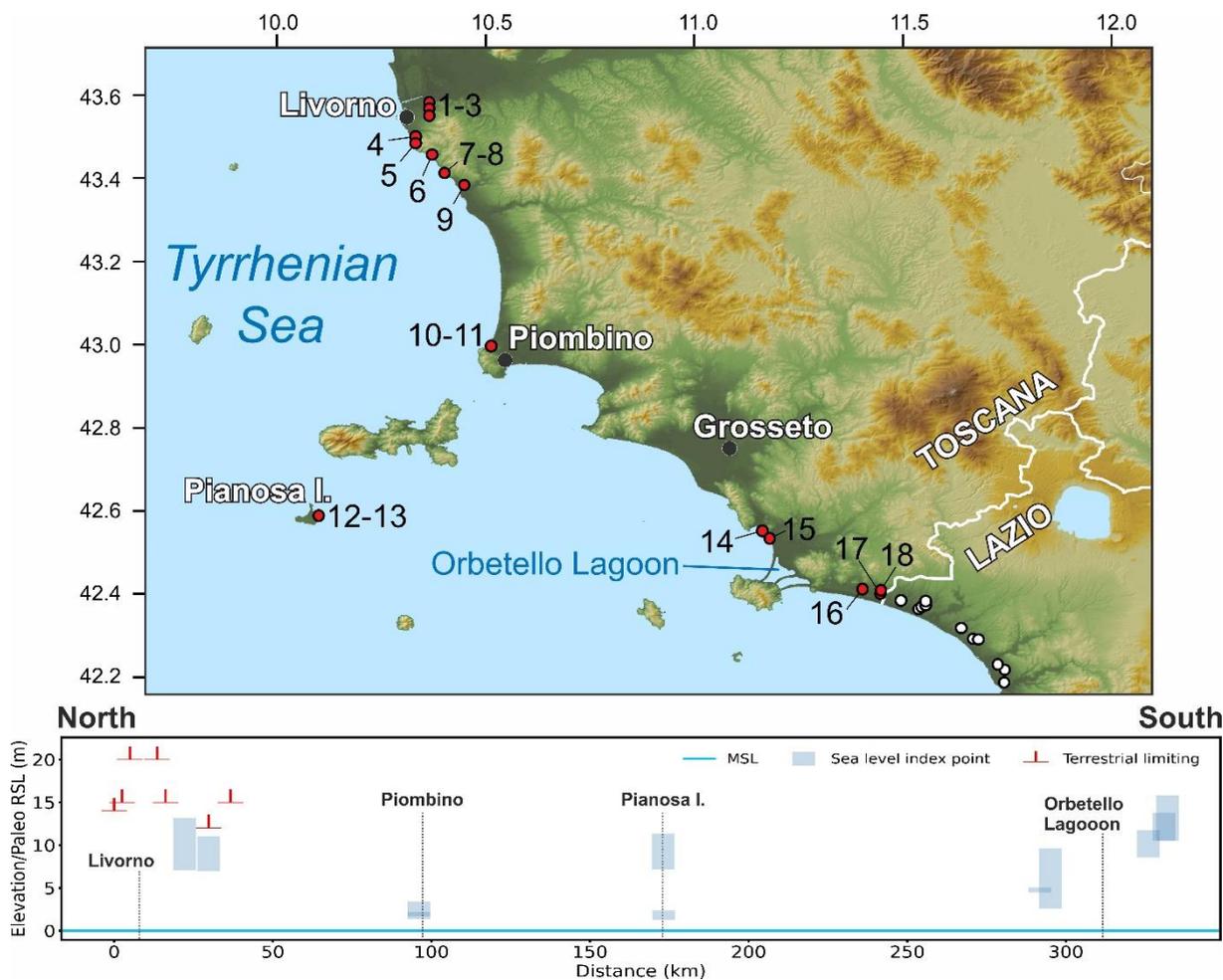



Figure 15: Last Interglacial sea-level data for Toscana (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from North (left) to South (right). Sites list: 1: Casale Vallino (RSL ID 250). 2: Pian di Rota (RSL ID 251). 3: Bagnetti (RSL ID 252). 4: Antignano (RSL ID 253). 5: Punta Casotto (RSL ID 254). 6: Quercianella (RSL ID 255). 7: Buca dei Corvi BdC1 (RSL ID 325). 8: Buca dei Corvi BdC2 (RSL ID 326). 9: Rosignano Solvay (RSL ID 329). 10: Baratti Bar 1 (RSL ID 327). 11: Baratti Bar 2 (RSL ID 328). 12: Pianosa - Cala dei turchi Upper notch and lithophaga boreholes (RSL ID 331). 13: Pianosa - Cala dei turchi Lower beach sequence (RSL ID 330). 14: Talamone (RSL ID 335). 15: Campo Regio (RSL ID 336). 16: Selva Nera (RSL ID 332). 17: San Angelino (RSL ID 334). 18: Vado Piano (RSL ID 333).

405 **Figure 16: Shelly-rich Last Interglacial deposit at Pianosa, Tuscany, Italy, at 1.7m above present sea level (RSL ID 330). Photo by A. Rovere.**

6.3.3 Lazio

The border between Toscana and Lazio (Latium) administrative regions (Figure 17) is located in the Montalto coastal plain.
Here, Hearty and Dai Pra (1987) identified and attributed to Aminozone E (corresponding to MIS 5e) several beach deposits,
410 most of them containing Senegalese fauna. Some of these deposits were already identified at the beginning of the last
century (Gignoux, 1913; Blanc, 1935; Blanc, 1936; Blanc and Segre, 1947; Blanc and Segre, 1953; Segre, 1949; Bonadonna,
1967a-b; Radtke, 1986; Ozer et al., 1987; Palieri and Sposato, 1988; Milli and Zarlenga, 1991), and were successively
reviewed by Bordoni and Valensise (1999), Nisi et al. (2003) and Ferranti et al. (2006). These Last Interglacial beach
deposits rise in elevation from the Tuscany-Latium border towards the town of Tarquinia, reaching 25 m a.s.l. at the *Aurelia*
415 *km 103* site (RSL ID 483). Towards the city of Tarquinia, the elevation of Last Interglacial beach deposits drops again to 13-
16 m a.s.l (RSL IDs 484, 479, 480), then rise in only 16 km near Civitavecchia up to 35 m a.s.l (RSL ID 494). Hearty and
Dai Pra (1986) report only two beach deposits dated to MIS 5e southwards, towards the city of Rome (RSL IDs 495-496). At
Cava Rinaldi (RSL ID 529), Marra et al. (2016, 2019) dated a fluvial-lacustrine deposit (that we consider in the database as a
terrestrial limiting point) at 26 m a.s.l to MIS 5e (129±2ka) with ^{40}Ar/^{39}Ar thanks to the presence of an intercalated
420 pyroclastic-flow deposit. Fifty kilometers south of Rome, (Marra et al., 2019) dated one mollusk (*Glycymeris sp*) with ESR
and one coral (*Cladocora sp.*) with U-Series from a locality called *Quadrato* (RSL ID 527), at 11 m a.s.l. The ESR sample
gave an age of 79±7ka, while the U-Series one yielded an age of 198±8ka, which was rejected due to a probable opening of

the U-Th system. Based on the ESR results and correlations of terrace levels across Lazio, Marra et al. (2019) conclude that MIS 5a peaked locally at 12 m a.s.l, MIS 5c at ca. 23 m a.s.l and MIS 5e attained much higher levels, at around 35 m a.s.l.

425 These conclusions are at odds with the attribution of similar deposits to Aminozone E (Hearty and Dai Pra, 1986, 1987). Also, two nearby sites (RSL IDs 497 and 498) were reported by Hearty and Dai Pra (1987) at roughly the same elevation and with similar stratigraphic characteristics of the *Quadrato* site were attributed to Aminozone E, hence to MIS 5e. Further to the South, in the Pontina plain (RSL IDs 513 to 518), Antonioli et al. (1999b) reported lagoonal deposits in cores reaching several meters below present sea level, again dated to Aminozone E. Similarly, in the Fondi plain (south of the city of

430 Latina), Antonioli et al. (1988) report MIS 5e deposits down to 6 m b.s.l (RSL ID 508). Last Interglacial sea-level indicators above present sea level (such as beach deposits and tidal notches correlated to them) were instead reported in the headlands of Circeo, Terracina, Torre Capovento, Sperlonga, and Gaeta (Hearty and Dai Pra, 1986; Bordoni and Valensise, 1999; Ferranti et al., 2006; Antonioli et al., 2018). Within two caves, called *Grotta dei Moscerini* and *Grotta Guattari*, Marra et al. (2019, 2020) report that Schwarcz et al. (1991a-b) dated "backbeach" deposits few meters above sea level to MIS 5a-MIS5c.

435 Within this study, it was possible to retrieve only the paper on *Grotta Guattari* by Schwarcz et al. (1991a), reporting that "*the sedimentary fill of Grotta Guattari was deposited over a short interval, commencing soon after the retreat of sea level after stage 5 and terminating at about 57,000 years B.P*". As it seems difficult to derive reliable sea-level information from similar indicators, we did not insert these data points into WALIS pending further studies on these sites.

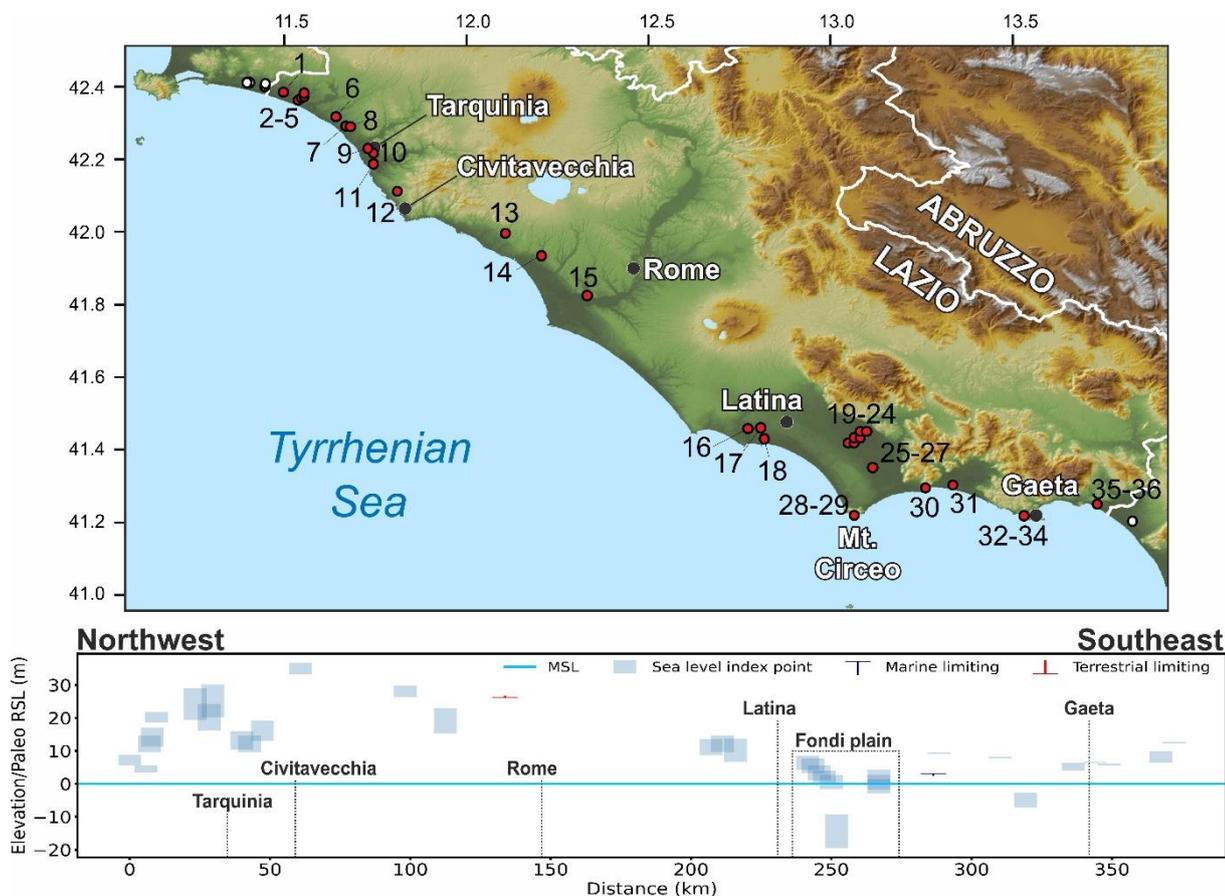



Figure 17: Last Interglacial sea level data for Lazio (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from Nortwest (left) to Southeast (right). Sites list: 1: Lasco Del Pozzo (RSL ID 354). 2: Centrale Nucleare Montalto di Castro (RSL ID 475). 3: La Ficonaccia (RSL ID 476). 4: Ponte Rotto (RSL ID 477). 5: Km 115.5 (RSL ID 478). 6: Il Mandrione, right bank of Arrone River (RSL ID 482). 7: Between Arrone and Mignone rivers (RSL ID 481). 8: Aurelia km 103 (RSL ID 483). 9: Northwest of Tarquinia railway station (RSL ID 484). 10: F. delle Serpe (RSL ID 479). 11: Casale Olivastro (RSL ID 480). 12: Monna Felice (RSL ID 494). 13: Monteroni - Cerveteri (RSL ID 495). 14: Casale di Statua (RSL ID 496). 15: Cava Rinaldi (point d) (RSL ID 529). 16: Quadrato (RSL ID 527). 17: Borgo Santa Maria, west of Latina (RSL ID 497). 18: Borgo Sabotino (RSL ID 498). 19: Pontinia I (RSL ID 513). 20: Pontinia II (RSL ID 514). 21: Pontinia III (RSL ID 515). 22: Pontinia IV (RSL ID 516). 23: Pontinia V (RSL ID 517). 24: Pontinia VI (RSL ID 518). 25: Borgo Vodice I (RSL ID 519). 26: Borgo Vodice II (RSL ID 520). 27: Borgo Vodice III (RSL ID 521). 28: Torre Rossa (RSL ID 499). 29: Circeo (Grotta delle Capre) (RSL ID 522). 30: Terracina (Pisco Montano) (RSL ID 523). 31: Fondi plain core ATP4 (RSL ID 508). 32: Torre Capovento (RSL ID 500). 33: Sperlonga (Sant'agostino) (RSL ID 524). 34: Gaeta (Grotta del Turco) (RSL ID 525). 35: Marina di Minturno (RSL ID 501). 36: Minturno (Monte d'Argento) (RSL ID 526).

6.3.4 Campania

South of Latium, Last Interglacial sea-level records in Campania have been reported both from subsurface (i.e., in the Garigliano and Campana coastal plains) and surface (mainly along the Cilento promontory, Sele Plain, Sorrento Peninsula, and Capri island) data (Figure 18). The most recent review on the Quaternary evolution of the Campania coastal plains was compiled by Santangelo et al. (2017). These authors reconstructed, with both previously published and new subsurface data, the distribution of a marine unit that was correlated to MIS 5e thanks to a U-Series age on fragments of *C. caespitosa* (126 ±11 ka, USeries ID1964) found in the *San Marcellino core* (RSL ID 722, Romano et al., 1994, see below).

In the Garigliano Plain, at the *Masseria Transitiello* site (near the Cellole Aurunci village, RSL ID 3624), Brancaccio et al. (1990) correlated biocalcarenites (AAR ID 168) cropping at few meters above sea level with a tidal notch at 8 m a.s.l. at *Minturno-Monte D'Argento* (RSL ID 526, see the previous section). Six specimens of *Glycimeris glycimeris* from *Masseria Transitiello* have been dated with AAR giving a D/L value (0.40 ± 0.02) corresponding to Amminozone E, correlated to MIS 5e by Hearty and Dai Pra (1986).

In the Campania plain, MIS 5e marine deposits have been found at 50 m b.s.l. in the *San Marcellino* core (RSL ID 722) (Romano et al., 1994). Last Interglacial sea-level proxies were also found at 18 m b.s.l. in the *San Marco Evangelista* borehole (Santangelo et al., 2010), near Caserta, about 28 km far from the modern coastline (RSL ID 739). In this borehole, the Last Interglacial transgression was constrained by the integration of tephro-stratigraphic and radiometric analysis ($^{40}Ar/^{39}Ar$) on volcanic layers. Towards the southern edge of the Campania Plain (near the town of Sarno), MIS 5e proxies were reported by Cinque et al. (1987) and Barra et al. (1991) at 23 m b.s.l. (top of marine unit), constrained by U-dating on *C. caespitosa* and the warm species *Sylvestra seminis* (RSL ID 790).

In the Cancello area, towards the northeast border of the Campania plain, Romano et al. (1994) assigned a marine terrace at 50 m a.s.l. to MIS 5e correlating it with the *C. caespitosa* dated at *San Marcellino* core, described above. However, a recent work (Cerrone et al., submitted) correlates the formation of this raised marine terrace to an older MIS, constrained by new U-Series dating. This point was therefore not inserted in the database.

Last Interglacial sea-level proxies in the Sorrento Peninsula crop out mainly on the southern edge, at elevations comparable with those recorded in other tectonically stable areas of the Tyrrhenian Sea. In particular, at *Cala di Ieranto* (RSL ID 721) and *Conca dei Marini* (RSL ID 720) Brancaccio et al. (1978) dated *C. caespitosa* and mollusks to constrain the age of tidal notches at 7.5 m a.s.l. According to these authors, their sample C-2 (USeries ID 1955, on a mollusk shell) yields an age younger than the one obtained for the *C. caespitosa* as a consequence of the opening of the chemical system as confirmed by the high $^{234}U/^{238}U$ ratio. In *Conca dei Marini*, U-Series dating and geomorphological investigations by Iannace et al. (2003)

and Riccio et al. (2001) allowed recognition of three distinct Last Interglacial sea-level peaks, with a double notch at 6.5 m

485 (RSL ID 766) and ca. 8 m a.s.l. (RSL ID 3565) and another tidal notch at 3.5 m a.s.l. (RSL ID 767). Moreover, Riccio et al. (2001) tentatively correlated to MIS 5a a tidal notch at 2 m a.s.l. at *Conca dei Marini*, and widespread visible on the southern edge of Sorrento Peninsula (RSL ID 3623). Such age estimation is supported by geomorphological correlation constrained on a date published by Brancaccio et al. (1978).

Ferranti and Antonioli (2007) measured the elevation of the Tyrrhenian tidal notch along the coasts of the Capri Island. The

490 elevation of the notch varies between 5.2 and 8 m a.s.l., and it has been assigned an MIS 5e age by correlation with a U-Series age on *C. caespitosa* from the bay of Ieranto, at the southern edge of Sorrento Peninsula (RSL IDs from 800 to 822, Figure 19) (Brancaccio et al., 1978).

In the Sele coastal plain, Brancaccio et al. (1986, 1987) have recognized and dated with AAR two marine deposits bearing *Glycimeris glycimeris* specimens. Based on such dating, the *Gromola ridge* site (up to 13 m a.s.l.) has been correlated to

495 MIS 5c (RSL ID 770), whereas the *Ponte Barizzo ridge* site, reaching an elevation of 25 m a.s.l., to MIS 5e (RSL 769).

Many records of MIS 5e were reported at elevations ranging from 7-8 up to 10-15 m a.s.l. along the coasts of the Cilento promontory. These were assigned an MIS 5 age with AAR, U-Series, and stratigraphic constraints (presence of *P. latus)*. In particular, Brancaccio et al. (1990) dated marine deposits bearing *Glycimeris glycimeris* associated with the marine terraces of *Ogliasto Marina* (RSL ID 592), *Sapri* (RSL ID 791-792), and Palinuro (*Lido Ficocella*, RSL ID 593). The age provided

500 from the Palinuro site is correlated to MIS 5. Also, the presence of *P. latus* fragments at elevations up to 2-3 m a.s.l. allowed Antonioli et al. (1994a) to correlate a tidal notch in the same elevation range along the Palinuro Cape (RSL ID 732) to MIS 5e.

Between Ogliastro Marina (Licosa Cape) and Agropoli, Cinque et al. (1994) recognized a flight of marine terraces and related the three lowest ones to the 3 peaks of MIS 5. This chronological attribution has been confirmed by Iannace et al.

505 (2001) using U-Series dating on coralline algae. In this area, the marine terrace at 1.5 m a.s.l. is related to MIS 5a, the one at 5 m a.s.l. to MIS 5c, and two distinct terraces at 9 and 6.6 m a.s.l. have been assigned an MIS 5e age. A detailed morpho-stratigraphic analysis based on cross-cut relationship and Th/U age on speleothems allowed Esposito et al. (2003) to identify MIS 5c and 5a sea-level proxies in the *Cava/Riparo degli Infreschi* at 8.5 and 3.5 m a.s.l., respectively. However, recent works by Bini et al. (2020), reported no evidence for MIS 5c and MIS 5a, proposing a different paleoenvironment

510 reconstruction of the *Riparo degli Infreschi* outcrop (RSL IDs 3568 to 3576) based on new U-Series dating and tephra correlations. The new U-Series dates were performed on speleothems and calcite filling *L. lithophaga* boreholes; since such materials take shape above sea level, they have been included in the database as terrestrial limiting. The top of *L. lithophaga* boreholes, measured at 8.9 m a.s.l. inside the *Riparo degli Infreschi* has been related to MIS 5e (RSL ID 3568).

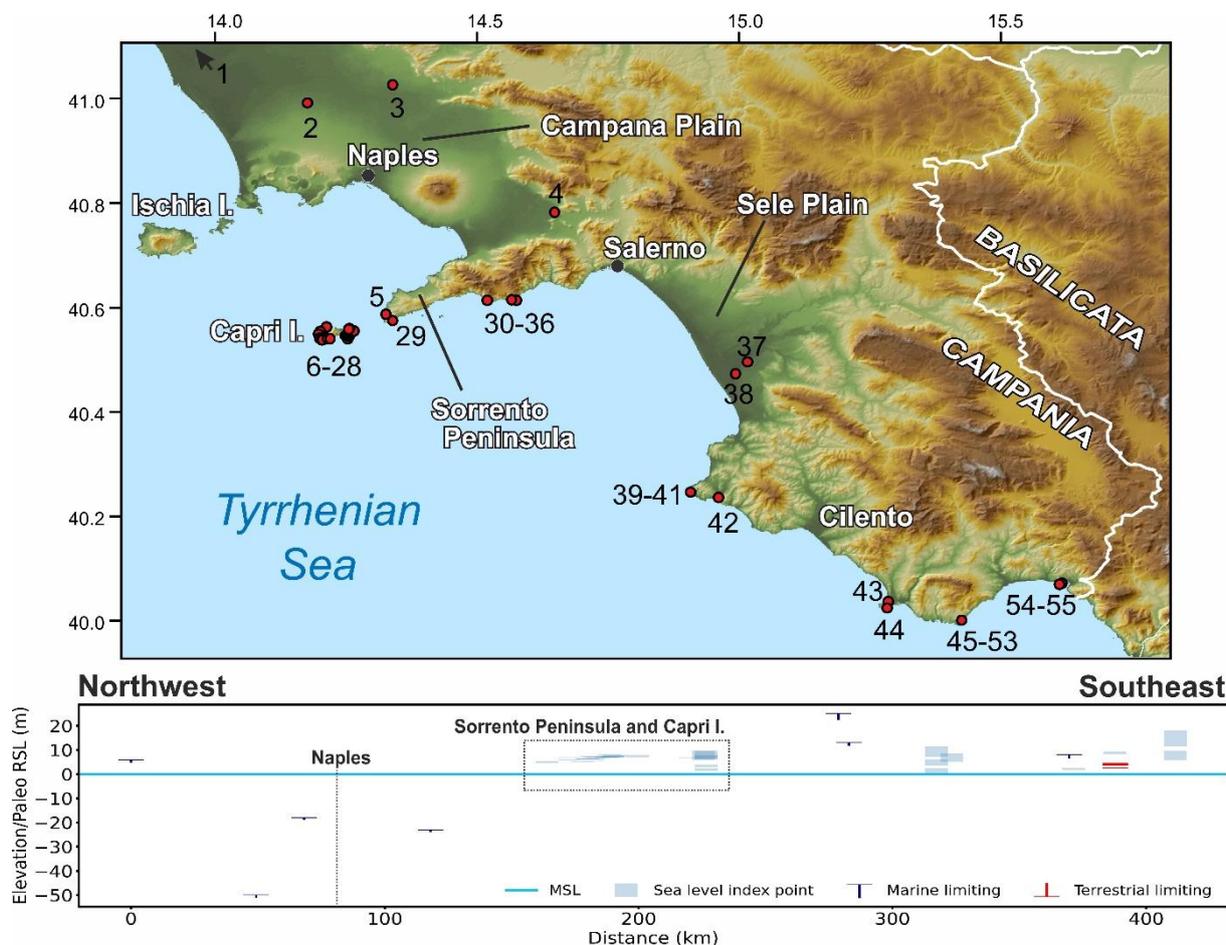



Figure 18: Last Interglacial sea level data for Campania (Italy). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from Northwest (left) to Southeast (right). Sites list: 1: Cellole Aurunci Masseria Transitiello (RSL ID 3624). 2: San Marcellino core (RSL ID 722). 3: San Marco Evangelista (RSL ID 739). 4: Sarno well (RSL ID 790). 5: Mitigliano (RSL ID 3581). 6: Scoglio Ricotta (I) Capri (RSL ID 821). 7: Scoglio Ricotta (II) Capri (RSL ID 822). 8: Grotta Testa del Cavallo Capri (RSL ID 800). 9: Grotta Jannarella Capri (RSL ID 801). 10: P.ta Campitiello Capri (RSL ID 802). 11: Cala del Limmo Capri (RSL ID 803). 12: Cala Articola (II) Capri (RSL ID 805). 13: Cala Articola (I) Capri (RSL ID 804). 14: Cala Articola (III) Capri (RSL ID 806). 15: Grotta Verde (I) Capri (RSL ID 807). 16: Grotta Verde (II) Capri (RSL ID 808). 17: Gr. Belvedere Capri (RSL ID 809). 18: Gr. Fontolina Capri (RSL ID 810). 19: I Faraglioni Capri (RSL ID 811). 20: Porto di Tragara (I) Capri (RSL ID 812). 21: Porto di Tragara (II) Capri (RSL ID 813). 22: P.ta di Masullo Capri (RSL ID 814). 23: a vascio funno Capri (RSL ID 815). 24: Cala Matermiana Capri (RSL ID 816). 25: Gr. Bianca (I) Capri (RSL ID 817). 26: Gr. Bianca (II) Capri (RSL ID 818). 27: P.ta della Chiavica Capri (RSL ID 819). 28: P.ta del Monaco Capri (RSL ID 820). 29: Cala di Ieranto (RSL ID 721). 30: Vettica Maggiore (RSL ID 823). 31: Grotta dello Smeraldo (RSL ID 798). 32: Conca dei Marini (III) Site I (RSL ID 767). 33: Conca dei Marini (II) Site I (RSL ID 766). 34: Conca dei Marini (I) Site I (RSL ID 720). 35: Conca dei Marini (V) (RSL ID 3623). 36: Conca dei Marini (IV) Site I (RSL ID 3565). 37: Ponte Barizzo (RSL ID 769). 38: Gromola (RSL ID 770). 39: Licosa Cape (III) (RSL ID 728). 40: Licosa Cape (II) (RSL ID 727). 41: Licosa Cape (I) (RSL ID 726). 42: Ogliastro Marina Baia Arena (RSL ID 592). 43: Palinuro Lido Ficocella (RSL ID 593). 44: Palinuro Cape (RSL ID 732). 45: The Riparo Infreschi cave (I) (RSL ID 3568). 46: The

Riparo Infreschi cave (II) (RSL ID 3569). 47: The Riparo Infreschi cave (III) (RSL ID 3570). 48: The Riparo Infreschi cave (VI) (RSL ID 3573). 49: The Riparo Infreschi cave (IX) (RSL ID 3576). 50: The Riparo Infreschi cave (VIII) (RSL ID 3575). 51: The Riparo Infreschi cave (VII) (RSL ID 3574). 52: The Riparo Infreschi cave (V) (RSL ID 3572). 53: The Riparo Infreschi cave (IV) (RSL ID 3571). 54: Sapri (II) (RSL ID 792). 55: Sapri (RSL ID 791).

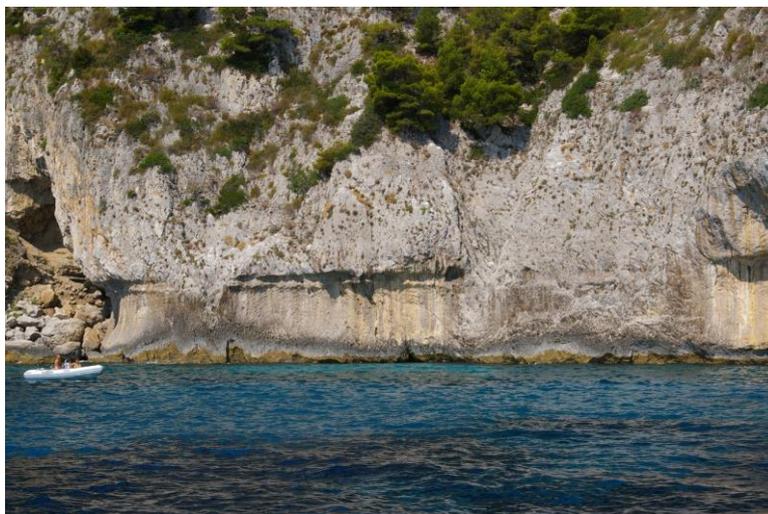



Figure 19: Tidal notch at Capri Island, *a Vascio Funno* site (RSL ID 815). Photo by A. Ascione

6.3.5 Basilicata and Calabria, Tyrrhenian side

The Last Interglacial sea-level proxies on the Tyrrhenian seaside of Basilicata have been attributed to the marine terraces up to ca. 8-10 m a.s.l (Figure 20), from Fiumicello to Castrocucco (Carobene et al., 1986; Carobene and Dai Pra, 1991), and northern Calabria coast, from Castrocucco to nearby Cetraro (Torre la Testa, Carobene et al. 1986; Carobene and Dai Pra 1990). Such interpretation is based on a geomorphological correlation derived from the identification of the Middle-Late Pleistocene terraces, which have been constrained by U-Series and AAR dating on *C. caespitosa* and Bivalvia respectively. However, recently Cerrone et al. (2018, 2021a) have rejected such dating and have reconstructed the evolution of the area spanning from nearby Fiumicello (Basilicata) to Scalea (Calabria), providing new U-Series dating on the marine deposits (biocalcarenites bearing *C. caespitosa* corals) associated with the marine terraces corresponding to MIS 5a, 5c, and 5e, which stand up to some tens of meters.

The promontory of Capo Vaticano (RSL ID 267 to 270, 314 to 316, 3430, and 3431) has been deeply investigated in the last decades and many dating (OSL, TL, and U-Series) have been provided, but a debate on the age and spatial distribution of the marine terraces of the area is still open due to the complexity of the structural setting. Bianca et al. (2011), performed OSL dating on unconsolidated sandy layers associated with marine terraces, and correlated to MIS 5c the marine terrace at 50 m a.s.l. in Vibo Marina. The 5c terrace of Bianca et al. (2011) reaches 175 m a.s.l. at Capo Vaticano (RSL ID 269). Such

correlation is strengthened by TL dating of Balescu et al. (1997). However, Pata (1947) reported *P. latus* specimens within the +50 m a.s.l. terrace in Vibo Marina (RSL ID 267), which allowed Dai Pra et al. (1991), Dumas et al. (1991), and Roberts et al. (2013) to consider such terrace of MIS 5e age. The last interpretation is supported by Roberts et al. (2013) based on U-Series dating (USeries ID 2665 and 2666) and by the use of a synchronous correlation method.

Starting from the work of Gignoux (1913) who reported the presence of *P. latus* and Senegalese fauna in the *Bovetto* (RSL ID 306) and *Ravagnese* areas (RSL ID 304 and 305) up to ca. 130 m a.s.l., this area was investigated by Hearty et al. (1986a-b) and Balescu et al. (1997), respectively dating the deposits with AAR and TL. Another terrace, at Altibano (RSL ID 313), was correlated by Balescu et al. (1997) to MIS 5e, while according to Dumas et al. (1988) and Dumas et al. (1987) the same terrace was formed before the Last Interglacial.

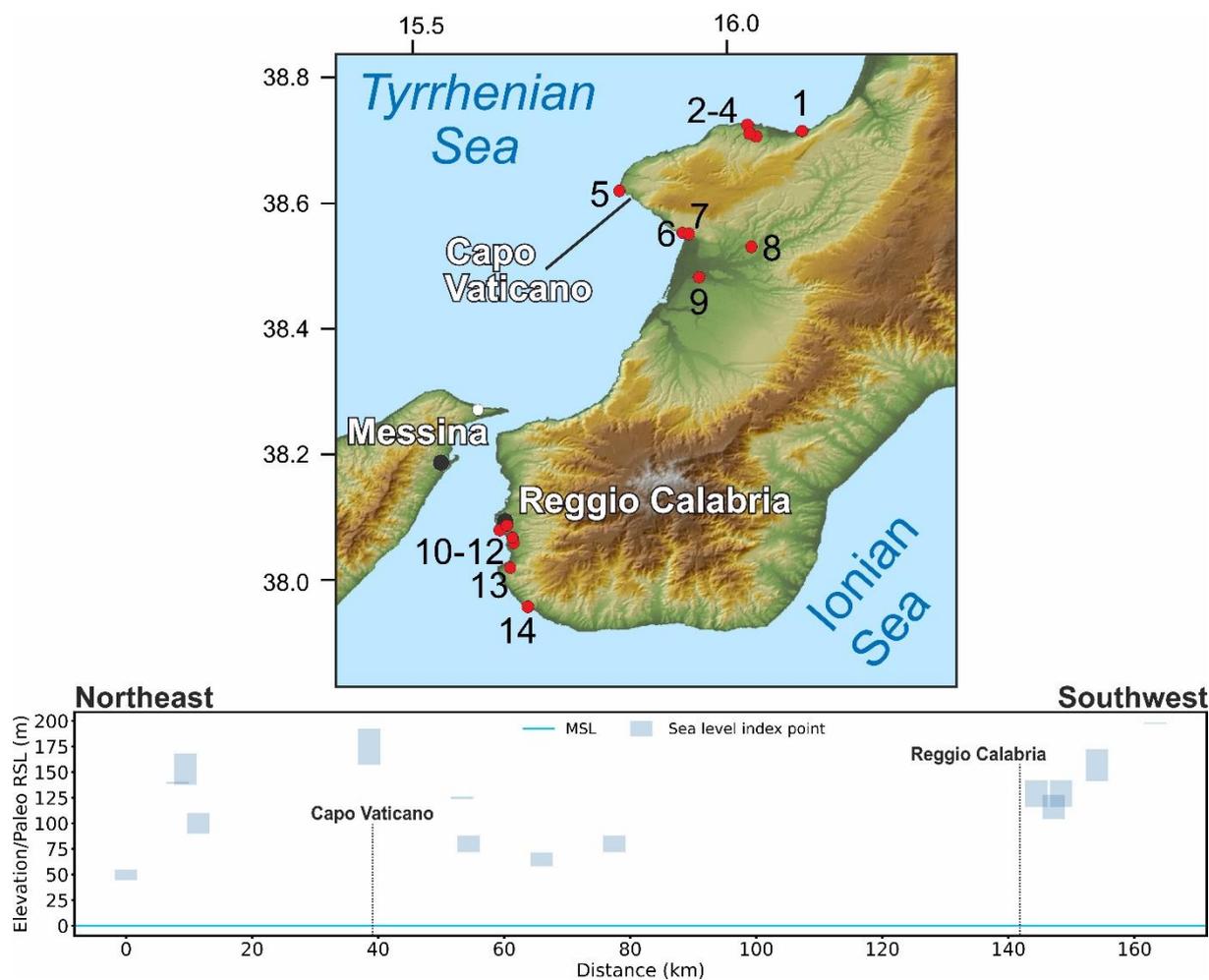



Figure 20: Last Interglacial sea-level data for the Tyrrhenian side of Calabria and Basilicata (Italy). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. Lower panel: Distance/Elevation graph, from Northeast (left) to Southwest (right). Sites list: 1: Vibo Marina (RSL ID 267). 2: Paradisoni (RSL ID 315). 3: Sacco (RSL ID 316). 4: Briatico (RSL ID 268). 5: Capo Vaticano (RSL ID 269). 6: Nicotera (RSL ID 270). 7: Gioia Tauro Contrada Iannì (nearby Nicotera) (RSL ID 3431). 8: Gioia Tauro basin (RSL ID 3430). 9: Rosarno (RSL ID 314). 10: Ravagnese (RSL ID 304). 11: Trombaca (RSL ID 312). 12: Bovetto (RSL ID 306). 13: Nocella Pellaro (RSL ID 1378). 14: Altibano (RSL ID 313).

6.3.6 The Ionian coast of Calabria and Basilicata

Along the Ionian Sea coasts of Calabria and Basilicata (Figure 21) we identified several reports of the Last Interglacial shorelines. The Pleistocene marine terraces in Crotone and Isola di Capo Rizzuto (RSL ID 563 to 566, 1379, 3428), were

first reported by Cortese (1895), and have been deeply studied by successive authors (Gignoux, 1913; Cosentino and Gliozzi,
575   1988; Belluomini et al., 1988; Selli, 1962; Palmentola et al., 1990; Mauz and Hassler, 2000; Ruggieri, 1948; Zecchin et al.,
2009; Nalin and Massari, 2009). The MIS 5e marine terrace in this area has been traced up to ca. 80-110 m a.s.l., and was
dated with AAR (Belluomini et al., 1988) and TL (Mauz and Hassler, 2000). However, based on such dating, the *Capo
Colonna* Terrace (RSL ID 3634) has been correlated either to 5c or 5a. However, Nalin et al. (2012) and Palmentola et al.
(1990) found *P. latus* fossils in the *Capo Colonna* Terrace. New findings of *P. latus* at the Crotone Peninsula have been
580   reported by Bracchi et al. (2011) and Nalin et al. (2012).

In Trebisacce (RSL ID 324), at the northern border of the Sibari coastal plain, Cucci (2004) attributed an MIS 5e age (AAR
IDs 97 and 98) to the marine terrace at 128 m a.s.l. The elevation of the MIS 5e marine terrace mapped by Cucci (2004)
between Trebisacce and Lauropoli spans between 145 m to 115 m a.s.l. In the database, only the inner edge of the marine
terrace corresponding to the Trebisacce site has been included because here a direct age constraint has been provided.

585   A few kilometers northeast from Trebisacce, in *Vaccarizzo* site (RSL ID 442), Santoro et al. (2009) constrained the MIS 5e
marine terrace at 125 m a.s.l. by ESR dating on *Cardium sp.* (ESR ID 100).

Even if a very well developed flight of marine terraces (decreasing in elevation towards North-East) crops out along the
Ionian coast of Basilicata, their age is poorly constrained.

In *Piano San Nicola* (RSL ID 416), near the town of Nova Siri, the marine terrace, which inner edge was reported at 90 m
590   a.s.l., was correlated to MIS 5c or 5a by AAR dating (Dai Pra and Hearty 1988). An MIS 5e terrace at the same site has been
identified based on geomorphological correlation. But, as no age constraints have been provided, it is not included in the
database.

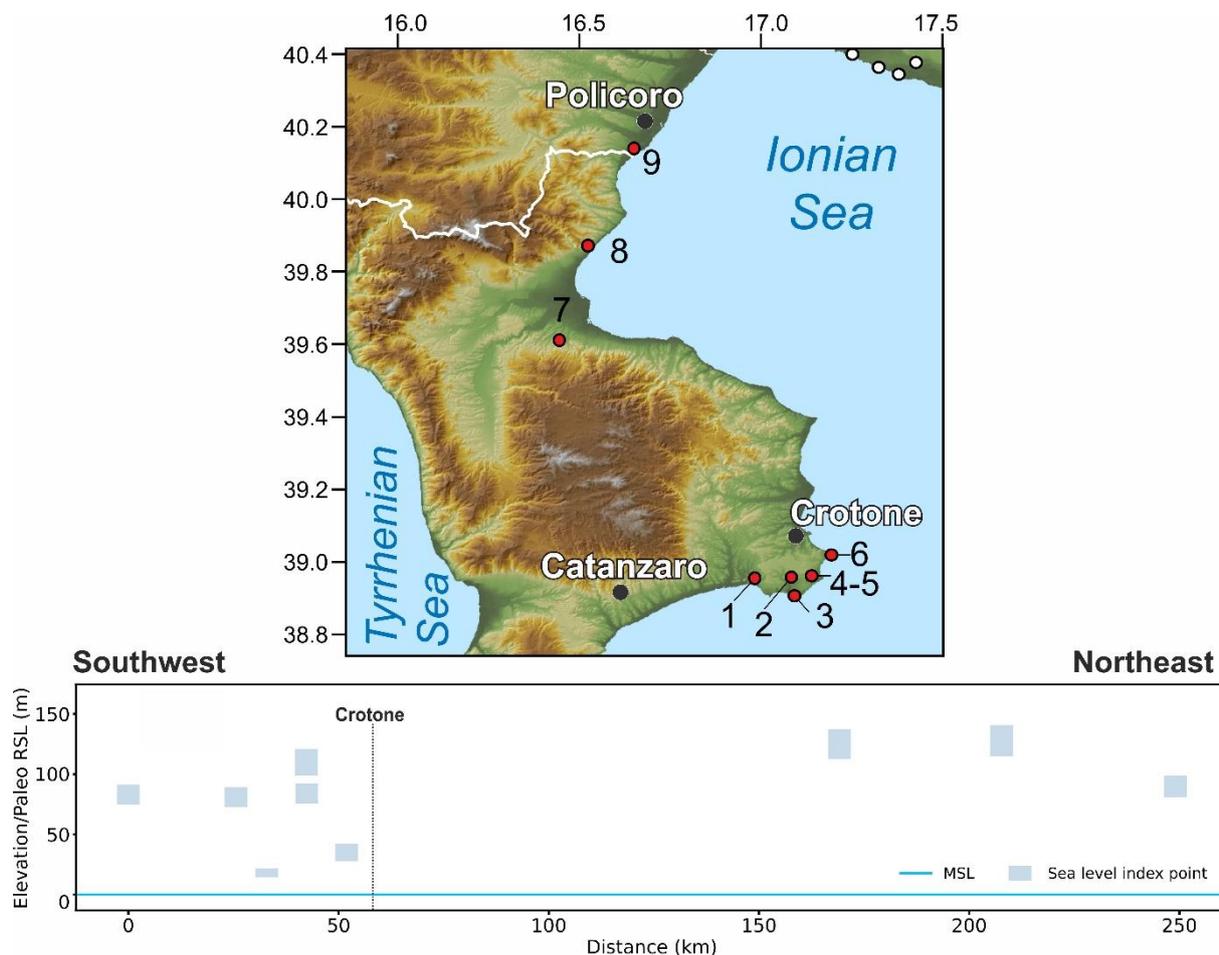



Figure 21: Last Interglacial sea-level data for the Ionian side of Calabria and Basilicata (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from Southwest (left) to Northeast (right). Sites list: 1: San Leonardo di Cutro (RSL ID 563). 2: Manca della Mozza. (RSL ID 566). 3: Isola di Capo Rizzuto (RSL ID 565). 4: Capo Rizzuto (RSL ID 564). 5: Crotone (II) (RSL ID 3428). 6: Crotone (RSL ID 1379). 7: Capo Colonna Terrace (RSL ID 3634). 8: Vaccarizzo (RSL ID 442). 9: Trebisacce (RSL ID 324). 10: Piano San Nicola (RSL ID 416).

6.3.7 Puglia

Along the Ionian coasts of Puglia (Figure 22), near the border with Basilicata, at *Ponte del Re-Castellaneta* site (RSL ID 355) a marine terrace up to 40 m a.s.l. was correlated with MIS 5e thanks to the presence of Senegalese fauna with *P. latus* (Boenzi et al., 1985). The correlation was later confirmed by AAR dating on marine deposits bearing *Glycymeris* (Dai Pra and Hearty, 1988). Eastwards of this site, in the Taranto area and Chéradi Islands, several outcrops were studied for nearly

one century (Gignoux 1913; Cotecchia et al. 1969; Hearty and Dai Pra 1992; Gigout 1960; Gigout 1962; Verri and De Angelis D'Ossat 1899; Richetti 1967; Caldara 1987). These deposits are characterized by the widespread presence of *P. latus,* Senegalese fauna and *C. caespitosa* corals (RSL ID 223 to 226, 228, 230, 355, 695 to 705, 3630 to 3632).

In particular, the section cropping out at *Il Fronte* (RSL ID 230, near the city of Taranto) has been recently analyzed in detail
610 for stratigraphy, chronology, sedimentology, and paleoecological aspects, highlighting the possibility to use this place as a Global Stratotype Section and Point (GSSP) (Amorosi et al. 2014). The outcrop of *Il Fronte* site consists of an 8.5 m thick succession made up of 5 marine Units. Detailed facies analyses integrated with sequence stratigraphy and U-series dating allowed Amorosi et al. (2014) to reconstruct in detail sea-level fluctuations during the MIS 5e at *Il Fronte* site. In particular, the base of the succession is characterized by nearshore deposits which evolve upwards to inner-shelf and middle-outer shelf
615 deposits. The MIS 5e coastline elevation in this area has been traced by Dai Pra and Stearns (1977) up to 35 m a.s.l. in Ponte Romano (RSL ID 3631).

South of Taranto, specimens of *P. latus* were reported in *Torre Castelluccia* (RSL ID 705), *Torre Castiglione* (RSL ID 696), and near Gallipoli. At *Torre Castelluccia*, a pocket beach at 3 m a.s.l. has been constrained to the Amminozone C (Dai Pra and Hearty 1988), while the MIS 5e shoreline, containing *P. latus*, was located at 28 m a.s.l. in the surroundings of *Lizzano*
620 (RSL ID 695). The MIS 5e terrace in *Torre Castiglione* (RSL ID 696) has been reported at 2.5 m a.s.l. (Dai Pra and Stearns 1977). Moreover, at *Gallipoli* site (RSL ID 3625, 3267, and 3268), *Glycymeris* specimens sampled at 8-10 m a.s.l. were constrained with AAR to MIS 5e (Dai Pra and Hearty 1988).

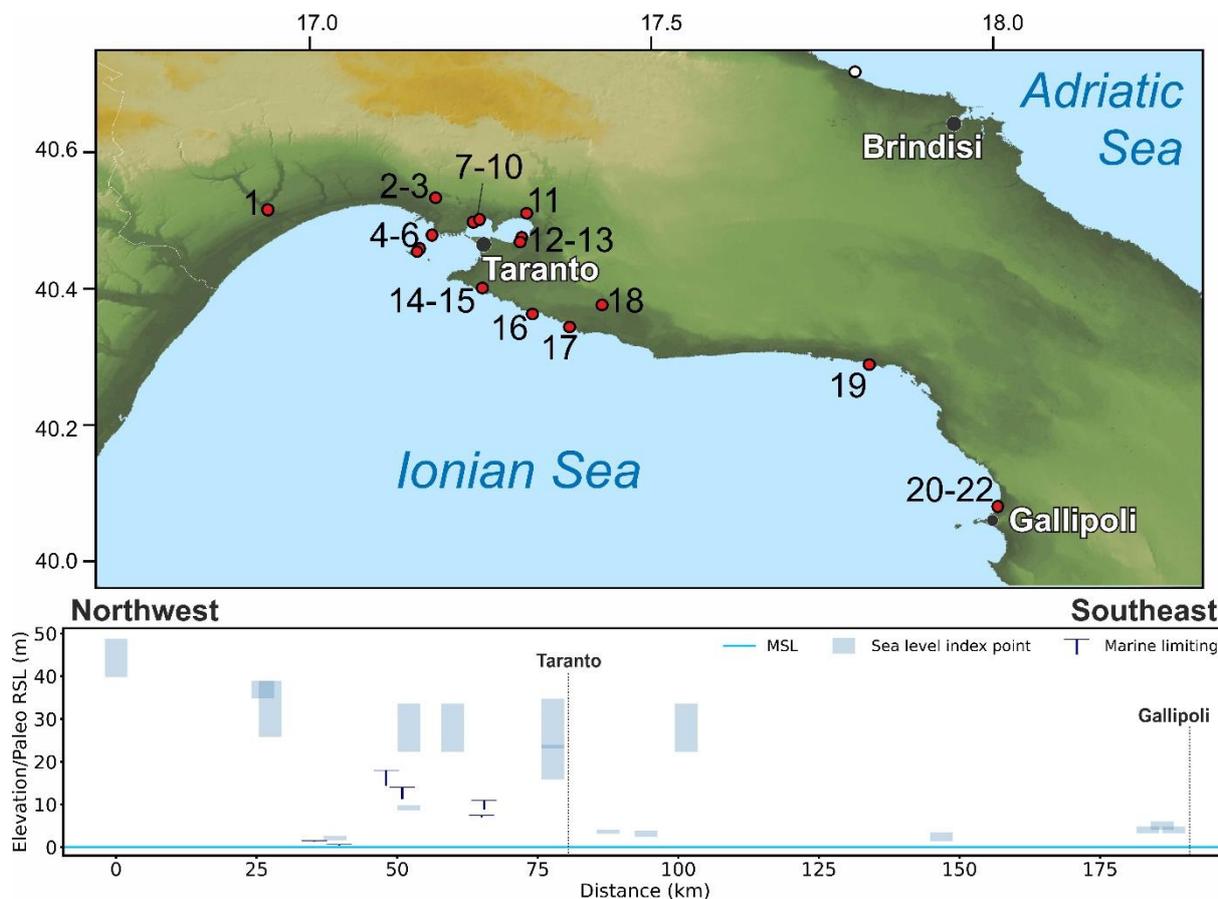



Figure 22: Last Interglacial sea level data for the Ionian side of Puglia (Italy). Upper panel: Map of sites. Red dots are sites in the 625 **region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from Northwest (left) to Southeast (right). Sites list: 1: Ponte del Re (RSL ID 355). 2: Ponte Romano Taranto (RSL ID 3631). 3: Masseria S. Giovanni Taranto (RSL ID 697). 4: Punta Rondinella (RSL ID 224). 5: Punta lo Scanno (RSL ID 225). 6: Apodonia (RSL ID 228). 7: Masseria Ruggiero Taranto (RSL ID 3632). 8: Masseria Bagnara (RSL ID 704). 9:** 630 **Masseria Santa Teresiola (RSL ID 223). 10: Masseria Santa Teresiola (II) (RSL ID 3630). 11: Masseria San Pietro (RSL ID 699). 12: Il Fronte (RSL ID 230). 13: Masseria Pantaleo (RSL ID 701). 14: Carelli Between Carelli and Saturo harbour (RSL ID 698). 15: Il Posto Between Il Posto and Torre Castelluccia (RSL ID 700). 16: Punta della Baracca (RSL ID 226). 17: Torre Castelluccia (RSL ID 705). 18: Lizzano (RSL ID 695). 19: Torre Castiglione (RSL ID 696). 20: Torre Sabea Gallipoli (RSL ID 3625). 21: Gallipoli (RSL ID 3627). 22: Torre San Giovanni Gallipoli (RSL ID 3628).**

635 Towards the Adriatic Sea side of Puglia (Figure 23), at the bottom of *Grotta Romanelli* (RSL ID 1319), a marine deposit

(elevation between 7 and 8 m a.s.l.) was correlated with MIS 5 (Blanc 1920,1928) and re-assessed by Cosentino and Gliozzi

(1988). These authors, though, wrongly reported the presence of *P. latus* (Mastronuzzi et al. 2007). Based on stratigraphic

correlations and U-Series dating of flowstones, Mastronuzzi et al. (2007) reported a series of sea caves along the southern

Salento coasts between 0 up to 10 m a.s.l (RSL IDs 1319,1320,1323 and 1324, 3635). The sea caves were reshaped by the

640   sea during the MIS 9.3, MIS 5e and MIS 5a. We included in the database only the speleothem (USeries ID 2958) constraining the MIS 5a at 3 m a.s.l. in the *Grotta del Diavolo* site (RSL ID 3635) because the others dating of Mastronuzzi et al. (2007) allow defining a sea-level transgression older than MIS 5. Overall, according to the evolution modeling proposed by Mastronuzzi et al. (2007), such sea caves have been reshaped by the sea during the MIS 5e testifying to the tectonic stability of the area.

645   In the Apulian Tavoliere plain, the dating of *Glycymeris sp.* from *MM4* borehole (De Santis et al. 2010) allowed to include in the database three marine limiting datapoints (RSL ID 452 to 454). North of the Gargano promontory, near Ripalta at the mouth of the Fortore River floodplain, Bordoni and Valensise (1999) tentatively associated the coastal plain at 25 m a.s.l. with MIS 5e based on the dating of the Holocene plain (Mastronuzzi et al. 1989). Due to the lack of robust direct dating, this site has been inserted in the database as a limiting point (RSL ID 1317).

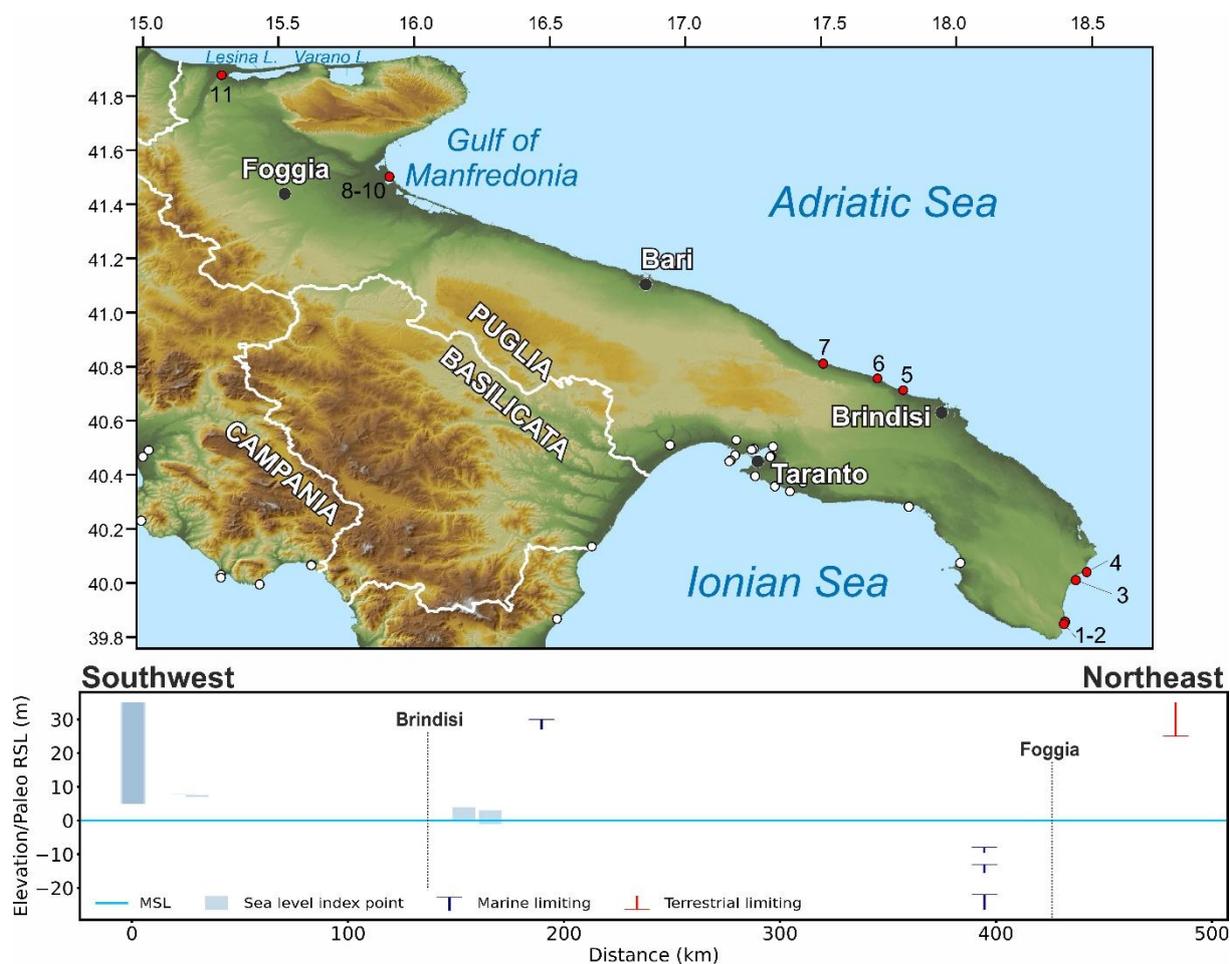



Figure 23: Last Interglacial sea-level data for the Adriatic side of Puglia (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from Southwest (left) to Northeast (right). Sites list: 1: Marina di Novaglie Southern Site of Marina di Novaglie (RSL ID 1324). 2: Marina di Novaglie Northern Site of Marina di Novaglie (RSL ID 1323). 3: Grotta Romanelli (RSL ID 1319). 4: Grotta delle Striare (RSL ID 1320). 5: Torre Mattarelle - Torre Guaceto (RSL ID 1321). 6: Torre Santa Sabina (RSL ID 1322). 7: Villanova-Monopoli (RSL ID 1318). 8: MM4 borehole Unit 13 (RSL ID 452). 9: MM4 borehole Unit 11 (RSL ID 453). 10: MM4 borehole Unit 10 (RSL ID 454). 11: Fortore River (RSL ID 1317).

6.3.8 Molise, Abruzzo and Marche

The coastal sector from Molise to the southern boundary of Romagna Plain (Figure 24) extends for about 300 km and is generally characterized by narrow sandy beaches occurring at the base of the pre-Quaternary bedrock, that is commonly very close to the Holocene coastal morphostratigraphic units and often separated from them by a cliff of 5-15 m of elevation. In

some limited sectors, the rocky coast is facing the sea as near Vasto, between Fossacesia and Ortona, Numana and Ancona, Fano and Pesaro and Pesaro and Gabicce.

665 The previous reviews and databases of sites with deposits of Last Interglacial in the Marche region described in Ferranti et al. (2006) are derived from the work by Vannoli et al. (2004) in which some of the terraces occurring along the coast of the Marche region have been attributed to the Last Interglacial. Anyhow, the surveys carried out in the framework of the new geological map of Italy (Guerrara and Tramontana, 2011) and other recent investigations didn't find any clear evidence of coastal deposits related to the Last Interglacial. On the contrary, the terraces consist of alluvial deposits dating to the Upper

670 Pleistocene, but they are referred to as MIS 3 and 2. In light of this new information, the sites described in Ferranti et al. (2006) as the inner margin of terraces are considered in our compilation as alluvial and not related to MIS 5e.

6.3.9 Emilia Romagna

The alluvial plains facing the Italian side of Northern Adriatic, from Rimini to Monfalcone, are characterized by a subsiding tectonic setting, mainly related to the crustal flexuring connected to the Apennines and the compaction of Quaternary

675 sediments (cf. Carminati et al., 2003; Ferranti et al., 2006). Thus, the deposits of MIS 5e are not cropping out in this area, but they are buried in the subsoil of the coastal plain at depths ranging from 35 to 120 m b.s.l. Anyhow, in Emilia-Romagna the Geological Survey of the region collected a vast database of underground data (i.e. logs of stratigraphic boreholes, geotechnical tests, and water wells) in which a significant number of cores sampled the coastal deposits of MIS 5e (Figure 24). The database has been mainly produced in the framework of the new geological map (CARG project) but has been also

680 checked and tuned with specific stratigraphic and paleoenvironmental studies. In particular, Amorosi et al. (1999, 2004) defined the main architecture of the subsoil and characterized the depositional units for their sedimentological and palynological content.

Along the northwestern coast of Adriatic, the sediments dated to the Last Interglacial correspond to a coastal wedge consisting of a transgressive-regressive cycle, which has an average maximum thickness of 15-20 m, overlapping over the

685 previous alluvial units, generally dating to MIS 6 (an example is reported in Figure 25). The marine transgression expanded on the plain and induced the progressive shifting to lagoonal, beach, and marine environments. These deposits have been later covered by the seaward progradation of deltaic systems, which can be generally related to the Po river system and the streams fed by Northern Apennines. The development of deltas probably occurred during the marine highstand of MIS 5e, around the peak of sea level. Thus, the beach facies recorded at the top of the regressive cycle are considered index points of

690 the past RSL with uncertainty between 7 and 10 m. A more significant role is played by the lagoonal and back-barrier deposits connected to the beach ridges, which have to be considered the most representative index point, with uncertainty

between 0 and -2 m with respect to the coeval RSL. Differently, the facies of prodelta and marine platform deposited several meters below sea level and are considered only as marine limiting points. The recognition of lagoonal and back-barrier facies is based on the micropaleontological content, but also on the mollusk association consisting of *Cerastoderma glaucum*,

695   *Loripes* sp., *Hydrobia* sp., *Bittium* sp., *Abra* sp, and *Cerithium* sp.

The marine transgression invested large areas and after the submersion, the action of waves developed an important ravinement surface that in many cases eroded almost completely the previous sediments connected to the sea-level rise (Figure 24). Thus, the beach and marine deposits of MIS 5e are often directly in contact over the older alluvial plain and separated from them by a sharp ravinement surface. It is worth noting that this sedimentary unconformity is rather easy to be

700   recognized in the cores in northern Adriatic, representing a major tool for stratigraphic correlation, anyhow, it is not a synchronous surface, but it is time-transgressive (Massari et al., 2004; Amorosi et al., 2008a-b).

Molluscs association is not a major chronological marker of the Last Interglacial in northern Adriatic, as the sediments are not characterized by the occurrence of Senegalese fauna with *P. latus*. Anyhow, the paleobotanical analyses carried out in few selected cores recognized the pollen associations related to warm temperate climate, characterized by broad-leafs trees

705   which can be correlated to the general Eemian biostratigraphic unit identified also in other cores of northern Italy (Massari et al., 2004; Mullenders et al., 1996; Ravazzi et al., 2014) and, in a broader scale, in northern Europe (Peeters et al., 2019). In light of this information, in our database, the stratigraphic unit of the coastal deposits of MIS 5e has been named with the generic definition of "Adriatic Tyrrhenian (Eemian pollen unit)". In Emilia-Romagna, reference cores for the pollen studies are the site *240-S13*, near Russi (RSL ID 1327), *240-S8*, near Milano Marittima (RSL ID 1308), and *223-S17*, at the southern

710   boundary of Valli di Comacchio (RSL ID 1326), and S1, south of Rimini (Amorosi et al., 1999; Campo et al., 2020).

Important geochronological constraints of these biostratigraphic units have been supported by Ferranti et al. (2006) through the ESR dates of the beach deposits forming the top of the coastal wedge and collected in cores *204-S8* (117. 0 m b.s.l., RSL ID 1308), *222-S2* (112.5 m b.s.l., RSL ID 1310) and *205-S10* (85.5 m b.s.l., RSL ID 1309). They gave an age of 129±18 ka, 154±26 ka, and 124±20 ka, respectively, demonstrating that the unit formed during MIS 5e. At the moment these are the

715   only published geochronological data in NW Adriatic for the Last Interglacial, whereas some other OSL dates for younger stages of MIS 5 have been recently produced (Amorosi et al., 2016; Campo et al., 2020).

The comparison between the elevation of the markers of the Last Interglacial with the maximum elevation reached by the sea during the highstand (i.e. some meters a.s.l.), clearly indicates that the index points recognized in the subsoil of Emilia-Romagna are not useful for investigating the paleo global mean sea level. On the contrary, these data have been used by

720   Ferranti et al. (2006) and Antonioli et al. (2009) for assessing the average rate of tectonic subsidence that occurred since the deposition of the coastal wedge of MIS 5e.

The coastal plain south of the course of the modern Po River has been significantly involved in the current tectonic deformation related to the crustal flexuring. In particular, the regional crustal subsidence increases with an SW trend; moreover, the system of thrusts and folds affecting the most external and buried part of the Apennines produced important relative uplift and downlift movements. Despite the vertical shifting suffered by the local sites, the limited chronological interval of the MIS 5e and their rather easy recognition in the subsoil allowed Amorosi et al. (2009) to reconstruct a part of the coastline and the inner limit of the lagoons extent during the Last Interglacial in the north-western Adriatic. Recently the paleogeographic setting at the MIS 5e highstand has been strongly updated and improved for the area between Rimini and the Po Delta by Campo et al. (2020). The analysis of the database of Emilia-Romagna allows mapping the environmental facies of the coastline existing at the marine highstand. We used these data, in combination with the other available markers detected in the subsoil of Northern Italy, to depict the coastline from the Apennines to the Dinaric Alps, for a length of about 300 km (Figure 24 and Figure 26).

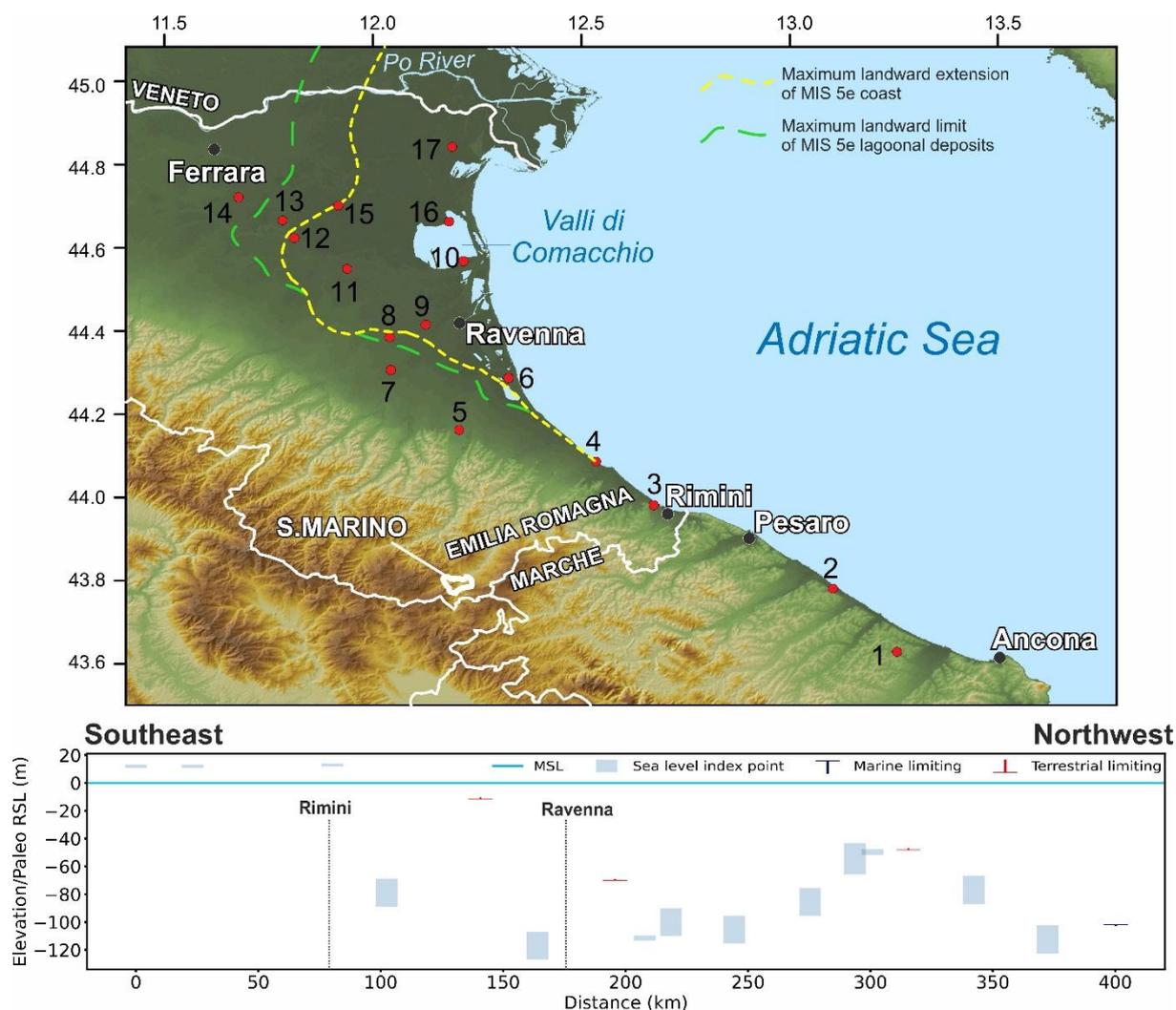



Figure 24: Last Interglacial sea level data for Marche and Emilia Romagna (Italy). Upper panel: Map of sites. The topography has
735 **been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower**
panel: Distance/Elevation graph, from Southwest (left) to Northeast (right). The lines depicting the most inner position of the
coastline and of a lagoon deposits of the MIS 5e are derived from Campo et al. (2020). Sites list: 1: Metauro River (RSL ID 1333).
2: Arzilla River (RSL ID 1332). 3: Conca River (RSL ID 1331). 4: 256-S3 Viserba Core S3 (RSL ID 1330). 5: 255-S4 Cesena Core
S4 (RSL ID 1329). 6: 240-S8 Milano Marittima Core S8 (RSL ID 1308). 7: 240-S2 Villafranca Core S2 (RSL ID 1328). 8: 240-S13
740 **Russi Core S13 (RSL ID 1327). 9: 223-S12 Ravenna Core S12 (RSL ID 1325). 10: 223-S17 Mandriole Core S17 (RSL ID 1326). 11:**
222-S2 Voltana Core S2 (RSL ID 1310). 12: 204-S17 Argenta Core S-17 (RSL ID 1313). 13: 204-S4 Consandolo Core S4 (RSL ID
1312). 14: 204-S15 Marrara Core S-15 (RSL ID 1315). 15: Core 204-S16 Core S-16 (RSL ID 1314). 16: 205-S10 Comacchio Core
S10 (RSL ID 1309). 17: Core F187_S1 Valle Giralda (RSL ID 1307).

6.3.10 Veneto

745   In the Venetian Plain (Figure 26) the number of available cores for investigating the MIS 5e marine highstand is limited but, North of the modern course of the Po River, the coastal plain has not been deeply involved in significant tectonic deformations as it is part of the foreland basin of both Alps and Apennines. Thus, despite the general regional subsidence affecting this area, the sediments of Late Quaternary have not been locally deformed by thrusts and folds and this setting preserved the original geometric relationships existing between the different sectors of the coastal wedge formed during the

750   Last Interglacial (Figure 25).

   In the Lagoon of Venice, the deposits of MIS 5e are found underground at a depth spanning between 90 and 55 m b.s.l. and often the stratigraphic cores document a transgressive-regressive cycle. This trend can be recognized according to the landward migration of the marine facies at the base of the sequence, which overlaps on the pre-existing alluvial plain, and that was followed by the progradation of deltas and related lagoons. Near Valle Averto (core *CARG 11*, RSL ID 1304), in the

755   southern part of the Venice Lagoon, deltaic sediments are found over the alluvial deposits between 67 and 64 m b.s.l., covered by littoral facies at 64 and 62 m b.s.l., and after by lagoon deposits at 62-60.5 m b.s.l. (Donnici and Serandrei-Barbero, 2004). According to stratigraphic correlations, the vertical succession documents the marine transgression and the successive deltaic progradation with the formation of lagoon environments (Tosi et al., 2007b). A rather similar stratigraphic setting is documented also in the northern sector of Venice Lagoon, near Portegrandi (core *CARG 12*, RSL ID 1302), where

760   paralic deposits are found between 70 to 55 m b.s.l. According to foraminifera analyses, from 70 to 65 m b.s.l. the depositional environments pass from neritic to lagoon, whereas, from 65 to 55 m b.s.l. the sediments are mainly sandy with few fossils, probably related to the delta front (Tosi et al., 2007a). This core can be used as an example of the rather low importance of this sequence for constraining the position of the sea level at the peak of the marine transgression of MIS 5e as the top portion could be used only as a marine limiting point at 55 m b.s.l.

765   In Venice, the reference stratigraphy for Pleistocene is the core *VE-1* and *VE-1bis* (RSL ID 1303), that were drilled in 1971 in the Tronchetto Island, NW of the city center (Kent et al., 2002; Massari et al., 2004 and references therein) and were analyzed for sedimentological, pollen and foraminiferal content. Core *VE-01* arrived at a depth of 950 m and, as explained in Massari et al. (2004), the tie point between the two cores is represented by a characteristic Eemian pollen assemblage correlative to MIS 5e at 74.30 m b.s.l. in the *VE-1* well and at 73.38 m b.s.l. in *VE-1bis*. The detailed investigations allowed

770   to recognize biostratigraphic units, mainly based on pollen assemblages for Upper Pleistocene (Mullenders et al., 1996). According to Massari et al. (2004), in the core the base of the MIS 5e marine transgression is found at 78 m of depth and sediments belong to coastal facies up to to 66 m of depth and are covered by alluvial and lagoonal sediments. At 59.40-59.00 m of depth in well *VE-1bis* a poorly developed lagoonal episode is recorded and, originally it was tentatively related to MIS

5c by Massari et al. (2004) but, in the light of some new unpublished cores in the Venice mainland, it is here considered as the peak of the MIS 5e transgression.

In the eastern sector of the Veneto region, several cores have been drilled in the framework of the CARG project and allowed to follow the deposits of the MIS 5.5 from the alluvial plain to the marine facies (Figure 25; Pini et al., 2009; Fontana et al., 2012). In particular, a stratigraphic section has been reconstructed from the mainland, at the boundary with Friuli Venezia Giulia (core *AZX*, RSL ID 1301), to core *PRA* (RSL ID 793), to the coast (core *TdM*, RSL ID 1295, Fontana et al., 2010). In core *AZX* the MIS 5e deposits correspond to alluvial sediments characterized by warm temperate pollen from an elevation of 45.59 to 42.25 m b.s.l. (Pini et al., 2009), whereas 8 km south of this site, in core *PRA*, hyposaline internal lagoonal deposits are found at a depth between 49.5 and 55 m (i.e. 45.5 and 51 m b.s.l.). These latter ca. 5 m rest over an alluvial plain with temperate cold pollens (Fontana et al., 2012) and have been deposited at the peak of the marine highstand when the lagoon reached its most internal position. This stratigraphic interval of lagoonal sediments represents a significant index point for relative sea-level during the peak of MIS 5e in NW Adriatic as the base of lagoon sediments rests over an over-consolidated alluvial plain referred to MIS 6 (Fontana et al., 2010).

The site of *PRA* is about 4 km upstream of the current isoline 0 m a.s.l., where brackish swamps were present up to the first part of the 20th century when reclamation has been carried out. Accordingly to this setting, also the coastline of MIS 5e reached a more landward position (Figure 25 and Figure 26), as in core *TdM*, where the coastal wedge sequence containing Eemian pollen association has its base at 70.5 m b.s.l. and the facies shift from inner shelf to delta front and deltaic up to 50.4-41.7 m b.s.l. A rather similar sequence is documented also in cores *LUG* (RSL ID 1294) and *VV* (RSL ID 1293).

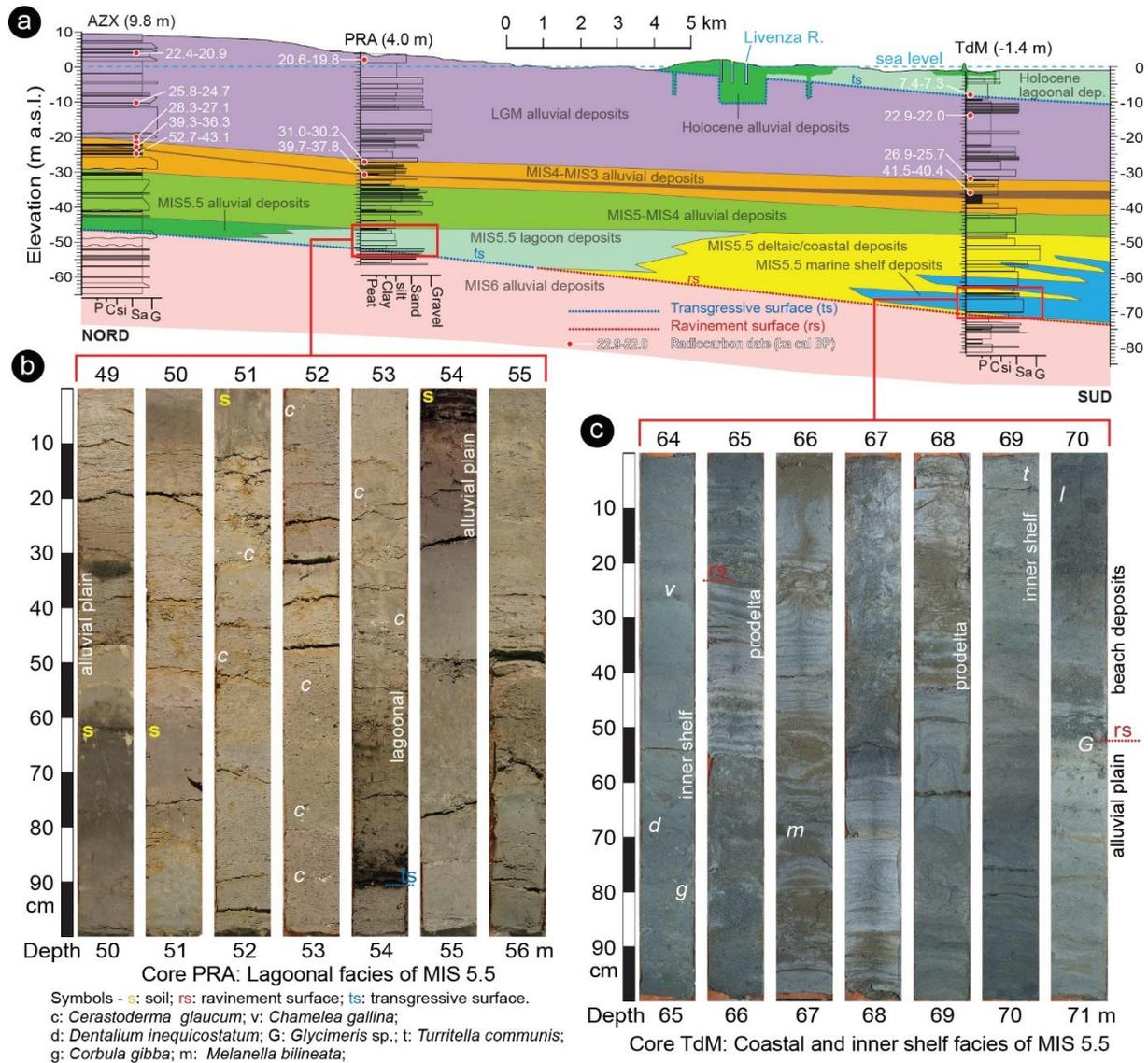



Figure 25: a) Stratigraphic section of the -Venetian Friulian Plain, from AZX Azzano core (RSL ID 1301) to PRA Belfiore core (RSL ID 793) to TdM Torre di Mosto core (RSL ID 1295) (modified from Fontana et al., 2010). Trace of section is indicated in Figure 26. b) Part of core PRA from 49 to 55 m of depth with typical sedimentary facies of lagoonal environment. c) Interval of core TdM from 64 to 71 m of depth with typical facies of the basal part of the MIS 5e marine transgression.

795

6.3.11 Friuli Venezia Giulia

Along the coastal plain, Veneto and Friuli Venezia Giulia are not separated by a physiographic boundary (Figure 26), so it is
800   not surprising that the stratigraphic setting described for the eastern sector of Veneto seems to be documented also in the
easternmost region of northern Italy. Few kilometers north of the western boundary of the Grado-Marano Lagoon, Feruglio
(1936) and Lipparini (1936) described for the first time in this sector the occurrence of a paralic unit of Pleistocene age at a
depth around 40-50 m. In core *PNC1* (RSL ID 1292), near Marianis of Piancada, paralic deposits are found between 57.7
b.s.l. and -35.6 m b.s.l. (Fontana et al., 2010). The top portion of this interval is characterized by the presence of coastal and
805   lagoon mollusks and this layer has been used as a marine limiting point by Antonioli et al. (2009). Core *PNC1* was drilled in
the framework of the VECTOR project (Bussetti et al., 2010), as borehole *BLG1* (RSL ID 1290), near Aquileia, which is a
reference for the eastern portion of the Grado-Marano Lagoon. In this core coastal deposits are found from 55.4 to 39.1 m of
depth, documenting the transgression from marine facies to lagoon deposits. This unit is interpreted as the evidence of Last
Interglacial based on stratigraphic correlation. Several samples of shells from this unit in core *BLG1* have been dated with
810   ESR, anyhow, the obtained results are characterized by large uncertainties and allow only to generically attribute the samples
to MIS 5.

East of Monfalcone the coast is rocky and characterized by a karst environment, where deposits and landforms related to the
Upper Pleistocene are almost completely lacking. Some evidence of Last Interglacial coastal features has been suggested in
this area of the Gulf of Trieste (Albrecht and Mosetti, 1987; Antonioli et al., 2009), but in the light of this review of data,
815   they seem not reliable. Recently, in the marine area of Miramare, the geophysical investigations highlighted the occurrence
of a buried prograding wedge at a depth between 70 and 50 m b.s.l. that has been interpreted as a coastal wedge and related
to MIS 5e (Romeo, 2009). It is worth noting that this sedimentary body is onlapping over the Flysch bedrock and, thus, its
present elevation should have been produced by tectonics, downlifting the bedrock for at least 60 m in the last 125 ka.
According to the structural framework of this region, it seems not likely to consider this unit as the product of the marine
820   highstand of the Last Interglacial.

10.5194/essd-2021-49
2021-02-25
en

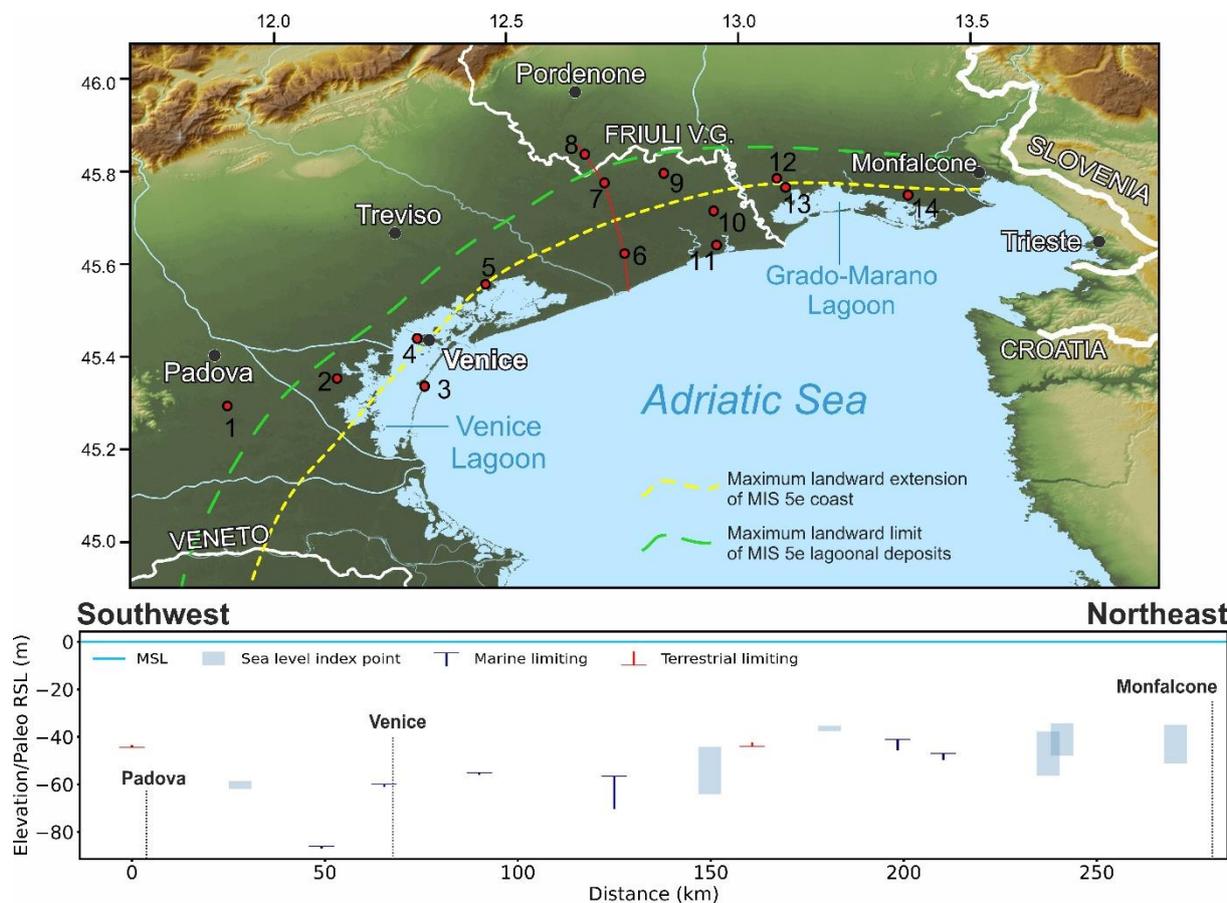



Figure 26: Last Interglacial sea-level data for Veneto and Friuli Venezia Giulia (Italy). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from Southwest (left) to Northeast (right). The lines depicting the most inner position of the coastline and of the lagoon deposits of the MIS 5e are modified after Antonioli et al., 2009. Sites list: 1: Ca' Borille Core (RSL ID 1306). 2: Valle Averto Core CARG 11 (RSL ID 1304). 3: Malamocco Core (RSL ID 1305). 4: VE-1 Core Venezia1 (RSL ID 1303). 5: Portegrandi Core CARG12 (RSL ID 1302). 6: TdM Torre di Mosto Core (RSL ID 1295). 7: PRA Belfiore Core (RSL ID 793). 8: AZX Azzano Core (RSL ID 1301). 9: CNC4 Concordia Sagittaria Core (RSL ID 1289). 10: LUG Lugugnana Core (RSL ID 1294). 11: VV Valle Vecchia Core (RSL ID 1293). 12: Piancada Piancada town (RSL ID 1291). 13: PNC1 Piancada Core (RSL ID 1292). 14: BLG1, Beligna Core (RSL ID 1290). The red line connecting points 6-7-8 represents the cross-section of Figure 25.

6.3.12 Istria, Kvarner Gulf and Dalmatia

Along the eastern side of the Adriatic Sea, the coast presents rather homogeneous characteristics from the Gulf of Trieste, in Italy, to the northern boundary of Albania. In particular, this stretch of coast, which includes the coasts of Slovenia, Croatia, Bosnia Herzegovina, and Montenegro, is influenced by the tectonic structures of the Dynaric Alps, which have NW-SE direction and largely consist of carbonatic bedrock (Pikelj and Juračić, 2013).

At the moment, along this sector of the coast with a length of over 600 km and characterized by karst landscape, no clear evidence of RSL indicators of the MIS 5e transgression is documented. Anyhow, some indirect information can be inferred by the comparison with the index points referred to MIS 5a, which have been recently documented in the Kvarner Gulf through isotopic analyses on speleothems (cf. Dumitru et al., 2020 for a synthesis of the whole Mediterranean coast). In the submerged cave of U Vode Pit in Krk Island, Surić et al. (2009) studied two stalagmites, K-14 and K-18, collected at 14.5 m and 18.8 m b.s.l., respectively. These speleothems have been dated through U/Th and investigated for their chemical composition, leading Surić et al. (2009) to infer that they have been submerged by marine waters during highstands of MIS 5a and, thus, in case of stable conditions, sea level was higher than 14 m b.s.l. The authors suggested also the possible occurrence of a general regional tectonic uplifting in the area with long-term rates of 0.15-0.25 mm/a.

According to the reconstructions of the global sea-level curves, it is likely that the RSL at the peak of the MIS 5e was over 20 m higher than the level reached for MIS 5a. Thus, these points can be eventually interpreted as marine limiting points also for MIS 5e, but with a larger uncertainty.

This setting strongly contrasts with the situation reconstructed along the western coast of Northern Adriatic, where subsidence has been a leading process during Quaternary. Anyhow, this asymmetric evolution of the opposite sides is not surprising, as along the Dalmatian coast the long-term geological data suggest general stability.

Another interesting site is located east of Lošinj Island, where Brunović et al. (2020) investigated the deposits recorded in the so-called Lošinj Channel, an isolation basin that during sea-level fall was separated by the rest of Adriatic because of a sill at 50 m b.s.l. In the area, the analysis of a core from a water depth of 64-62 m documented the occurrence of marine deposits and these have been tentatively dated to MS 5a based on correlation with the data produced by Surić et al. (2009). Also in this case the area is considered a stable sector because the Lateglacial and Holocene RSL index points are in agreement with the predicted sea-level curve, suggesting a limited vertical displacement.

In the northern sector of Albania, near the Bay of Drini, Marku and Gjani (2018) suggested the existence of a tidal notch at an elevation between 30 and 40 m a.s.l. referred to MIS 5e. Anyhow, as the morphological evidence supporting this interpretation is not very consistent and the age estimation is only hypothesized, this site is not considered in WALIS as a proxy for the RSL of Last Interglacial.

6.4 Corsica, Sardinia and Sicily

6.4.1 Corsica

865 Corse (Corsica) is the third-largest western Mediterranean Island and hosts a great number of Quaternary marine deposits (Figure 27) which span the whole perimeter of the Island (Conchon, 1985, 1999). Along the northern coasts of the Island (Macinaccio and St. Florent) the presence of upper limit of *Lithophaga* boreholes (RSL ID 931) and shallow coastal deposits (RSL ID 299, Figure 28) dominated by *Arca noe* and *Patella ferruginea* (Ottmann, 1954) seems to indicate that the maximal transgression during the last interglacial did not exceed 6.25 m a.s.l. The single chronological constrain available in this area is represented by a *Glycimeris* shell dated with AAR techniques (AAR ID 93, Hearty et al., 1986a) which yielded MIS 5e 870 age.

Along the mid to southern coasts of the Island, Conchon (1999) reports several shallow marine or lagoonal deposits that were found at elevations ranging from 1 to 3 m a.s.l. Among these, the most robust indicator is represented by some oysters found in lagoonal facies (RSL ID 321) near Figari, which allowed reconstructing a paleo-sea level at 4 ± 1.1 m a.s.l. This is consistent with the elevation of some marine encrustations which constrain the paleo sea level above 3.25 m a.s.l. near 875 Bonifacio (RSL ID 277, Nesteroff, 1984). We assumed a general MIS 5 age of this paleo sea-level stand even if a robust chronological attribution is currently not available. The shells found in all these deposits were only dated with radiocarbon techniques yielding unreliable (19 to 40 ka) ages (Delibrias et al., 1972; Nesteroff, 1984).

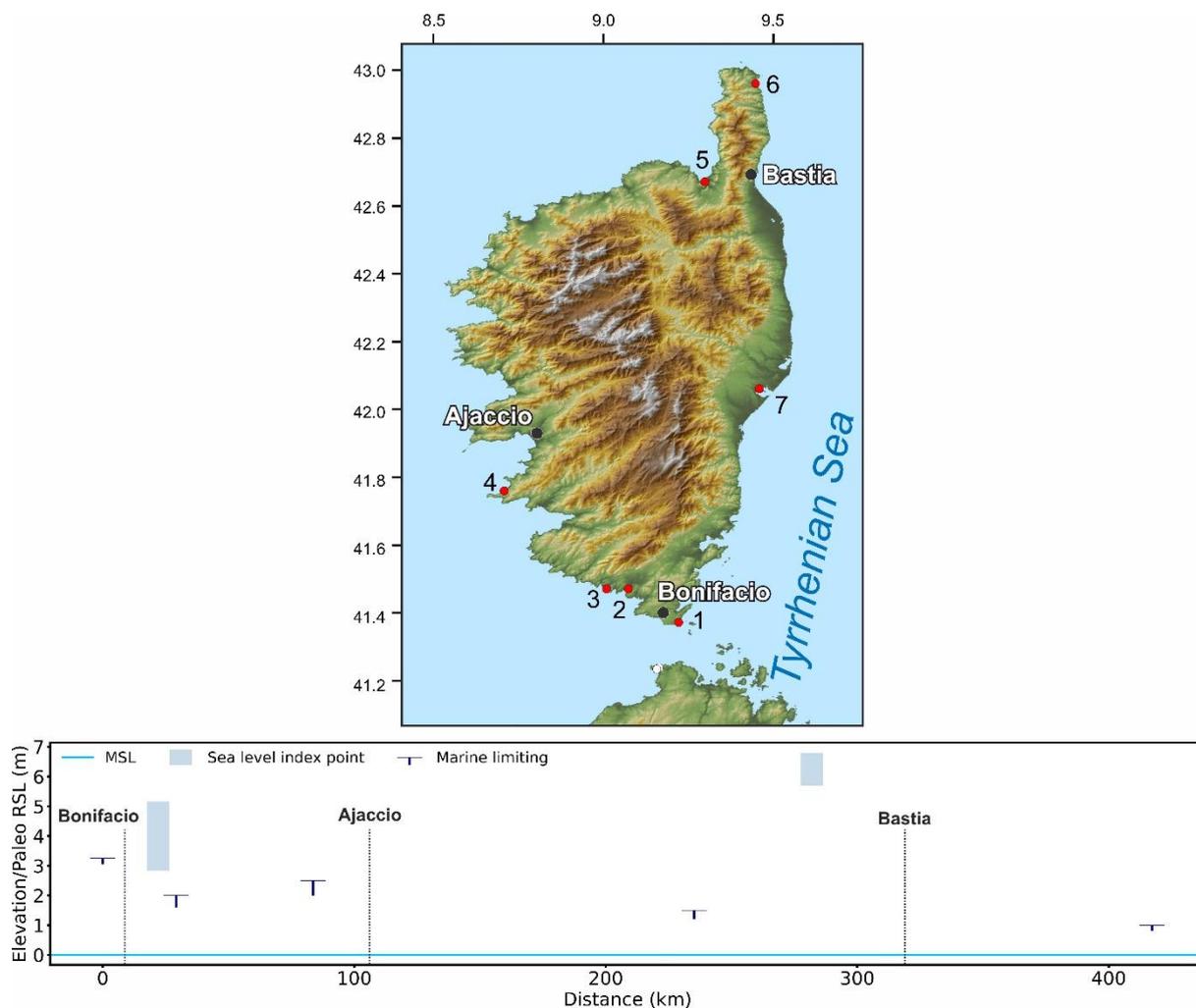



Figure 27: Last Interglacial sea-level data for Corsica (France). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, clockwise around the island starting from the southernmost point. Sites list: 1: Piantarella (RSL ID 277). 2: Figari (RSL ID 321). 3: Arbitru (RSL ID 323). 4: Ajaccio Gulf Capo Moru (RSL ID 303). 5: St Florent (RSL ID 299). 6: Macinaggio Tamarone (RSL ID 931). 7: Urbino (RSL ID 322).

880

885 **Figure 28: Littoral deposits in St Florent, Corsica (RSL ID 299). Photo by M. Vacchi.**

6.4.2 Sardegna

Sardegna (Sardinia) represents a key Mediterranean region for the study of the Last Interglacial landforms and deposits. It is among the most tectonically stable areas of the whole Mediterranean and hosts a large abundance of late Pleistocene coastal deposits, as well as well-preserved erosional evidence of paleo sea-level highstands (Andreucci et al., 2010; Ferranti et al.,

890 2006; Ulzega and Hearty, 1986, Figure 29). The most outstanding evidence of paleo sea-level stand is the presence of a fossil tidal notch that can be observed, at different elevations, both on the eastern and western coasts of the Island (Antonioli et al., 2018). Along the eastern coast, the fossil notch was observed in several sites showing variability in elevation. In *Pedralonga* (RSL ID 432) and *Capo Monte Santu* (RSL ID 435), the notch is placed at average elevations between 7.4 and 7.6 a.s.l., while it increases to 9.5 m a.s.l. in the central part of the Gulf of Orosei (RSL ID 434). In the Northern portion of

895 the East coast, the notch was observed both in Capo Figari (RSL ID 430) and in Tavolara Island (RSL ID 431) at average elevations ranging from 4.7±0.4 m to 6.7±0.5 m a.s.l. In Tavolara, *Glycimeris* shells found in a marine deposit (correlated with the notch) yielded an MIS 5e age (AAR ID 92, Belluomini et al., 1986). This date is the only chronological constraint available for the whole eastern coast of Sardinia.

Along the Northern coast, Ozer et al. (1980) reported *P. latus* in beach deposits found at 2.5 m a.s.l. in Capo Testa. This

900 level lies above a subtidal facies which was dated with AAR (AAR ID 90) yielding an age of 120 ka (Belluomini and Delitala, 1988; Kindler et al., 1997). The lack of clear intertidal deposits at this location did not allow for a precise definition

of the sea-level evolution during the whole last interglacial period. The available data only indicate that the paleo sea-level was above 1.5 m a.s.l. during the MIS 5e and at or slightly below 1 m during the MIS 5c (AAR ID 91). This trend is further confirmed by an additional date (AAR ID 94) which constrain the paleo sea level above 1.5 m a.s.l. during MIS 5e

905 (Belluomini and Delitala, 1988).

The western coast of Sardinia hosts a large number of LIG littoral deposits which were already identified at the beginning of the last century (Issel, 1914) and widely investigated in the last 40 years (Ulzega and Hearty, 1986; Sechi et al., 2020; Carboni et al., 2014). In Capo Caccia, Alghero, and Bosa, the concomitant presence of well-preserved fossil notches (RSL IDs 382-383, Antonioli et al., 2018), beach deposits (RSL ID 388, Casini et al., 2020), and fossil bioincrustations (RSL ID

910 234-238, Sechi et al., 2020) robustly placed the MIS 5e shoreline between 3 and 4 m a.s.l. The quality of the chronological constrain for this area was significantly increased by a series of recent OSL dates performed near Capo Caccia (LUM ID 120; Casini et al., 2020), Alghero (LUM ID 61-64-68, Sechi et al., 2020; Andreucci et al., 2010) and in Bosa (LUM ID 75, Sechi et al., 2020).

More southwards, impressive outcrops of Upper Pleistocene littoral deposits occur in the San Giovanni del Sinis (Figure 30)

915 area (Carboni et al., 2014; Andreucci et al., 2009; Lecca and Carboni, 2007). These are represented by a complete sequence which includes shoreface, foreshore, lagoonal, and dunal deposits. The age of these deposits was investigated both with OSL (Andreucci et al., 2009) and with U/Th on corals (Carboni et al., 2014; D'Orefice et al., 2012). Both techniques, (LUM ID 81 and U-Series ID 550-551 and 555 to 557) confirmed the MIS 5 ages for most of these littoral deposits, as already suggested by the presence of Senegalese fauna (Carboni and Lecca, 2008). A further AAR date (AAR ID 203) yielded MIS

920 5c age (Ulzega and Hearty, 1986) while a basal unit found in the northernmost sector of San Giovanni del Sinis yielded MIS 7 age (LUM ID 81, Andreucci et al., 2009). The coupled analysis of all these data indicates RSL was placed between 2 and 5 m a.s.l. during MIS 5e (RSL IDs 262, 263, 265, 266, 271). The analysis stratigraphic facies of San Giovanni del Sinis seems also to indicate that the maximal sea-level highstand is preceded by millennial sea-level oscillations within MIS 5e, which were recorded by the different littoral facies (Carboni et al., 2014).

925 In the southwestern portion of the Island, the occurrence of a well-preserved tidal notch at ~2.8 to 3.5 m a.s.l. was observed from Buggerru to the Island of Sant'Antioco (RSL IDs 433,436 and 437, Antonioli et al., 2018). An MIS 5e age was attributed to this paleo-shoreline thanks to the correlation with some littoral deposits found at similar elevations. They are rich in Senegalese fauna (including *P. latus*) and were dated with AAR techniques (AAR ID 127, Ulzega and Ozer, 1980; Ulzega and Hearty, 1986).

930 Along the southern coast of the Island, beach deposits rich in Senegalese fauna (including *P. latus*) were found in some littoral deposits near the archeological site of Nora (Ulzega and Hearty, 1986; Kindler et al., 1997). Two AAR dates (AAR

IDs 204-205) yielded MIS 5e age even if some contrasting interpretation of the age of these deposits are present in literature (Kindler et al., 1997). The facies analysis of this outcrop allowed reconstructing a paleo-shoreline placed at ~3.3 m during MIS 5e (RSL ID 1337). This elevation is in agreement with the paleo-shoreline reconstructed in the Cagliari area (RSL IDs

935   132, 276, 1338) whose MIS 5e age was constrained by U-Series and AAR dating (Hearty et al., 1986a; Ulzega and Hearty, 1986).

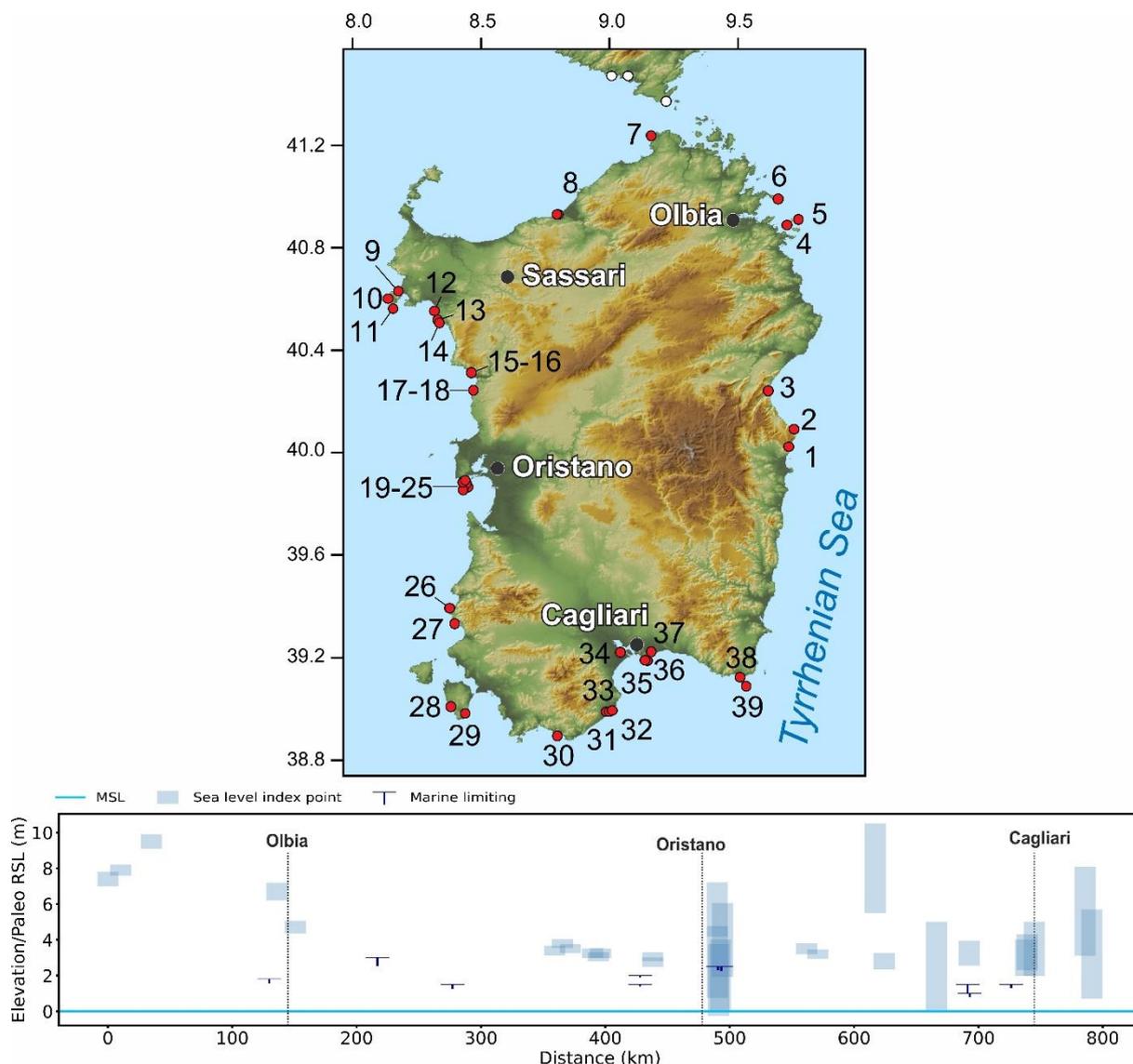



Figure 29: Last Interglacial sea-level data for Sardegna (Italy). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel:
940   **Distance/Elevation graph, counterclockwise around the island. Sites list: 1: Pedralonga (RSL ID 432). 2: Capo Monte Santu (RSL ID 435). 3: Orosei Nord (RSL ID 434). 4: Tavolara Punta la mandria (RSL ID 292). 5: Tavolara (RSL ID 431). 6: Capo Figari (RSL ID 430). 7: Capo Testa_santa Reparata Terrestrial limiting (RSL ID 289). 8: Capo Testa_santa Reparata Marine limiting (RSL ID 290). 9: Badesi Mare San Pietro a Mare (RSL ID 300). 10: Cala Viola (RSL ID 388). 11: Capo Caccia 1 (RSL ID 382). 12: Capo Caccia 2 (RSL ID 383). 13: El tra (RSL ID 234). 14: Punta Padre Bellu (RSL ID 235). 15: Baurantinu (RSL ID 236). 16: Bosa**
945   **(RSL ID 241). 17: Bosa (RSL ID 243). 18: Bosa (RSL ID 244). 19: San Giovanni del Sinis (RSL ID 262). 19: Porto Alabe (RSL ID 238). 20: San Giovanni del Sinis (RSL ID 271). 21: San Giovanni del Sinis (RSL ID 272). 22: San Giovanni del Sinis (RSL ID 265). 23: Faro Capo San Marco (RSL ID 266). 24: Capo San Marco (RSL ID 261). 25: San Giovanni del Sinis (RSL ID 263). 26:**

Buggerru (RSL ID 437). 27: Masua (RSL ID 436). 28: Sant'Antioco Cala Sapone (RSL ID 296). 29: Sant'Antioco (RSL ID 433). 30: Capo Malfatano (RSL ID 295). 31: Nora (RSL ID 1336). 32: Nora Is Fradis (RSL ID 1337). 33: Nora-Is Fradis (RSL ID 279). 34: Sa Illetta (RSL ID 278). 35: Cagliari Marina Piccola (RSL ID 1338). 36: Cagliari Cala Mosca (RSL ID 132). 37: Is Arenas (RSL ID 276). 38: Capo Carbonara Villasimius (RSL ID 293). 39: Capo Carbonara Isola dei cavoli-Cala Ponente (RSL ID 294).

Figure 30: Last Interglacial outcrop at San Giovanni del Sinis (RSL ID 262). In the photo, A. Rovere is pointing to the contact between subtidal (below) and intertidal (above) beds. Photo by E. Casella.

6.4.3 Sicilia

Antonioli et al., 2006 reviewed the elevation of RSL indicators of the last interglacial around the coasts of Sicilia (Sicily) and the Egadi, Lampedusa, Ustica, and Eolian islands, updating former compilations, most notably the one by such as the one by Bordoni and Valensise (1999). Within the island, Antonioli et al. (2006) distinguished four distinct tectonic sectors, that are described separately hereafter.

Sector 1 (Figure 31) spans between the coastal towns of Trapani and Cefalù and includes the Egadi Islands to the West. Along the Egadi island coasts, *P. latus* specimens and Senegalese fauna within fossil beaches have been found in the island of Levanzo, between 2 and 6 m a.s.l. (RSL IDs 852 to 854) by Malatesta (1957) and up to 12 m a.s.l. in Favignana (RSL ID

855) by Abate et al. (1992, 1996). Antonioli et al. (2002) measured the elevation of the tidal notches on Marettimo island at ca. 5-8 m a.s.l. (RSL ID 833 to 843). On the mainland, the areas surrounding the towns of Trapani and Marsala are characterized by marine deposits bearing *P. latus* at elevations of 2 to 5 m a.s.l. (Ruggieri and Buccheri, 1968; Ruggieri and Unti, 1988, RSL IDs 919 and 920). A similar elevation range, 2-3 m a.s.l., with the presence of sediments bearing *P. latus,* has been evaluated also between Marsala and Mazzara del Vallo area (Ruggieri et al., 1975). These deposits lie on a terrace that has the inner edge at 34 m a.s.l. (RSL ID 899).

Northwest of Trapani, Mauz et al. (1997) surveyed Last Interglacial sea-level proxies in the Gulf of Castellammare and Capo San Vito (RSL ID 827 to 845) integrating thermoluminescence dating and paleontological investigations. These authors recognized evidence of MIS 5e in the 5-18 m elevation range. Moreover, in Capo San Vito, Abate et al. (1991) signal the presence of Senegalese fauna, and Antonioli et al. (2002) dated with U-Series speleothems to constrain the age of a tidal notch. These studies have confirmed the presence of a marine terrace up to 14 m a.s.l. (RSL ID 923) and a tidal notch up to 8 m a.s.l. (RSL ID 922), both correlated to MIS 5e (Abate et al., 1996; Abate et al., 1993). Fabiani (1941), Gignoux (1913) and Antonioli et al. (2006) reported specimens of *P. latus* between 2 and 10 m a.s.l. in Palermo (RSL IDs 896 and 832) and nearby areas (Capo Gallo, RSL ID 897), while AAR dating on *Glycimeris* allowed Hearty (1986) to reject the correlation of fossil marine deposits few tens of meters a.s.l. to MIS 5e, previously made by Ruggieri and Buccheri (1968).

Towards the easternmost point of Sector 1, Antonioli et al. (2006) have constrained *Glycimeris*-bearing marine deposits to MIS 5a and 5c between ca. 7 to ca. 10 m a.s.l. in the area of Cefalù (RSL ID 862) with AAR. This constraint allowed to correlate to MIS 5e a tidal notch in Cefalù promontory and *La Kalura* promontory (RSL ID 863) at 29 and 30 m a.s.l. respectively. The elevation of the tidal notch decreases considerably eastward, in fact, in Capo Zafferano (RSL ID 831) it has been found at 7 m a.s.l. and constrained by AAR dating on *Arca* shells (Antonioli et al., 1994b).

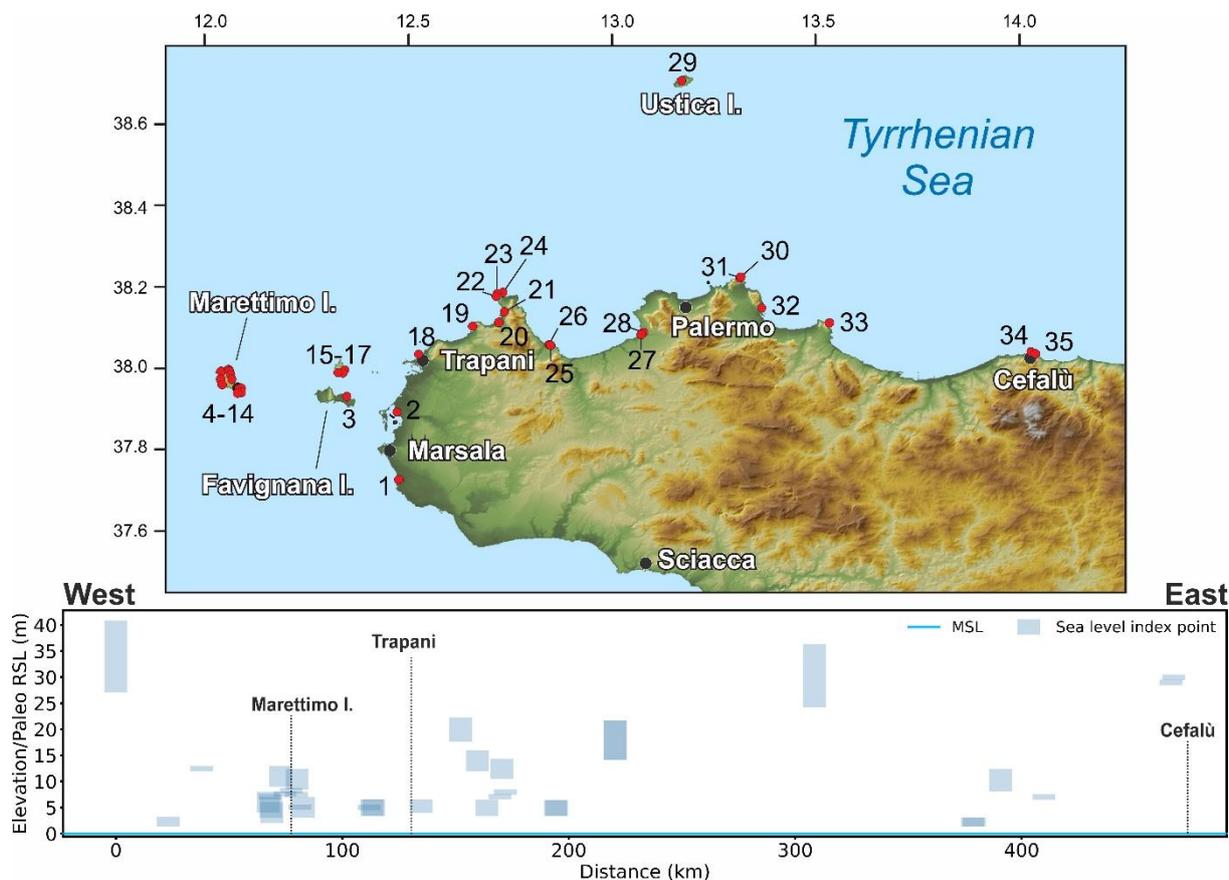



Figure 31: Last Interglacial sea-level data for Sicilia, sector 1 (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, from West (left) to East (right). Sites list: 1: Marsala-Mazzaro del Vallo Torre Scibiliana (RSL ID 899). 2: Trapani Birgi (RSL ID 919). 3: Favignana Egadi archipelago (RSL ID 855). 4: Facciazzo Marettimo Island (RSL ID 841). 5: Cala Marino Marettimo Island (RSL ID 836). 6: Cala Marino (II) Marettimo Island (RSL ID 840). 7: Cala Conca Marettimo Island (RSL ID 842). 8: Cala Nera Marettimo Island (RSL ID 843). 9: P. Pegna Marettimo Island (RSL ID 837). 10: P.ta Due Frati Marettimo Island (RSL ID 833). 11: Scalo Maestro Marettimo Island (RSL ID 834). 12: Tuono Marettimo Island (RSL ID 838). 13: Sco. Camello Marettimo Island (RSL ID 835). 14: Passo del Bue Marettimo Island (RSL ID 839). 15: Pietre Varate Levanzo Island (Egadi archipelago) (RSL ID 854). 16: Cala Dogana Levanzo Island (Egadi archipelago) (RSL ID 852). 17: Cala Fredda Levanzo Island (Egadi archipelago) (RSL ID 853). 18: Trapani- Tonnara S. Giuliano (RSL ID 920). 19: Monte Cofano Trapani (RSL ID 894). 20: Castelluzzo San Vito lo Capo (RSL ID 845). 21: Macari (RSL ID 830). 22: Cala Mancino San Vito lo Capo (RSL ID 844). 23: San Vito lo Capo W side (RSL ID 923). 24: San Vito lo Capo NE side (RSL ID 922). 25: Cala Rossa (RSL ID 828). 26: Cala Bianca (RSL ID 829). 27: Torre San Cataldo (RSL ID 827). 28: Nocella (RSL ID 826). 29: Ustica (RSL ID 916). 30: Palermo Capo Gallo (RSL ID 897). 31: Capo Gallo (RSL ID 832). 32: Palermo (RSL ID 896). 33: Capo Zafferano (RSL ID 831). 34: Cefalù (RSL ID 862). 35: Cefalù (II) La Kalura (RSL ID 863).

In southwestern Sicily (Sector 2), Antonioli et al. (2006) reported that in the area spanning from Granitola Cape to Passero Cape no evidence of MIS 5 is present. Probably, the bedrock lithologies have played an important role in terms of

preservation of RSL indicators along the coast of Sector 2, or negative vertical movements could have downthrown MIS 5 indicators.

Sector 3 extends from the town of Pachino (to the South) to Monte Tauro (to the North). *P. latus* specimens embedded into a
1005   beach deposit have been reported by Malatesta (1985) at 15 m a.s.l. in the Pachino area (RSL ID 900). By geomorphological correlation with this terrace, beach deposits assigned to MIS 5e have been reported also in S. Lorenzo and Avola sites, at 4 and 5 m a.s.l. In Augusta (Monte Tauro), Di Grande and Scamarda (1973) and Di Grande and Neri (1988) report the presence of *P. latus* correlated with a marine terrace inner edge at 15 m a.s.l. (RSL ID 901). Meschis et al. (2020) have mapped the marine terraces along the Syracuse coast by synchronous correlation method using as age constraints U-Series
1010   dating on speleothems (Dutton et al., 2009a), which provide a terrestrial limiting point for the end of MIS 5a (*Plemmiro Cave*, RSL ID 3577). The MIS 5e terrace, according to the reconstruction of Meschis et al. (2020) spans from ca. 30 up to ca. 70 m a.s.l. This estimate, which was based on ESR dating on mammals teeth (Rhodes, 1996), is at odds with the interpretation of Bianca et al. (1999), according to which the MIS 5e marine terrace decreases from 10 m in Augusta to 75 m in Avola. In particular, the 5e terrace of Meschis et al. (2020) corresponds to the MIS 3.3 terrace of Bianca et al. (1999).
1015   However, the dating of Rhodes (1996) used by Bianca et al. (1999) has not been included in the database, as it was discarded by Antonioli et al. (2006) as not robust.

The last sector covers the NE part of Sicily (Sector 4, Figure 32), and extends between the city of Catania and the town of Acquedolci, near Messina. MIS 5e sea-level proxies along the Etna coast were chronologically constrained indirectly by K-Ar dating on lava flows (Gillot et al., 1994), which was successively incised by a marine terrace (Monaco et al., 2000). The
1020   inner margin of this terrace has been reported at a maximum of 175 m a.s.l. in Aci Trezza (RSL IDs 846 to 848) and slowly decrease in elevation towards the south, reaching a maximum of 165 m a.s.l. in Catania (RSL IDs 849 to 851).

Catalano and Guidi (2003) mapped a staircase sequence of marine terraces, including the Last Interglacial one, for the NE sector of Sicily, from the Straits of Messina to the Taormina area, but no dating or Senegalese fauna reports for these terraces are available. The first MIS 5 age constraint for the Taormina sector is an ESR dating on littoral fossils *Patella* and
1025   *Venerupis* shells, provided by Antonioli et al. (2006) at 115 m a.s.l. (RSL ID 903), whereas Bonfiglio (1981) reports a tidal notch with serpulids in a cave at 130 m a.s.l. (RSL ID 3626).

At the northern tip of Sector 4 lies Capo Peloro, where Bonfiglio and Violanti (1983) recognized specimens of *P. latus* at 86 m. a.s.l. These were correlated to MIS 5e with AAR by Hearty et al. (1986b). The marine terrace inner edge corresponding to MIS 5e has been placed at 110 m a.s.l. (RSL ID 902) by Antonioli et al. (2004) and at 125 m a.s.l. by Catalano and Guidi
1030   (2003). Since the elevation proposed by Catalano et al. (2003) is based only on a geomorphological correlation with a marine

terrace at Capo Rasocolmo at 125 m a.s.l. and in the absence of more dating, such point has not been included in the database.

Hearty and Dai Pra (1986) dated *Arca* and *Glycimeris* shells related to MIS 5e deposits in the Capo Milazzo area, at ca. 90 m a.s.l. (RSL ID 921).

1035   In the northern edge of Sector 4, Giunta et al. (2012) mapped five orders of marine terraces, two of which were dated by OSL on unconsolidated marine sands. These ages allowed correlating the terrace at 50 m a.s.l. to MIS 5e (RSL ID 924). Such correlation is supported by a synchronous correlation method (Meschis et al., 2018).

In front of the northern coast of Sector 4, also the Aeolian Islands underwent long-term uplift. The inner edge of marine terraces related to MIS 5.5 spans from 40 m a.sl. in Filicudi (RSL ID 913-914, Lucchi et al., 2004a,b), 45 m a.s.l. on Lipari

1040   Island (RSL IDs 909 to 911), and 115 m a.s.l. in Panarea Island (RSL IDs 917-918, Radtke, 1986).

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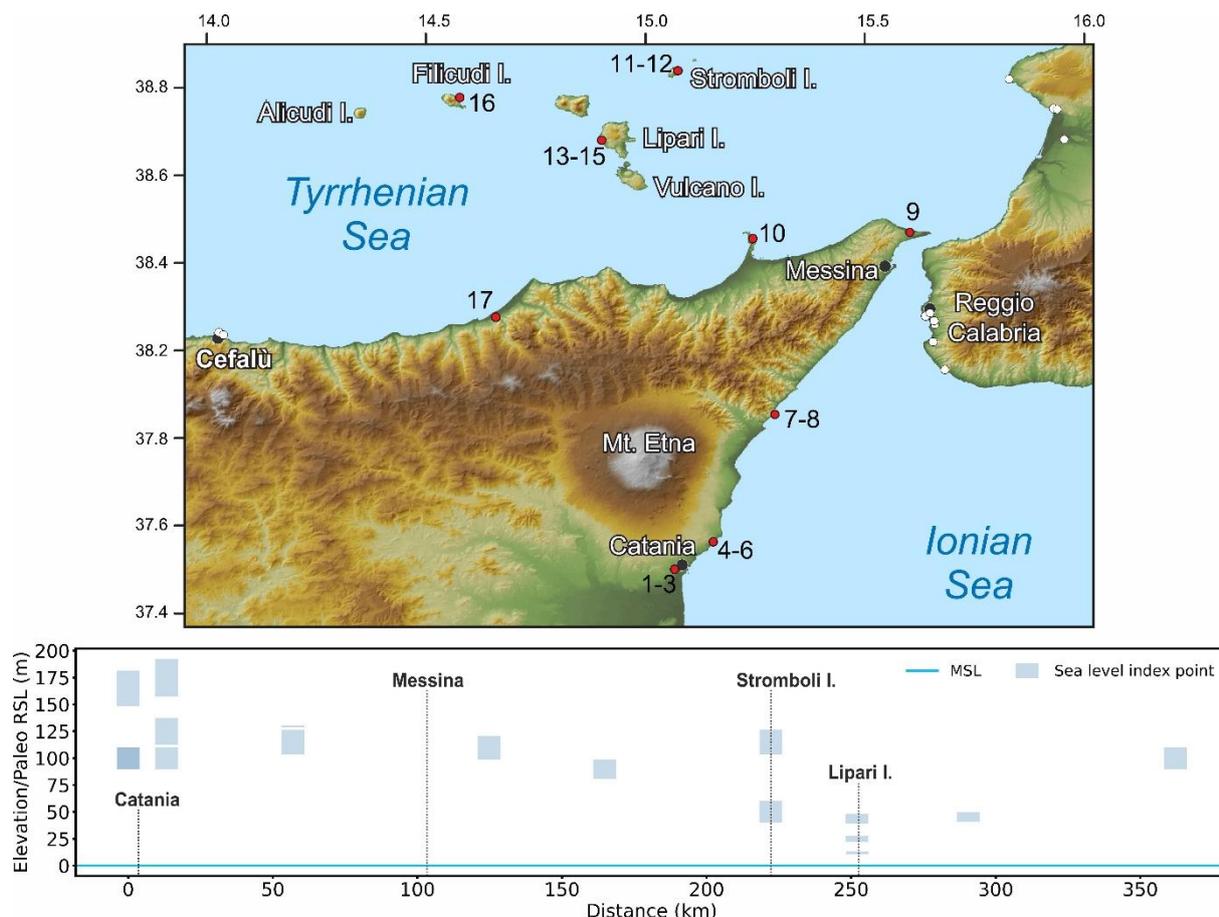
Figure 32: Last Interglacial sea-level data for Sicilia, sector 4 (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel: Distance/Elevation graph, counterclockwise from Catania to Cefaù. Sites list: 1: Catania (RSL ID 849). 2: Catania (II) (RSL ID 850). 3: Catania (III) (RSL ID 851). 4: Aci Trezza (RSL ID 846). 5: Aci Trezza (II) (RSL ID 847). 6: Aci Trezza (III) (RSL ID 848). 7: Taormina (II) (RSL ID 3626). 8: Taormina (RSL ID 903). 9: Capo Peloro (RSL ID 902). 10: Milazzo (RSL ID 921). 11: Panarea (RSL ID 917). 12: Panarea (II) (RSL ID 918). 13: Lipari (I) (RSL ID 909). 14: Lipari (II) (RSL ID 910). 15: Lipari (III) (RSL ID 911). 16: Filicudi (RSL ID 914). 17: Sant'Agata di Militello (RSL ID 924).

West of the Aeolian Islands, the Last Interglacial at Ustica Island is constrained by U-Series dating on *Cladocora* and by the presence of *P. latus* at 30 m a.s.l. (RSL 916) (de Vita et al., 1998; Ruggieri and Unti, 1988; Hearty, 1986). Southwards, in front of the coasts of Tunisia, Lampedusa Island is considered stable due to the presence of a fossil beach deposit bearing *P. latus* up to 4 m a.s.l. (RSL ID 907, Buccheri et al., 1999; Segre, 1960).

6.5 Algeria

1055 One of the earliest reports of Pleistocene deposits in Algeria (Figure 33) is contained in a paper written in 1911 by de Lamothe (de Lamothe, 1911). In the 1960s, this early study was further expanded upon by Stearns and Thurber (1965) and Vita-Finzi (1967), and later by Saoudi (1989). In the 1990s, studies on the tectonics of Algeria used Last Interglacial shorelines to calculate vertical tectonic rates (Meghraoui et al., 1996), an approach that has continued in more recent times (Maouche et al., 2011). The most recent study related to the Last Interglacial sea-level indicators in Algeria was done by
1060 Authemayou et al. (2016), who focused on the record in the Tipasa Province, west of Algiers. The sea-level information reviewed for Algeria was extracted from two studies: Authemayou et al. (2016) for the Tipasa area and Meghraoui et al. (1996) for the areas of Oran and Ain Techmouchent.

6.5.1 Tipasa

In the Tipasa province, Authemayou et al. (2016) identified six sites from which cross-sections were extracted and beach
1065 deposits were sampled. To measure elevations, the authors used a combination of SPOT Digital Elevation Model (20-m vertical accuracy) and a barometric altimeter. No detailed stratigraphic description of the beach deposits is given other than their characterization as "*shelly sandstone units*". Mollusk samples for U-Series radiometric dating were collected from what Atemayou et al. (2016) call "Terrace 1". Three U-Series ages, identified by the original authors as Age ID n. 4, Age ID n. 21, and Age ID n. 48 are reported. Age ID n.4 was done on a sample taken from the profile *AT1* (Chenoua, RSL ID 4) and gives
1070 an age of 67 ka. Age ID n. 21 was taken from the profile *AT3* (Boun Haroun, RSL ID 6) and gives an age of 102 ka. Age ID n. 48 was taken from *AT5* (Ain Benian, RSL ID 9) and gives an age of 130.5 ka (+4.5/-4.3). Other ages correlated to Terrace 1 come from Tipasa (*AT2* and *AT2'*, respectively RSL IDs 5 and 7) and were published by Stearns and Thurber (1965). They report U-Series ages of 140±10 ka (sample L-779a) and 125±10ka (sample L-779B); however radiometric data is not available and was not inserted in the database. The samples were taken from what the original authors called "*low-*
1075 *Quaternary beach deposits*".

Maouche et al., 2011 suggested that the "Terrace 1" in the area of Tipasa is located at 175-185m a.s.l., at odds with other descriptions of this terrace. Subsequent comments and replies (Pedoja et al., 2013; Maouche et al., 2013) did not clarify this controversy, until the work of Authemayou et al. (2016) where it seems clear that the "Terrace 1" is located only up to 10 m a.s.l.

6.5.2 Oran and Ain Techmouchent

In the Oran and Ain Techmouchent provinces, the Last Interglacial terrace is reported by Meghraoui et al. (1996) in a table within the paper, with elevations derived most likely from topographic maps (Arzew, RSL ID 11 and Cap Figalo, RSL ID 12). The only chronologic constraint that points to the Last Interglacial age is the reported presence, on these terraces, of *P. latus* which grants a tentative chronostratigraphic correlation with "Terrace 1" in the Tipasa province deposits where the same species was found.

6.6 Morocco

The Quaternary marine terraces cropping out along the Mediterranean Moroccan coasts (Figure 33) testify uplift during the Quaternary (El Gharbaoui, 1977). However, they have not been studied deeply as the counterpart on the Spanish coast. Pieces of evidence of the Last Interglacial from Tanger to Pointe Ciress have been related to paleo shorelines between 8 and ~20 m a.s.l (Cadet et al., 1977; El Fahssi, 1999; Poujol et al., 2014), whereas the marine Achakkar terrace at 6 m a.s.l. (Brébion et al., 1986), nearby Tanger on the Atlantic side has been U-Series constrained on mollusk shells by Stearns and Thurber, 1965 to the Last Interglacial (120 ± 10 ka).

6.6.1 The Dhâda terrace

The *Dhâda* terrace (RSL ID 248-249) has been identified between 13 and 15 m a.s.l. and was characterized firstly by (El Abdellaoui et al., 2016). The terrace, which extends for about 1 km along the coast, is made of marine sands within shell fragments and eolian deposits. (El Abdellaoui et al., 2016) recognized two transgressive phases related to the Last Interglacial (MIS 5e) based on four U-Series dating on *Dendrophyllia ramea* (Linnaeus) corals. The age provided must be considered as a minimum age because of the high 234U/238 activity ratio. Moreover, the Authors reject a U-Series age obtained from *Lithothamnion calcareum* algae sampled (USeries ID 2943) within the same Unit of the corals, as considered rejuvenated by secondary uranium. Such dating (USeries ID 546 to 549), allowed El Abdellaoui et al. (2016) to stratigraphically correlating the *Zhâra* (RSL ID 3598) and *Hejar-Lasfar* (RSL ID 3599) marine terraces, few kilometers eastward and westward respectively to *Dhâda* terrace, with the MIS 5e. The inner edge of the *Zhâra* and *Hejar-Lasfar* terraces is in the 13-14 m elevation range.

6.6.2 Cape Leona

The first attempt to date the Cape Leona staircase sequence of marine terraces has been proposed by El Kadiri et al. (2010) by correlation with the U-Series dated travertines at the nearby *Beni Younech* site (RSL ID 259). Such correlation is supported by El Kadiri et al. (2010) by geochronological and topographic comparison between the Cape Leona and

Moroccan Atlantic coast marine terraces (El Fahssi, 1999). However, in the same area, Abad et al. (2013) have been constrained by U-Series dating on flowstones covering marine sediments both a minimum elevation (marine limiting) and a

1110   tidal notch for the MIS 5e and 5a respectively at ca. 14 m a.s.l. (RSL ID 259) and 10 m a.s.l. (RSL ID 260). The notch at 10 m has been assigned to MIS 5a by geomorphological correlation with a beach deposit bearing calcareous algae dated ca. 84 ka (USeries ID 554), but, according to El Abdellaoui et al. (2016), such dating is not reliable because of rejuvenation processes occurring in calcareous algae as evidenced for the *Dhâda* terrace (see the previous paragraph).

6.6.3 Al-Hoceima

1115   The Al-Hoceima region is situated at the eastern edge of Mediterranean Morocco. At the Al-Hoceima site (RSL ID 929), Hearty (1986) dated marine deposits (AAR ID 195) bearing *Glycimeris glycimeris* and reported the occurrence of Senegalese fauna with *P. latus*. The inner-edge of the marine terrace related to MIS 5e was assessed by Poujol et al. (2014) at 22± 1 m a.s.l. (RSL ID 3622). Such correlation is based on U-Series dating on corals (USeries ID 2952 and 2953) and *P. Latus* (USeries IDs 2954 and 2955) from the MIS 7 marine terrace. However, it is worth noting that the samples of Poujol et al.

1120   (2014) are affected by chemical weathering.
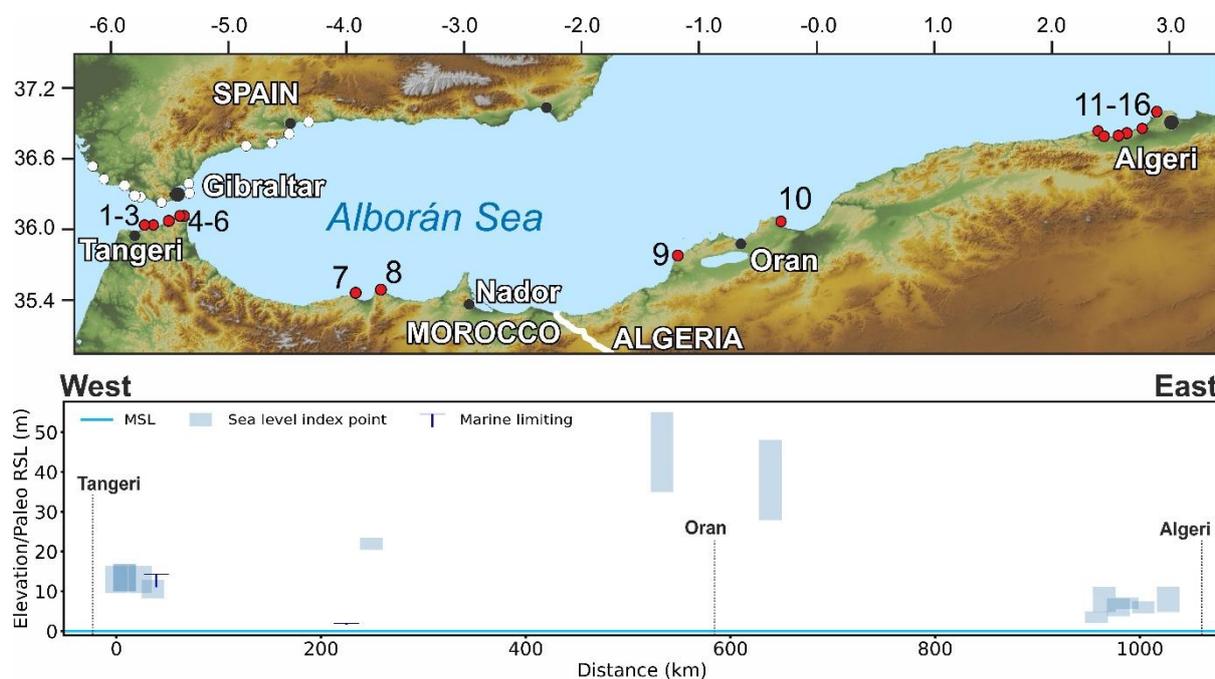
Figure 33: Last Interglacial sea level data for Algeria and Morocco. Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset. Lower panel:

1125 **Distance/Elevation graph, from West (left) to East (right). Sites list: 1: Hejar Lasfar marine terrace (RSL ID 3599). 2: Dhada marine terrace S2 (RSL ID 248). 3: Dhada marine terrace S3 (RSL ID 249). 4: Zhâra marine terrace (RSL ID 3598). 5: Cape Leona Section C (RSL ID 260). 6: Bel Younech Beach Section A (RSL ID 259). 7: Al Hoceima (RSL ID 929). 8: Rastarf Cape Al-Hoceima (RSL ID 3622). 9: Cap Figalo (RSL ID 12). 10: Arzew (RSL ID 11). 11: Chenoua Transect AT1 (RSL ID 4). 12: Tipasa Transect AT2 (RSL ID 5). 13: Tipasa Transect AT2' (RSL ID 7). 14: Bou Haroun Transect AT3 (RSL ID 6). 15: Mazafran**
1130 **Transect AT4 (RSL ID 8). 16: Ain Benian Transect AT5 (RSL ID 9).**

7 Final remarks

MIS 5 sea-level proxies have been preserved at several sites along the coasts of the Western Mediterranean in different geological facies. In stable to slowly uplifting sites, beach deposits containing warmer-water faunal assemblages can be found a few meters above present sea level, or inside coastal caves. Along uplifted coasts, marine terraces (locally capped by

1135 coastal or marine deposits) mark the peak of the Last Interglacial transgression, which is instead found as a transgressive sequence in cores drilled in subsiding areas.

Besides MIS 5e, several locations (especially in uplifted areas) preserved remnants of MIS 5a and 5c sea-level proxies (that were also inserted in the database) and former interglacials. For example, Zazo et al. (2013) report terraces attributed to MIS 7, MIS 9, and MIS 11 along the Spanish coasts. Recent studies on cave deposits in Mallorca allowed placing important

1140 benchmarks on Early Pleistocene and Pliocene highstands (Dumitru et al., 2021; Dumitru et al., 2019). Similarly, marine overgrowth on speleothems collected from the Argentarola Cave, in Italy, allowed to establish minimum positions of sea level during the penultimate interglacial (MIS 7, Dutton et al., 2009b; Bard et al., 2002). At the moment, a standardized review of pre-MIS 5 sea-level proxies is not available. Instead, Holocene sea-level studies were compiled within a single database (Vacchi et al., 2016, 2018) following the standardized template of Khan et al. (2019). These recent reviews

1145 summarized the large tradition of studies related to Holocene sea-level proxies in this part of the Mediterranean basin (see Lambeck et al., 2004 for an overview).

While Western Mediterranean MIS 5 sites are often characterized by geological units with narrow indicative ranges, there has been a lack of precise measurement and datum attribution, which researchers started to address only recently (e.g., Stocchi et al., 2018; Lorscheid et al., 2017; Muhs et al., 2015; Antonioli et al., 2018). As sea-level studies progress in the

1150 Western Mediterranean, it is imperative that the elevation of the most relevant outcrops is re-measured with accurate instrumentation (e.g., differential GNSS systems) and that elevations are referred to well-defined sea level datums.

Another issue that is common within Western Mediterranean MIS 5 proxies is the paucity of reliable absolute ages. This is in part compensated with correlations between sites supported by (bio)stratigraphic and Amino Acid Racemization correlations, but this hinders the possibility of detailing intra-interglacial dynamics, such as the presence and timing of sea-level

1155 fluctuations. While it is indeed considered possible that some Mediterranean sites recorded MIS 5e sea-level fluctuations

(e.g., Hearty et al., 2007), these are often inferred from either superimposed deposits with slightly different AAR ratios or from the concurrent presence of lower deposit and upper notches (that can be only dated indirectly). In this context, future studies should be aimed at obtaining more reliable ages at sites where the MIS 5e stratigraphy points to sea-level fluctuations. This is of particular importance for the southern coasts of France and Corsica, where several interesting Last Interglacial outcrops were never corroborated by robust and state-of-the-art dating techniques. These coastal zones, mostly occurring in regions with minimal or negligible neotectonics, have the potential to provide important insights into the magnitude and the sea-level fluctuations within the MIS 5e in the western Mediterranean.

A particular situation characterizes the coastal plains of the northwestern Adriatic Sea where, because of the regional subsiding setting, deposits related to MIS 5e are found at considerable depth. Despite the limited accessibility through stratigraphic cores, they allow investigating the 3D relations existing between different sedimentary facies formed during the marine transgression. In this area, the chronostratigraphy is mainly based on pollen analyses which correlate with the Eemian paleobotanic assemblages recognized in other European regions.

Gathering more reliable ages would also help solve several scientific debates over different sites (the main ones were briefly summarized in the regional descriptions above), as well as the long-lasting debate over the presence, in the Western Mediterranean, of Senegalese fauna (and, in particular, *P. latus*) also in stages other than MIS 5e.

8 Data availability

The Western Mediterranean sea-level database is available open access and kept updated as necessary at this link: https://doi.org/10.5281/zenodo.4497365 (Cerrone et al, 2021b). The files at this link were exported from the WALIS database interface on the 3rd of February 2021. Description of each field in the database is contained at this link: https://doi.org/10.5281/zenodo.3961544, which is readily accessible and searchable here: https://walis-help.readthedocs.io/en/latest/. More information on the World Atlas of Last Interglacial Shorelines can be found here: https://warmcoasts.eu/world-atlas.html. Users of our database are encouraged to cite the original data sources alongside our database and this article. The background topography for geographic images has been obtained from the Shuttle Radar Topography Mission void-filled DEM (Farr et al., 2007) unless specifically noted in the image.

Author contributions

All authors compiled the database and wrote the manuscript jointly. C. Cerrone curated the text for southern Italy and the southern portion of the Western Mediterranean (Algeria and Morocco). M. Vacchi curated text for France, Corsica and

Sardinia. A. Fontana curated text for the Adriatic Sea. A. Rovere curated the text and data for Spain and Tyrrhenian Northern Italy.

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References

Abad, M., Rodríguez-Vidal, J., Aboumaria, K., Zaghloul, M. N., Cáceres, L. M., Ruiz, F., Martínez-Aguirre, A., Izquierdo, T. and Chamorro, S.: Evidence of MIS 5 sea-level highstands in Gebel Mousa coast (Strait of Gibraltar, North of Africa), Geomorphology, 182(January), 133–146, doi:10.1016/j.geomorph.2012.11.004, 2013.

Abate, B., Buccheri, G., Renda, P. and Incandela, A.: Le Sezioni Tirreniane delle località La Conca e Punta Libeccio (Isola di Marettimo-Arcipelago delle Egadi, Sicilia N-O). Indagini stratigrafica e paleoecologica, Bollettino Società Geologica Italiana, 115, 145–158, 1996.

Abate, B., Di Maggio, C., Incandela, A. and Renda, P.: Carta geologica dei Monti di Capo San Vito, scala 1:25.000, Dipartimento di Geologia e Geodesia dell'Università di Palermo, 1993.

Abate, B., Ferrini, G., Incandela, A. and Renda, P.: Ritrovamento di depositi a Strombus bubonius nell'isola di Favignana, Rivista Mineraria Siciliana, 162, 37–46, 1992.

Abate, B., Di Maggio, C., Incandela, A. and Renda, P.: Nuovi dati sulla geologia della penisola di Capo San Vito (Sicilia NW), Memorie Società Geologica Italiana, 47, 15–25, 1991.

Albrecht. P. and Mosetti, F.: Karst evolution and sea level. Memorie Società Geologica Italiana, 40, 383-387, 1987.

Ambert, P.: Les formations littorales pléistocènes du Languedoc [Pleistocene shorelines of Languedoc], Quaternaire, 10(2), 83–93, doi:10.3406/quate.1999.1633, 1999.

Amorosi, A., Maselli, V. and Trincardi, F.: Onshore to offshore anatomy of a late Quaternary source-to-sink system (Po PlainAdriatic Sea Italy), Earth-Science Reviews, 153, 212–237, doi:10.1016/j.earscirev.2015.10.010, 2016.

1210 Amorosi, A., Antonioli, F., Bertini, A., Marabini, S., Mastronuzzi, G., Montagna, P., Negri, A., Rossi, V., Scarponi, D., Taviani, M., Angeletti, L., Piva, A. and Vai, G. B.: The Middle-Upper Pleistocene Fronte Section (Taranto, Italy): An exceptionally preserved marine record of the Last Interglacial, Global and Planetary Change, 119, 23–38, doi:10.1016/j.gloplacha.2014.04.007, 2014.

Amorosi, A., Fontana, A., Antonioli, F., Primon, S. and Bondesan, A.: Post-LGM sedimentation and Holocene shoreline
1215 evolution in the NW Adriatic coastal area, GeoActa, 7, 41–67 [online] Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-69249239331&partnerID=40&md5=08ea5323ae7f00a626efe15b6336921a, 2008a.

Amorosi, A., Pavesi, M., Lucchi, M. R., Sarti, G. and Piccin, A.: Climatic signature of cyclic fluvial architecture from the Quaternary of the central Po Plain Italy, Sedimentary Geology, 209(1-4), 58–68, doi:10.1016/j.sedgeo.2008.06.010, 2008b.

1220 Amorosi, A., Colalongo, M. L., Fiorini, F., Fusco, F., Pasini, G., Vaiani, S. C. and Sarti, G.: Palaeogeographic and palaeoclimatic evolution of the Po Plain from 150-ky core records, Global and Planetary Change, 40(1-2), 55–78, doi:10.1016/s0921-8181(03)00098-5, 2004.

Amorosi, Colalongo, Pasini and Preti: Sedimentary response to Late Quaternary sea-level changes in the Romagna coastal plain (northern Italy), Sedimentology, 46(1), 99–121, doi:10.1046/j.1365-3091.1999.00205.x, 1999.

1225 Andreucci, S., Clemmensen, L. B., Murray, A. S. and Pascucci, V.: Middle to late Pleistocene coastal deposits of Alghero northwest Sardinia (Italy): Chronology and evolution, Quaternary International, 222(1-2), 3–16, doi:10.1016/j.quaint.2009.07.025, 2010.

Andreucci, S., Pascucci, V., Murray, A. S. and Clemmensen, L. B.: Late Pleistocene coastal evolution of San Giovanni di Sinis, west Sardinia (Western Mediterranean), Sedimentary Geology, 216(3-4), 104–116, 2009.

1230 Antonioli, F., Ferranti, L., Stocchi, P., Deiana, G., Presti, V. L., Furlani, S., Marino, C., Orru, P., Scicchitano, G., Trainito, E. and others: Morphometry and elevation of the last interglacial tidal notches in tectonically stable coasts of the Mediterranean Sea, Earth-Science Reviews, 185, 600–623, 2018.

Antonioli, F., Presti, V. L., Rovere, A., Ferranti, L., Anzidei, M., Furlani, S., Mastronuzzi, G., Orru, P. E., Scicchitano, G., Sannino, G. and others: Tidal notches in Mediterranean Sea: a comprehensive analysis, Quaternary Science Reviews, 119,
1235 66–84, 2015.

Antonioli, F., D'Orefice, M., Ducci, S., Firmati, M., Foresi, L. M., Graciotti, R., Pantaloni, M., Perazzi, P. and Principe, C.: Palaeogeographic reconstruction of northern Tyrrhenian coast using archaeological and geomorphological markers at Pianosa island (Italy), Quaternary International, 232(1-2), 31–44, doi:10.1016/j.quaint.2010.03.017, 2011.

Antonioli, F., Ferranti, L., Fontana, A., Amorosi, A., Bondesan, A., Braitenberg, C., Dutton, A., Fontolan, G., Furlani, S., Lambeck, K., Mastronuzzi, G., Monaco, C., Spada, G. and Stocchi, P.: Holocene relative sea-level changes and vertical movements along the Italian and Istrian coastlines, Quaternary International, 206(1-2), 102–133, doi:10.1016/j.quaint.2008.11.008, 2009.

Antonioli, F., Kershaw, S., Renda, P., Rust, D., Belluomini, G., Cerasoli, M., Radtke, U. and Silenzi, S.: Elevation of the last interglacial highstand in Sicily (Italy): A benchmark of coastal tectonics, Quaternary International, 145-146, 3–18, doi:10.1016/j.quaint.2005.07.002, 2006.

Antonioli, F., Lambeck, K., Kershaw, S., Rust, D., Sylos Labini, S., Segre, A. G., Verrubbi, Belluomini, G., Dai Pra, G., Ferranti, L., Improta, S. and Vesica, P.: Evidence for non-uniform uplift rates in southern Italy (Calabria and eastern Sicily: Taormina, St. Alessio, Ganzirri, Scilla, Ioppolo, Capo Rizzuto) on glacialcycle timescales, Quaternaria Nova, VIII, 187–192, 2004.

Antonioli, F., Cremona, G., Immordino, F., Puglisi, C., Romagnoli, C., Silenzi, S., Valpreda, E. and Verrubbi, V.: New data on the Holocenic sea-level rise in NW Sicily (Central Mediterranean Sea), Global and Planetary Change, 34(1-2), 121–140, doi:10.1016/S0921-8181(02)00109-1, 2002.

Antonioli, F., Girotti, O., Improta, S., Nisi, M. F., Puglisi, C. and Verrubbi, V.: Nuovi dati sulla trasgressione marina olocenica nella pianura versiliese, in Proceedings of the Meeting 'Le Pianure', Ferrara, pp. 214–218., 1999a.

Antonioli, F., Silenzi, S., Vittori, E. and Villani, C.: Sea level changes and tectonic mobility: Precise measurements in three coastlines of Italy considered stable during the last 125 ky, Physics and Chemistry of the Earth Part A: Solid Earth and Geodesy, 24(4), 337–342, doi:10.1016/s1464-1895(99)00038-1, 1999b.

Antonioli, F., Cinque, A., Ferranti, L. and Romano, P.: Emerged and submerged quaternary marine terraces of Palinuro Cape (southern Italy), Memorie Descrittive Carta Geologica d'Italia, LII, 237–260, 1994a.

Antonioli, F., Belluomini, G., Ferranti, L., Improta, S. and Reitano, G.: Il sito preistorico dell'arco naturale di Capo Zafferano (Sicilia). Aspetti geomorfologici e relazione con le variazioni del livello marino olocenico, Il Quaternario, 7 (1), 109–118, 1994b.

Antonioli, F., Dai Pra, G. and Hearty, P. J.: I sedimenti quaternari nella fascia costiera della Piana di Fondi (Lazio meridonale), Bollettino della Societa Geologica Italiana, 107(3-4), 491–501, 1988.

1265   Authemayou, C., Pedoja, K., Heddar, A., Molliex, S., Boudiaf, A., Ghaleb, B., Lanoe, B. V. V., Delcaillau, B., Djellit, H., Yelles, K. and Nexer, M.: Coastal uplift west of Algiers (Algeria): pre- and post-Messinian sequences of marine terraces and rasas and their associated drainage pattern, International Journal of Earth Sciences, 106(1), 19–41, doi:10.1007/s00531-016-1292-5, 2016.

Balescu, S., Lamothe, M. and Lh, R.: Thermoluminescence dating tests of Pleistocene sediments from uplifted marine

1270   shorelines along the southwest coastline of the Calabrian Peninsula (southern Italy), Palaeogeography, Palaeoclimatology, Palaeoecology, 130, 25–41, doi:10.1016/S0031-0182(96)00119-8, 1997.

Bard, E., Antonioli, F. and Silenzi, S.: Sea-level during the penultimate interglacial period based on a submerged stalagmite from Argentarola Cave (Italy), Earth and Planetary Science Letters, 196(3-4), 135–146, 2002.

Bardají, T., Cabero, A., Lario, J., Zazo, C., Silva, P. G., Goy, J. L. and Dabrio, C. J.: Coseismic vs. climatic factors in the

1275   record of relative sea level changes: an example from the Last Interglacials in SE Spain, Quaternary Science Reviews, 113, 60–77, doi:10.1016/j.quascirev.2014.10.005, 2015.

Bardají, T., Goy, J. L., Zazo, C., Hillaire-Marcel, C., Dabrio, C. J., Cabero, A., Ghaleb, B., Silva, P. G. and Lario, J.: Sea level and climate changes during OIS 5e in the Western Mediterranean, Geomorphology, 104(1-2), 22–37, doi:10.1016/j.geomorph.2008.05.027, 2009a.

1280   Bardají, T., Goy, J. L., Zazo, C., Hillaire-Marcel, C., Dabrio, C. J., Cabero, A., Ghaleb, B., Silva, P. G. and Lario, J.: Reply to the comments by Mauz B. and Antonioli, F. on Sea Level and Climate Changes during OIS 5e in the Western Mediterranean, Geomorphology, 110(3-4), 231–235, doi:10.1016/j.geomorph.2009.05.007, 2009b.

Bardají, T., Civis, J., Dabrio, C. J., Goy, J. L. and Somoza, L.: Geomorfología y estratigrafía de las secuencías marinas y continentales cuaternarias de la Cuenca de Cope, Murcia, España, in Estudios sobre Geomorfología del Sur de España, pp.

1285   11–16., 1986.

Barra, D., Cinque, A., Gewelt, M. and Hurtgen, C.: L'ospite caldo Sylvestra seminis (Bonaduce, Masoli and Pugliese, 1976) (Crustacea, Ostracoda): un possibile marker dell'Ultimo Interglaciale dell'area Mediterranea, Il Quaternario, 4 (2), 327–332, 1991.

Barrière, J.: Le rivage tyrrhénén de létang de Bages et de Sigean (Aude), Bulletin de lAssociation française pour létude du

1290   quaternaire, 3(4), 251–283, doi:10.3406/quate.1966.1046, 1966.

Belluomini, G. and Delitala, L.: Amino acid racemization dating of Quaternary deposits of Central and Southern Italy, Organic geochemistry, 13(4-6), 735–740, 1988.

Belluomini, G., Gliozzi, E., Ruggieri, G., Branca, M. and Delitalia, L.: First dates on the terraces of the Crotone Peninsula (Calabria, Southern Italy), Bollettino Società Geologic Italiana, 107, 249–254, 1988.

1295 Belluomini, G., Branca, M., Delitala, L., Pecorini, G. and Spano, C.: Isoleucine epimerization dating of Quaternary marine deposits in Sardinia, Italy in Dating Mediterranean shorelines, Zeitschrift für Geomorphologie. Supplementband, (62), 109–117, 1986.

Benjamin, J., Rovere, A., Fontana, A., Furlani, S., Vacchi, M., Inglis, R. H., Galili, E., Antonioli, F., Sivan, D., Miko, S. and others: Late Quaternary sea-level changes and early human societies in the central and eastern Mediterranean Basin: An 1300 interdisciplinary review, Quaternary International, 449, 29–57, 2017.

Bernat, M., JC, E., JC, B. and others: Nouvelles datations Io-U sur des Strombes du dernier Interglaciaire en Mediterranée (La Marina, Espagne) et implications geologiques, Comptes rendus des seances de l'academie de Sciences de Paris, II-295, 1982.

Bianca, M., Catalano, S., De Guidi, G., Gueli, A. M., Monaco, C., Ristuccia, G. M., Stella, G., Tortorici, G., Tortorici, L. 1305 and Troja, S. O.: Luminescence chronology of Pleistocene marine terraces of Capo Vaticano peninsula (Calabria, Southern Italy), Quaternary International, 232(1-2), 114–121, doi:10.1016/j.quaint.2010.07.013, 2011.

Bianca, M., Monaco, C., Tortorici, L. and Cernobori, L.: Quaternary normal faulting in southeastern Sicily (Italy): A seismic source for the 1693 large earthquake, Geophysical Journal International, 139(2), 370–394, doi:10.1046/j.1365-246X.1999.00942.x, 1999.

1310 Bini, M., Zanchetta, G., Drysdale, R. N., Giaccio, B., Stocchi, P., Vacchi, M., Hellstrom, J. C., Couchoud, I., Monaco, L., Ratti, A., Martini, F. and Sarti, L.: An end to the Last Interglacial highstand before 120 ka: Relative sea-level evidence from Infreschi Cave (Southern Italy), Quaternary Science Reviews, 250, 106658, doi:10.1016/j.quascirev.2020.106658, 2020.

Blanc, A. C. and Segre, A. G.: Excursion au Mont Circé, in 4th Conf Int Assoc Quatern Res. Rome-Pisa, pp. 87–106., 1953.

Blanc, A. C. and Segre, A. G.: Nuovi giacimenti tirreniani e paleolitici sulla costiera tra Sperlonga e Gaeta, Historia 1315 Naturalis, 2, 1–2, 1947.

Blanc, A. C.: Una spiaggia pleistocenica a Strombus bu bonius presso Palidoro (Roma), Ist. Ital. di Antropologia., 1936.

Blanc, A. C.: Stratigrafia del Canale Mussolini nell'Agro Pontino, N/A., 1935.

Blanc, G. A.: Grotta Romanelli. Dati ecologici e paleontologici, Archivio per l'Archeologia e l'Etnologia, 58, 1–50, 1928.

Blanc, G. A.: Grotta Romanelli I. Stratigrafia dei depositi e natura e origine di essi, Archivio per l'Antropologia e l'Etnologia, 50, 1–39, 1920.

Boenzi, F., Caldara, M. and Pennetta, L.: (The Tyrrhenian transgression in the Castellaneta environs, Taranto, Italy)., Geologia Applicata e Idrogeologia, 20(1), 163–175, 1985.

Bonadonna, F. P.: Studi sul Pleistocene del Lazio. III. Linee di costa lungo il litorale di Tarquinia (Lazio settentrionale), Geologica Romana, 6, 131–135, 1967a.

Bonadonna, F. P.: Stud sul pleistocene del Lazio; IV, La linea di costa tirreniana di Ponte Galeria (Roma), Quaternaria, 9, 285–299, 1967b.

Bonfiglio, L. and Violanti, L.: Prima segnalazione di Tirreniano ed evoluzione Pleistocenica del Capo Peloro (Sicilia Nord-Orientale), Geografia Fisica Dinamica Quaternaria, 6, 3–15, 1983.

Bonfiglio, L.: Terrazzi marini e depositi continentali quaternari di Taormina (Sicilia), Quaternaria, 1981.

Bonifay, E. and Mars, P.: Le Tyrrhénien dans le cadre de la chronologie quaternaire mediterranéenne, Bulletin de la Société Géologique de France, S7-I(1), 62–78, doi:10.2113/gssgfbull.s7-i.1.62, 1959.

Bordoni, P. and Valensise, G.: Deformation of the 125 ka marine terrace in Italy: tectonic implications, Geological Society London, Special Publications, 146(1), 71–110, doi:10.1144/gsl.sp.1999.146.01.05, 1999.

Boschian, G., Bossio, A., Dallantonia, B. and Mazzanti, R.: Il Quaternario della Toscana Costiera, 2006.

Bracchi, V. A., Nalin, R. and Basso, D.: Persistrombus latus-bearing deposits south of Isola di Capo Rizzuto, Calabria (Southern Italy), Il Quaternario - Italian Journal of Quaternary Sciences, 24, 23–25, 2011.

Brancaccio, L., Cinque, A., Russo, F., Beluomini, G., Branca, M. and Delitalia, L.: Segnalazione e datazione di depositi marini tirreniani sulla costa campana, Bollettino della Società geologica italiana, 109(2), 259–265, 1990.

Brancaccio, L., Cinque, A., D'Angelo, G., Russo, F., Santangelo, N. and Sgrosso, I.: Evoluzione tettonica e geomorfologica della Piana del Sele (Campania, Appennino meridionale), Geografia Fisica e Dinamica Quaternaria, 10(January), 47–55, 1987.

Brancaccio, L., Cinque, A., Belluomini, G., Branca, M. and Delitalia, L.: Isoleucine epimerization dating and tectonic significance of Upper Pleistocene sea-level features of the Sele Plain (Southern Italy), Zeitschrift für Geomorphologie, 62, 159–166, 1986.

1345 Brancaccio, L., Capaldi, G., Cinque, A., Pece, R. and Sgrosso, I.: Th/U dating of corals from a Tyrrhenian beach in Sorrentine Peninsula (southern Italy), Quaternaria, 20, 175–183, 1978.

Brunović, D., Miko, S., Hasan, O., Papatheodorou, G., Ilijanić, N., Miserocchi, S., Correggiari, A. and Geraga, M.: Late Pleistocene and Holocene paleoenvironmental reconstruction of a drowned karst isolation basin (Lošinj Channel NE Adriatic Sea), Palaeogeography, Palaeoclimatology, Palaeoecology, 544, 109587, doi:10.1016/j.palaeo.2020.109587, 2020.

1350 Brückner, H.: Stratigraphy, evolution and age of quaternary marine terraces in Marocco and Spain, Zeitschrift für Geomorphologie. Supplementband, 62, 83–101, 1986.

Brückner, H. and Radtke, U.: Paleoclimatic implications derived from profiles along the Spanish Mediterranean coast, in Symposium on climatic fluctuations during the Quaternary in the Western Mediterranean regions, pp. 467–486., 1986.

Brébion, P., Raynal, J. P., Texier, J. P. and Alouan, M.: Nouvelles données sur le Quaternaire atlantique à Casablanca et
1355 Achakar, Comptes Rendus de l'Acadèmie des Sciences, Série II, 302 (14), 901–904, 1986.

Buccheri, G., Renda, P., Morreale, C. and Sorrentino, G.: Il Tirreniano dell'isola di Lampedusa (Arcipelago Pelagiano, Agrigento, Italia). Le successioni di cala Maluk e Cala Uccello, Bollettino Società Geologica Italiana, 118, 361–373, 1999.

Busetti, M., Baradello, L., Caburlotto, A., Gordini, E., Zanolla, C., Accettella, D., Antonioli, F., Paganini, P.: Indagini geofisiche per lo studio dell'evoluzione Tardo-Pleistocenica ed Olocenica della Laguna di Grado e Marano (Adriatico
1360 Settentrionale). Workshop finale Project VECTOR (VulnErability of the Italian coastal area and marine Ecosystems to Climatic changes and Their rOle in the Mediterranean caRbon cycles), Roma, 18-19 ottobre 2010.

Butzer, K. W. and Cuerda, J.: Coastal stratigraphy of southern Mallorca and its implications for the Pleistocene chronology of the Mediterranean Sea, The Journal of Geology, 70(4), 398–416, 1962.

Cadet, J.-P., Fourniguet, J., Gigout, M., Guillemin, M. and Pierre, G.: Les resultats de l'analyse structurale et de la
1365 neotectonique des littoraux; La neotectonique des littoraux, Bulletin de la Société Géologique de France, S7-XIX(3), 600–605, doi:10.2113/gssgfbull.S7-XIX.3.600, 1977.

Caldara, M.: La sezione tirreniana di Ponte del Re (Castellaneta Marina, Taranto): analisi paleoecologica, Atti della Società Toscana Scienze Naturali Mem. A XCIII (1986), 129–163, 1987.

Campo, B., Bruno, L. and Amorosi, A.: Basin-scale stratigraphic correlation of late Pleistocene-Holocene (MIS 5e-MIS 1)
1370 strata across the rapidly subsiding Po Basin (northern Italy), Quaternary Science Reviews, 237, 106300, doi:10.1016/j.quascirev.2020.106300, 2020.

Carboni, S., Lecca, L., Hillaire-Marcel, C. and Ghaleb, B.: MIS 5e at San Giovanni di Sinis (Sardinia Italy): Stratigraphy, U/Th dating and eustatic inferences, Quaternary International, 328-329, 21–30, doi:10.1016/j.quaint.2013.12.052, 2014.

Carboni, M. G., Bergamin, L., Di Bella, L., Esu, D., Cerone, E. P., Antonioli, F. and Verrubbi, V.: Palaeoenvironmental reconstruction of late Quaternary foraminifera and molluscs from the ENEA borehole (Versilian plain, Tuscany, Italy), Quaternary Research, 74(2), 265–276, 2010.

Carboni, S. and Lecca, L.: L'archivio stratigrafico del Tirreniano della Sardegna, 2008.

Carminati, E., Doglioni, C. and Scrocca, D.: Apennines subduction-related subsidence of Venice (Italy), Geophysical Research Letters, 30(13), doi:10.1029/2003gl017001, 2003.

Carobene, L.: Marine Notches and Sea-Cave Bioerosional Grooves in Microtidal Areas: Examples from the Tyrrhenian and Ligurian Coasts Italy, Journal of Coastal Research, 313, 536–556, doi:10.2112/jcoastres-d-14-00068.1, 2015.

Carobene, L. and Dai Pra, G.: Middle and Upper Pleistocene sea level highstands along the Tyrrhenian coast of Basilicata (Southern Italy), Il Quaternario, 4, 173–202 [online] Available from: http://www.aiqua.it/images/directory/1327416874Quaternario41apag.173-202.pdf, 1991.

Carobene, L. and Dai Pra, G.: Genesis, Chronology and Tectonics of the Quaternary marine terraces of the Tyrrhenian coast of northern Calabria (Italy). Their correlation with climatic variations, Il Quaternario, 3(2), 75–94, 1990.

Carobene, L., Dai Pra, G. and Gewelt, M.: Niveaux marins du Pléistocène moyen-supérieur de la côte tyrrhénienne de la Calabre (Italie méridionale) Datations 230Th/234U et tectonique récente, Zeitschrift für Geomorphologie, Supp.-Bd., 141–158, 1986.

Casini, L., Andreucci, S., Sechi, D., Huang, C.-Y., Shen, C.-C. and Pascucci, V.: Luminescence dating of Late Pleistocene faults as evidence of uplift and active tectonics in Sardinia, W Mediterranean, Terra Nova, 2020.

Catalano, S. and Guidi, G. D.: Late Quaternary uplift of northeastern Sicily : relation with the active normal faulting deformation, Journal of Geodynamics, 36, 445–467, doi:10.1016/S0264-3707(02)00035-2, 2003.

Catalano, S., De Guidi, G., Monaco, C., Tortorici, G. and Tortorici, L.: Long-term behaviour of the late Quaternary normal faults in the Straits of Messina area (Calabria arc): structural and morphological constraints, Quaternary International, 101/102, 81–91, 2003.

Cerrone, C., Ascione, A., Robustelli, G., Balassone, G., Soligo, M. and Tuccimei, P.: Late Quaternary uplift and sea level fluctuations along the Tyrrhenian margin of Basilicata - northern Calabria (southern Italy): New constraints from raised paleoshorelines, Geomorphology, submitted, 2021a.

1400 Cerrone, Ciro, Vacchi, Matteo, Fontana, Alessandro and Rovere, Alessio: Last interglacial sea-level index points in the Western Mediterranean, doi:10.5281/zenodo.4497365, 2021b.

Cerrone, C., Di Donato, V., Robustelli, G., Soligo, M., Tuccimei, P. and Ascione, A.: Evolution of the Campania Plain Quaternary coastal graben (Southern Apennines): constraints from raised paleoshorelines, Geomorphology, submitted, 2020.

Cerrone, C., Ascione, A., Balassone, G., Mormone, A., Robustelli, G., Soligo, M. and Tuccimei, P.: INQUA Focus Group
1405 Earthquake Geology and Seismic Hazards INQUA Focus Group Earthquake Geology and Seismic Hazards, Active Tectonics and Archeoseismology (PATA), (June), 25–27, 2018.

Ciampalini, A., Ciulli, L., Sarti, G. and Zanchetta, G.: Nuovi dati geologici del sottosuolo del "Terrazzo di Livorno", Atti della Società Toscana di Scienze Naturali, Memorie, 111, 75–82, 2006.

Cinque, A., Romano, P., Rosskopf, C., Santangelo, N. and Santo, A.: Morfologie costiere e depositi quaternari tra Agropoli e
1410 Ogliastro Marina (Cilento- Italia meridionale), Il Quaternario, 7 (1), 3–16, 1994.

Cinque, A., Alinaghi, H. H., Laureti, L. and Russo, F.: Preliminary observations on the geomorphological evolution of the Sarno Plain, Campania, southern Apennines, Geografia Fisica e Dinamica Quaternaria, 10(1), 161–174, 1987.

Conchon, O.: Le Quaternaire littoral de Corse: nouvelles données, Bulletin de l'Association française pour létude du quaternaire, 22(1), 13–20, doi:10.3406/quate.1985.1522, 1985.

1415 Conchon, O.: Le littoral de Corse (France) au Quaternaire [Corsica coast (France Western Mediterranea) during the Quaternary], Quaternaire, 10(2), 95–105, doi:10.3406/quate.1999.1634, 1999.

Cortese, E.: Descrizione geologica della Calabria, Memorie Desc. Carta Geologica Italia, 9, 1–310, 1895.

Cosentino, D. and Gliozzi, E.: Considerazioni sulle velocità di sollevamento di depositi eutirreniani dell'Italia meridionale e della Sicilia, Memorie della Società Geologica Italiana, 41, 653–665, 1988.

1420 Cotecchia, V., Dai Pra, G. and Magri, G.: Oscillazioni tirreniane e oloceniche del livello del mare nel Golfo di Taranto, corredate da datazioni con il metodo del radiocarbonio, Geologia Applicata e Idrogeologia, 4, 93–148, 1969.

Cucci, L.: Raised marine terraces in the Northern Calabrian Arc (Southern Italy): A ~ 600 kyr-long geological record of regional uplift, Annals of Geophysics, 47(4), 1391–1406, doi:10.4401/ag-3350, 2004.

Cuerda, J.: Fauna marina del Tirreniense de la Bahía de Palma (Mallorca), Bolletí de la Societat d'Història Natural de les
1425   Balears, 3, 3–75, 1957.

Dabrio, C. J., Zazo Cardeña, C., Goy Goy, J. L., Santisteban Bové, C., Bardají Azcárate, T. and Somoza Losada, L.:
Neogene and Quaternary fan-delta deposits in southeastern Spain. Field Guide, Cuadernos de geología ibérica, (15), 327–
400, 1991.

Dai Pra, G., Miyauchi, T., Anselmi, B., Galletti, M., Paganin, G.: Età dei depositi a Strombus bubonius di Vibo Valentia
1430   Marina (Italia Meridionale). Quaternario, 6 (1), 139-144, 1991

Dai Pra, G. and Hearty, P. J.: I livelli marini pleistocenici del Golfo di Taranto. Sintesi Geocronostratigrafica e tettonica,
Memorie Società Geologica Italiana, 41(September), 637–644, 1988.

Dai Pra, G. and Stearns, C. E.: Sul Tirreniano di Taranto. Datazioni su coralli con il metodo del Th230/U234, Geologica
Romana, 16, 231–242, 1977.

1435   De Lumley, H.: Le Paléolithique inférieur et moyen du Midi méditerranéen dans son cadre géologique. Tome I. Ligurie–
Provence, Persée-Portail des revues scientifics en SHS., 1969.

De Santis, V., Caldara, M., Torres, T. D. and Ortiz, J. E.: Stratigraphic units of the Apulian Tavoliere plain (Southern Italy):
Chronology, correlation with marine isotope stages and implications regarding vertical movements, Sedimentary Geology,
228(3-4), 255–270, doi:10.1016/j.sedgeo.2010.05.001, 2010.

1440   Delibrias, G., Guillier, M. T. and Labeyrie, J.: Gif natural radiocarbon measurements VII, Radiocarbon, 14(2), 280–320,
1972.

Di Grande, A. and Neri, M.: Tirreniano a Strombus bubonius a M. Tauro (Augusta-Siracusa), Rendiconti Società Geologica
Italiana, 11, 57–58, 1988.

Di Grande, A. and Scamarda, G.: Segnalazione di livelli a Strombus B. nei dintorni di Augusta, Bollettino delle Seudte
1445   dell'Accademia Gioenia di Scienze Naturali di Catania, XI, 157–172, 1973.

Donnici, S. and Serandrei-Barbero R.: Paleogeografia e cronologia dei sedimenti tardopleistonici ed olocenici presenti nel
sottosuolo di Valle Averto (Laguna di Venezia, bacino centrale). Lavori Società Veneziana Scienze Naturali, 29, 2004.

Dubar, M., Innocent, C. and Sivan, O.: Radiometric dating (U/Th) of the lower marine terrace (MIS 5.5) west of Nice
(French Riviera): Morphological and neotectonic quantitative implications, Comptes Rendus Geoscience, 340(11), 723–731,
1450   doi:10.1016/j.crte.2008.07.012, 2008.

Dumas, B., Guérémy, P., Haong, C.T., Lhénaff, R. and Raffy, J.: Gisement et rivages tyrrhnéniens de Vibo Marina (Italie du Sud): datacion 230Th /234U, soulèvement différentiel de la Calabre méridionale. Comptes Rendus Acad. Des Sci. Paris, 312, 785-791, 1991.

Dumas, B., Gueremy, P., Hearty, P. J., Lhenaff, R. and Raffy, J.: Morphometric analysis and amino acid geochronology of uplifted shorelines in a tectonic region near reggio Calabbria, South Italy, Palaeogeography, Palaeoclimatology, Palaeoecology, 68(2-4), 273–289, doi:10.1016/0031-0182(88)90045-4, 1988.

Dumas, B., Gueremy, P., Lhenaff, R. and Raffy, J.: Rates of uplift as shown by raised Quaternary shorelines in Southern Calabria (Italy)No Title, Zeitschrift fur Geomorphologie, N.F. Supplementband, 63, 119–132, 1987.

Dumitru, O. A., Austermann, J., Polyak, V. J., Fornós, J. J., Asmerom, Y., Ginés, J., Ginés, A. and Onac, B. P.: Sea-level stands from the Western Mediterranean over the past 6.5 million years, Scientific reports, 11(1), 1–10, 2021.

Dumitru, O.-A., Polyak, V. J., Asmerom, Y. and Onac, B. P.: A global standardized database of Last Interglacial (sensu lato, 130 to 75 ka) sea level records from U-series dated cave deposits, doi:10.5281/zenodo.4313861, 2020.

Dumitru, O. A., Austermann, J., Polyak, V. J., Fornós, J. J., Asmerom, Y., Ginés, J., Ginés, A. and Onac, B. P.: Constraints on global mean sea level during Pliocene warmth, Nature, 574(7777), 233–236, 2019.

Dutton, A., Scicchitano, G., Monaco, C., Desmarchelier, J. M., Antonioli, F., Lambeck, K., Esat, T. M., Fifield, L. K., McCulloch, M. T. and Mortimer, G.: Uplift rates defined by U-series and 14C ages of serpulid-encrusted speleothems from submerged caves near Siracusa, Sicily (Italy), Quaternary Geochronology, 4(1), 2–10, doi:10.1016/j.quageo.2008.06.003, 2009a.

Dutton, A., Bard, E., Antonioli, F., Esat, T. M., Lambeck, K. and McCulloch, M. T.: Phasing and amplitude of sea-level and climate change during the penultimate interglacial, Nature Geoscience, 2(5), 355–359, 2009b.

D'Orefice, M., Graciotti, R., Lo Mastro, S., Muraro, C., Pantaloni, M., Soligo, M. and Tuccimei, P.: U/Th dating of a Cladocora coespitosa from Capo San Marco marine Quaternary deposits (Sardinia, Italy), Alpine and Mediterranean Quaternary, 25(1), 3, 2012.

El Abdellaoui, J. E., Petit, F., Ghaleb, B. and Ozer, A.: Sea-level fluctuation during MIS 5e and geomorphological context on the southern coast of the Strait of Gibraltar (Morocco), Géomorphologie: Relief, Processus, Environnement, 22(3), 287–301, doi:10.4000/geomorphologie.11467, 2016.

El Fahssi, A.: Tectonique Alpine, Néotectonique et étude des formations marines quaternaire de la rive sud de Détroit de Gibraltar entre Tanger et Sebta (Rif-Maroc), Thèse de doctorat de troisième cycle, Université Mohammed V, Rabat, MAroc, 253, 1999.

1480   El Gharbaoui, A.: Note préliminaire sur l'évolution géomorphologique de la pénnsule de Tanger, Bull. Soc. géol. Fr., 19(3), 615–622, doi:10.2113/gssgfbull.s7-xix.3.615, 1977.

El Kadiri, K., Galdeano, C. S. de, Pedrera, A., Chalouan, A., Galindo-Zaldívar, J., Julià, R., Akil, M., Hlila, R. and Ahmamou, M.: Eustatic and tectonic controls on Quaternary Ras Leona marine terraces (Strait of Gibraltar, northern Morocco), Quaternary Research, 74(2), 277–288, doi:10.1016/j.yqres.2010.06.008, 2010.

1485   Esposito, C., Filocamo, F., Marciano, R., Romano, P., Santangelo, N., Scarciglia, F. and Tuccimei, P.: Late Quaternary shorelines in southern Cilento (Mt . Bulgheria): morphostratigraphy and chronology, Il Quaternario, 16 (1), 3–14, 2003.

Fabiani, R.: Tracce di Tirreniano a Strombus bubonius entro la città di Palermo, Bollettino Società Scienze Naturali ed Economiche, XIX, 1–7, 1941.

Farr, T.G., Rosen, P.A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L. and 1490   Seal, D. The shuttle radar topography mission. Reviews of geophysics, 45(2), 2007.

Federici, P. R. and Pappalardo, M.: Evidence of Marine Isotope Stage 5.5 highstand in Liguria (Italy) and its tectonic significance, Quaternary International, 145-146, 68–77, doi:10.1016/j.quaint.2005.07.003, 2006.

Ferranti, L. and Antonioli, F.: Misure del solco Tirreniano (MIS 5.5) nell'isola di Capri: valutazione di attività tettonica durante il Pleistocene superiore, 20(2), 125–136, 2007.

1495   Ferranti, L., Antonioli, F., Mauz, B., Amorosi, A., Pra, G. D., Mastronuzzi, G., Monaco, C., Orrù, P., Pappalardo, M., Radtke, U., Renda, P., Romano, P., Sansò, P. and Verrubbi, V.: Markers of the last interglacial sea-level high stand along the coast of Italy: Tectonic implications, Quaternary International, 145-146, 30–54, doi:10.1016/j.quaint.2005.07.009, 2006.

Feruglio, E.: Sedimenti marini nel sottosuolo della bassa friulana, Bollettino Società Geologica Italiana, 55, 1936.

Flemming, N. C. and Webb, C. O.: Regional patterns of coastal tectonics and eustatic change of sea level in the 1500   Mediterranean during the last 10,000 years derived from archaeological data, Zeitschrift für Geomorphologie. December, Suppl-Bd62, 1–29, 1986.

Fontana A., Bondesan A., MeneghelM., Toffoletto F., Vitturi A. and Bassan V. (eds): Note illustrative della Carta Geologica d'Italia alla scala 1:50.000 - Foglio 107 Portogruaro. Regione Veneto, Infocartografica, 216 pp., 2012

Fontana, A., Mozzi, P. and Bondesan, A.: Late pleistocene evolution of the Venetian Friulian Plain, Rendiconti Lincei, 21(S1), 181–196, doi:10.1007/s12210-010-0093-1, 2010.

Gigout, M.: Sur le Tyrrhènien de la Mèditerranée occidental, Quaternaria, 6, 1962.

Gigout, M.: Sur le quaternaire marin de Tarente (Italie), Comptes Rendus hebdomadaires de l'Acadèmie des Sèances, 250, 1094–1096, 1960.

Gignoux, M.: Les formations marines pliocenes et quaternaires de l'Italie du Sud et de la Sicilie., Ann. Univ. Lyon, 35, 1–693, 1913.

Gilli, E.: Karstodyssée 2016, Analyse des marqueurs eustatiques, tectoniques et tsunamiques dans les karsts littoraux méditerranéens, in Rapport de mission, Paris 8 University, 2018.

Gillot, P.-Y., Kiefer, G. and Romano, R.: The evolution of Mount Etna in the light of potassium-argon dating, Annali di Geofisica, 36, 267–282, 1994.

Giunta, G., Gueli, A. M., Monaco, C., Orioli, S., Ristuccia, G. M., Stella, G. and Troja, S. O.: Middle-Late Pleistocene marine terraces and fault activity in the Sant'Agata di Militello coastal area (north-eastern Sicily), Journal of Geodynamics, 55, 32–40, doi:10.1016/j.jog.2011.11.005, 2012.

Goy, J. L. and Zazo, C.: The role of neotectonics in the morphologic distribution of the Quaternary marine and continental deposits of the Elche Basin, southeast Spain, Tectonophysics, 163(3-4), 219–225, 1989.

Goy, J. L. and Zazo, C.: Sequences of quaternary marine levels in Elche Basin (eastern Betic Cordillera, Spain), Palaeogeography, palaeoclimatology, palaeoecology, 68(2-4), 301–310, 1988.

Goy, J. L., Hillaire-Marcel, C., Zazo, C., Ghaleb, B., Dabrio, C. J., González, Ángel, Bardají, T., Civis, J., Preda, M., Yébenes, A. and Forte, A. M.: Further evidence for a relatively high sea level during the penultimate interglacial: open-system U-series ages from La Marina (Alicante East Spain), Geodinamica Acta, 19(6), 409–426, doi:10.3166/ga.19.409-426, 2006.

Guerrera, F. and Tramontana, M. (Eds.): Note illustrative della Carta Geologica d'Italia alla scala 1:250.000, Foglio 241 Senigallia. Regione Marche, ISPRA, 116 pp., 2011.

Harzhauser, M. and Kronenberg, G.: A note on Strombus coronatus Defrance, 1827 and Strombus coronatus Roding, 1798 (Mollusca: Gastropoda), The Veliger, 50(2), 120–128, 2008.

1530 Hearty, P. J., Hollin, J. T., Neumann, A. C., O'Leary, M. J. and McCulloch, M.: Global sea-level fluctuations during the Last Interglaciation (MIS 5e), Quaternary Science Reviews, 26(17-18), 2090–2112, 2007.

Hearty, P. and Dai Pra, G.: The age and stratigraphy of middle Pleistocene and younger deposits along the Gulf of Taranto (southeast Italy), Journal of coastal research, 8(4), 882–905, 1992.

Hearty, P. J., Hollin, J. T. and Dumas, B.: Geochronology of Pleistocene littoral deposits on the Alicante and Almeria coasts
1535 of Spain, Trabajos sobre Neogeno-Quaternario, 10, 1987.

Hearty, P. J.: New data on the Pleistocene of Mallorca, Quaternary Science Reviews, 6(3-4), 245–257, 1987.

Hearty, P. J. and Dai Pra, G.: Ricostruzione paleogeografica degli ambienti litoranei quaternari della Toscana e del Lazio settentrionale con l'impiego dell'aminostratigrafia, Boll. Servizio Geologico d'Italia, 106, 189–224, 1987.

Hearty, P. J.: An inventory of last Interglacial (sensu lato) age deposits from the Mediterranean basin: a study of isoleucine
1540 epimerization and U- series dating., Zeitschrift fur Geomorphologie, Supplementband, 62(January 1986), 51–69, 1986.

Hearty, P. J. and Dai Pra, G.: Aminostratigraphy of Quaternary marine deposits in the Lazio region of central Italy, Zeitschrift für Geomorphologie, 62(Suppl. NF), 131–140, 1986.

Hearty, P. J., Miller, G. H., Stearns, C. E. and Szabo, B. J.: Aminostratigraphy of Quaternary shorelines in the Mediterranean basin, Geological Society of America Bulletin, 97(7), 850–858, 1986a.

1545 Hearty, P. J., Bonfiglio, L., Donata, V. and Barney, J. S.: Age of Late Quaternary marine deposits of southern Italy determined by aminostratigraphy, faunal correlation and uranium-series dating, Rivista Italiana di Paleontologia Stratigrafica, 92, 149–164, 1986b.

Hillaire-Marcel, C., Gariépy, C., Ghaleb, B., Goy, J.-L., Zazo, C. and Barcelo, J. C.: U-series measurements in tyrrhenian deposits from mallorca Further evidence for two last-interglacial high sea levels in the Balearic Islands, Quaternary Science
1550 Reviews, 15(1), 53–62, doi:10.1016/0277-3791(95)00079-8, 1996.

Iannace, A., Romano, P. and Tuccimei, P.: U/Th dating and geochemistry of carbonate concretions associated with upper Pleistocene fossil shorelines of the Sorrento Peninsula (Conca dei Marini, southern Italy), Il Quaternario - Italian Journal of Quaternary Sciences, 6 (1Bis), 49–54, 2003.

Iannace, A., Romano, P., Santangelo, N., Santo, A. and Tuccimei, P.: The OIS 5c along Licosa cape promontory (Campania
1555 region, southern Italy): morphostratigraphy and U/Th dating, Zeitschrift für Geomorphologie N.F., 45 (3), 307–319, 2001.

Isetti, G., Lumley, H. de and Miskovsky, J. C.: Il giacimento musteriano della grotta della Madonna dell'Arma presso Bussana (Sanremo), Rivista di studi liguri, (28), 5–116, 1962.

Issel, A.: Lembi fossiliferi quaternari o recenti osservati nella Sardegna meridionale dai prof, D. Lovisato, 1914.

Issel, A.: Liguria preistorica, a cura della Società ligure di Storia Patria., 1908.

Kent, D. V., Rio, D., Massari, F., Kukla, G. and Lanci, L.: Emergence of Venice during the Pleistocene, Quaternary Science Reviews, 21(14-15), 1719–1727, doi:10.1016/s0277-3791(01)00153-6, 2002.

Khan, N. S., Horton, B. P., Engelhart, S., Rovere, A., Vacchi, M., Ashe, E. L., Törnqvist, T. E., Dutton, A., Hijma, M. P. and Shennan, I.: Inception of a global atlas of sea levels since the Last Glacial Maximum, Quaternary Science Reviews, 220, 359–371, doi:10.1016/j.quascirev.2019.07.016, 2019.

Kindler, P., Davaud, E. and Strasser, A.: Tyrrhenian coastal deposits from Sardinia (Italy): a petrographic record of high sea levels and shifting climate belts during the last interglacial (isotopic substage 5e), Palaeogeography, Palaeoclimatology, Palaeoecology, 133(1-2), 1–25, 1997.

Kronenberg, G. and Lee, H. G.: Genera of american strombid gastopods (Gastropoda: Strombidae) and remarks on their phylogeny, The Veliger, 49(4), 256–264, 2006.

Laborel, J. and Laborel-Deguen, F.: Biological indicators of relative sea-level variations and of co-seismic displacements in the Mediterranean region, Journal of coastal research, 395–415, 1994.

Lambeck, K., Antonioli, F., Purcell, A. and Silenzi, S.: Sea-level change along the Italian coast for the past 10,000yr, Quaternary Science Reviews, 23(14-15), 1567–1598, doi:10.1016/j.quascirev.2004.02.009, 2004.

Lamothe, R. de: Les anciennes lignes de rivage du Sahel d'Alger et d'une partie de la côte Algérienne, Société géologique de France., 1911.

Lecca, L. and Carboni, S.: The Tyrrhenian section of San Giovanni di Sinis (Sardinia): stratigraphic record of an irregular single high stand, Rivista Italiana di Paleontologia e Stratigrafia, 113(3), 509, 2007.

Lipparini, T.: I fossili dei sedimenti marini nel sottosuolo della bassa pianura friulana, Bollettino Società Geologica Italiana, 55, 1936.

Lorscheid, T. and Rovere, A.: The indicative meaning calculator quantification of paleo sea-level relationships by using global wave and tide datasets, Open Geospatial Data Software and Standards, 4(1), doi:10.1186/s40965-019-0069-8, 2019.

Lorscheid, T., Stocchi, P., Casella, E., Gómez-Pujol, L., Vacchi, M., Mann, T. and Rovere, A.: Paleo sea-level changes and relative sea-level indicators: Precise measurements indicative meaning and glacial isostatic adjustment perspectives from Mallorca (Western Mediterranean), Palaeogeography, Palaeoclimatology, Palaeoecology, 473, 94–107, doi:10.1016/j.palaeo.2017.02.028, 2017.

Lucchi, F., Tranne, C. A., Calanchi, N. and Rossi, P. L.: Late Quaternary fossil shorelines in the Aeolian Islands (Southern Tyrrhenian Sea): evaluation of long-term vertical displacements, Quaternaria Nova, VIII, 49–62, 2004a.

Lucchi, F., Tranne, C. A., Calanchi, N., Pirazzoli, P., Romagnoli, C., Radtke, U., Reyss, J. L. and Rossi, P. L.: Stratigraphic constraints to date Late-Quaternary ancient shorelines and to evaluate vertical movements at Lipari (Aeolian Islands), Quaternary International, 115/116, 105–115, 2004b.

Lumley, H. D., Khatib, S., Echassoux, A. and Todisco, D.: Les lignes de rivage quaternaire en relation avec les sites paléolithiques des Alpes-Maritimes et de la Ligurie occidentale., Revue dArchéométrie, 25(1), 125–134, doi:10.3406/arsci.2001.1008, 2001.

Malatesta, A.: Geologia e paleobiologia dell'era glaciale, La Nuova Italia Scientifica, 282, 1985.

Malatesta, A.: Terreni faune ed industrie quaternarie dell'arcipelago delle Egadi, Quaternaria, IV, 165–257, 1957.

Maouche, S., Meghraoui, M., Morhange, C., Belabbes, S., Bouhadad, Y. and Haddoum, H.: Reply to the comment of Pedoja et al. by Maouche, S., Meghraoui, M., Morhange, C., Belabbes, S., Bouhadad, Y. and Haddoum, H. on the published paper: Maouche, S., Meghraoui, M., Morhange, C., Belabbes, S., Bouhadad, Y. and Haddoum, H.: Active coastal thrusting and folding, and uplift rate of the Sahel anticline and Zemmouri earthquake area (Tell Atlas, Algeria), Tectonophysics, 509 (2011) 69–80, Tectonophysics, (601), 245–247, 2013.

Maouche, S., Meghraoui, M., Morhange, C., Belabbes, S., Bouhadad, Y. and Haddoum, H.: Active coastal thrusting and folding, and uplift rate of the Sahel Anticline and Zemmouri earthquake area (Tell Atlas, Algeria), Tectonophysics, 509(1-2), 69–80, 2011.

Marku, S. and Gjani, E.: The evolution of Holocene Transgression in Drini Bay. Northewstern Albania. Journal International Environmental Application and Science, 13(1), 33-40, 2018.

Marra, F., Rolfo, M. F., Gaeta, M. and Florindo, F.: Anomalous Last Interglacial Tyrrhenian sea levels and Neanderthal settling at Guattari and Moscerini caves (central Italy), Scientific Reports, 10(1), doi:10.1038/s41598-020-68604-z, 2020.

Marra, F., Bahain, J.-J., Jicha, B. R., Nomade, S., Palladino, D. M., Pereira, A., Tolomei, C., Voinchet, P., Anzidei, M., Aureli, D., Ceruleo, P., Falguères, C., Florindo, F., Gatta, M., Ghaleb, B., Rosa, M. L., Peretto, C., Petronio, C., Rocca, R.,

1610 Rolfo, M. F., Salari, L., Smedile, A. and Tombret, O.: Reconstruction of the MIS 5.5 5.3 and 5.1 coastal terraces in Latium (central Italy): A re-evaluation of the sea-level history in the Mediterranean Sea during the last interglacial, Quaternary International, 525, 54–77, doi:10.1016/j.quaint.2019.09.001, 2019.

Marra, F., Florindo, F., Anzidei, M. and Sepe, V.: Paleo-surfaces of glacio-eustatically forced aggradational successions in the coastal area of Rome: Assessing interplay between tectonics and sea-level during the last ten interglacials, Quaternary
1615 Science Reviews, 148, 85–100, doi:10.1016/j.quascirev.2016.07.003, 2016.

Massari, F., Rio, D., Barbero, R. S., Asioli, A., Capraro, L., Fornaciari, E. and Vergerio, P. P.: The environment of Venice area in the past two million years, Palaeogeography Palaeoclimatology, Palaeoecology, 202(3-4), 273–308, doi:10.1016/s0031-0182(03)00640-0, 2004.

Mastronuzzi, G., Quinif, Y., Sansò, P. and Selleri, G.: Middle-Late Pleistocene polycyclic evolution of a stable coastal area
1620 (southern Apulia, Italy), Geomorphology, 86(3-4), 393–408, doi:10.1016/j.geomorph.2006.09.014, 2007.

Mastronuzzi, G., Palmentola, G. and Richetti, G. and: Aspetti della evoluzione olocenica della costa pugliese, Memorie della Società Geologica Italiana, 42, 287–300, 1989.

Masurel, Y.: Observations sur la structure et la morphologie des Iles dHyères, Annales de Géographie, 62(332), 241–258, doi:10.3406/geo.1953.13610, 1953.

1625 Mauz, B.: Database of last interglacial sea-level proxies in the eastern Mediterranean, doi:10.5281/zenodo.4454553, 2020.

Mauz, B., Vacchi, M., Green, A., Hoffmann, G. and Cooper, A.: Beachrock: a tool for reconstructing relative sea level in the far-field, Marine Geology, 362, 1–16, 2015.

Mauz, B., Fanelli, F., Elmejdoub, N. and Barbieri, R.: Coastal response to climate change: Mediterranean shorelines during the Last Interglacial (MIS 5), Quaternary Science Reviews, 54, 89–98, doi:10.1016/j.quascirev.2012.02.021, 2012.

1630 Mauz, B. and Antonioli, F.: Comment on Sea level and climate changes during OIS 5e in the Western Mediterranean by T. Bardají J.L. Goy J.L., C. Zazo, C. Hillaire-Marcel, C.J. Dabrio, A. Cabero, B. Ghaleb, P.G. Silva, J. Lario, Geomorphology 104 (2009), 2237, Geomorphology, 110(3-4), 227–230, doi:10.1016/j.geomorph.2009.05.001, 2009.

Mauz, B. and Hassler, U.: Luminescence chronology of Late Pleistocene raised beaches in southern Italy: new data of relative sea-level changes, Marine Geology, 170, 187–203, 2000.

1635 Mauz, B.: Late Pleistocene records of littoral processes at the Tyrrhenian Coast (Central Italy): depositional environments and luminescence chronology, Quaternary Science Reviews, 18(10-11), 1173–1184, doi:10.1016/s0277-3791(98)00071-7, 1999.

Mauz, B., Buccheri, G., Zöller, L. and Greco, A.: Middle to upper Pleistocene morphostructural evolution of the NW-coast of Sicily: Thermoluminescence dating and palaeontological-stratigraphical evaluations of littoral deposits, Palaeogeography,
1640 Palaeoclimatology, Palaeoecology, 128(1-4), 269–285, doi:10.1016/S0031-0182(96)00033-8, 1997.

Meghraoui, M., Morel, J. L., Andrieux, J. and Dahmani, M.: Pliocene and Quaternary tectonics of the Tell-Rif mountains and Alboran sea, a complex zone of continent continent convergence, Bulletin de la Société Géologique de France, 167(1), 141–157, 1996.

Meschis, M., Scicchitano, G., Roberts, G. P., Robertson, J., Barreca, G., Monaco, C., Spampinato, C., Sahy, D., Antonioli,
1645 F., Mildon, Z. K. and Scardino, G.: Regional Deformation and Offshore Crustal Local Faulting as Combined Processes to Explain Uplift Through Time Constrained by Investigating Differentially Uplifted Late Quaternary Paleoshorelines: The Foreland Hyblean Plateau, SE Sicily, Tectonics, 39(12), doi:10.1029/2020tc006187, 2020.

Meschis, M., Roberts, G. P., Robertson, J. and Briant, R. M.: The Relationships Between Regional Quaternary Uplift, Deformation Across Active Normal Faults, and Historical Seismicity in the Upper Plate of Subduction Zones: The Capo
1650 D'Orlando Fault, NE Sicily, Tectonics, 37, 1231–1255, doi:https://doi.org/10.1029/ 2017TC004705, 2018.

Milli, S. and Zarlenga, F.: Analisi di facies dei depositi tirreniani (Duna Rossa) affioranti nell'area di Castel Porziano-Pomezia (Roma), Il Quaternario, 4(15), 233–248, 1991.

Monaco, C., Catalano, S., De Guidi, G., Gresta, S., Langer, H. and Tortorici, L.: The Geological map of the urban area of Catania (Eastern Sicily): morphotectonic and seismotectonic implication, Memorie Società Geologica Italiana, 55, 425–438,
1655 2000.

Muhs, D. R., Simmons, K. R., Meco, J. and Porat, N.: Uranium-series ages of fossil corals from Mallorca Spain: The Neotyrrhenian high stand of the Mediterranean Sea revisited, Palaeogeography, Palaeoclimatology, Palaeoecology, 438, 408–424, doi:10.1016/j.palaeo.2015.06.043, 2015.

Mullenders, W., Favero, V., Coremans, M. and Dirickx, M.: Analysis of pollen surveys from Venice [Analyses polliniques
1660 de sondages a Venise (VE-I, VE-I BIS, VE-II)], Aardkundige Mededelingen, 7, 87–117 [online] Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-0030307973&partnerID=40&md5=7c245ba696c8b2ce15d9ddaa1e57cb2a, 1996.

Nalin, R. and Massari, F.: Facies and stratigraphic anatomy of a temperate carbonate sequence (Capo Colonna Terrace, late Pleistocene, southern Italy), Journal Sed. Research, 79, 210–225, 2009.

1665   Nalin, R., Bracchi, V. A., Basso, D. and Francescoand M.: Persistrombus latus (Gmelin) in the upper Pleistocene deposits of the marine terraces of the Crotone peninsula (southern Italy), Italian Journal of Geosciences, 131 (1), 95–101, doi:https://doi.org/10.3301/IJG.2011.25, 2012.

Nesteroff, W.: Étude de quelques grès de plage du sud de la Corse: datations ^{14}C et implications néotectoniques pour le bloc corso-sarde, MOM Éditions, 8(1), 99–111, 1984.

1670   Nisi, M. F., Antonioli, F., Pra, G. D., Leoni, G. and Silenzi, S.: Coastal deformation between the Versilia and the Garigliano plains (Italy) since the last interglacial stage, Journal of Quaternary Science, 18(8), 709–721, doi:10.1002/jqs.803, 2003.

Ottmann, F.: Le Quaternaire marin du cap Corse [with discussion], Bulletin de la Société Géologique de France, S6-IV(7-9), 565–570, doi:10.2113/gssgfbull.s6-iv.7-9.565, 1954.

Otvos, E. G.: Beach ridges—definitions and significance, Geomorphology, 32(1-2), 83–108, 2000.

1675   Ozer, A., Demoulin, A. and Dai Pra, G.: Les indices morphologiques temoins de la stabilite tectonique de la bordure littorale du Lazio meridional (Italie), Zeitschrift für Geomorphologie. Supplementband, 63, 103–117, 1987.

Ozer, A., Paskoff, R., Sanlaville, P. and Ulzega, A.: Essai de corrélation du Pléistocène supérieur de la Sardaigne et de la Tunisie, Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences. Série D, Sciences Naturelles, 291, 801–804, 1980.

1680   Palieri, L. and Sposato, A.: Segnalazione di fauna a Strombus bubonius nell'area compresa tra Tarquinia e Montalto di Castro, Il Quaternario, 1(2), 161–166, 1988.

Palmentola, G., Carobene, L., Mastronuzzi, G. andSansò, P.: I terrazzi marini pleistocenici della penisola di Crotone (Calabria), Geografia Fisica e Dinamica Quaternaria, 13, 75–80, 1990.

Pata, O.: Su di un nuovo giacimento a Strombus bubonius Lmk. Presso Vibo Valentia. Atti della Soc. Toscana di Sci. Nat.,
1685   54, 156-166, 1947.

Pedoja, K., Djellit, H., Authemayou, C., Deverchere, J., Strzerzynski, P., Heddar, A., Nexer, M. and Boudiaf, A.: Comment on Active coastal thrusting and folding, and uplift rate of the Sahel Anticline and Zemmouri earthquake area (Tell Atlas, Algeria), by S. Maouche, M. Meghraoui, C. Morhange, S. Belabbes, Y. Bouhadad, H. Haddoum. [Tectonophysics, 2011, 509, 69-80, Tectonophysics, 601, 236–244, doi:10.1016/j.tecto.2012.08.043, 2013.

1690 Peeters, J., Cohen, K. M., Thrana, C., Busschers, F. S., Martinius, A. W., Stouthamer, E. and Middelkoop, H.: Preservation of Last Interglacial and Holocene transgressive systems tracts in the Netherlands and its applicability as a North Sea Basin reservoir analogue, Earth-Science Reviews, 188, 482–497, doi:10.1016/j.earscirev.2018.10.010, 2019.

Pikelj, K. and Juračić, M.: Eastern Adriatic Coast (EAC): Geomorphology and Coastal Vulnerability of a Karstic Coast, Journal of Coastal Research, 289, 944–957, doi:10.2112/jcoastres-d-12-00136.1, 2013.

1695 Pini, R., Ravazzi, C. and Donegana, M.: Pollen stratigraphy, vegetation and climate history of the last 215 ka in the Azzano Decimo core (plain of Friuli, north-eastern Italy), Quaternary Science Reviews, 28(13-14), 1268–1290, doi:10.1016/j.quascirev.2008.12.017, 2009.

Pirazzoli, P. A.: Marine terraces, Encyclopedia of Coastal Science. Springer Netherlands, Dordrecht, 632–633, 2005.

Polyak, V. J., Onac, B. P., Fornós, J. J., Hay, C., Asmerom, Y., Dorale, J. A., Ginés, J., Tuccimei, P. and Ginés, A.: A highly
1700 resolved record of relative sea level in the western Mediterranean Sea during the last interglacial period, Nature Geoscience, 11(11), 860–864, 2018.

Poujol, A., Ritz, J. F., Tahayt, A., Vernant, P., Condomines, M., Blard, P. H., Billant, J., Vacher, L., Tibari, B., Hni, L. and Idrissi, A. K.: Active tectonics of the Northern Rif (Morocco) from geomorphic and geochronological data, Journal of Geodynamics, 77, 70–88, doi:10.1016/j.jog.2014.01.004, 2014.

1705 Provansal, M., Quinif, Y., Verrecchia, E. and Arnaud, P. M.: Identification d'un littoral tyrrhénien en bordure de l'Etang de Berre (Bouches-du-Rhône, France méridionale), Comptes rendus de l'Académie des sciences. Série 2. Sciences de la terre et des planètes, 320(9), 867–872, 1995.

Radtke, U.: Value and risk of radiometric dating of shorelines-geomorphological and geochronological investigations in Central Italy, Eolian Islands and Ustica (Sicily), Zeitschrift für Geomorphologie. Supplementband, 62, 167–181, 1986.

1710 Ravazzi, C., Pini, R., Badino, F., De Amicis, M., Londeix, L. and Reimer, P. J.: The latest LGM culmination of the Garda Glacier (Italian Alps) and the onset of glacial termination. Age of glacial collapse and vegetation chronosequence, Quaternary Science Reviews, 105, 26–47, doi:10.1016/j.quascirev.2014.09.014, 2014.

Rhodes, E. J.: ESR dating of tooth enamel, In: Basile, B., Chilardi, S. (Eds.), Siracusa, le Ossa dei Giganti, lo scavo archeologico di Contrada Fusco. Lombardi, Palermo, 39–44, 1996.

1715 Riccio, A., Riggio, F. and Romano, P.: Sea level fluctuations during Oxygen Isotope Stage 5: New data from fossil shorelines in the Sorrento Peninsula (Southern Italy), Zeitschrift für Geomorphologie, 45, 121–138, 2001.

Richetti, G.: Osservazioni preliminari sulla geologia e morfologia dei depositi quaternari dei dintorni del Mar Piccolo (Taranto), Atti dell'Accademia Gioenia di Scienze Naturali. Catania, 6 (XVIII), 123–130, 1967.

Roberts, G.P., Meschis, M., Houghton, S., Under wood, C., Briant, R.M.: The implication of revised Quaternary paleoshoreline chronologies for the rates of active extension and uplift in the upper plate of subduction zone. Quaternary Science Reviews, 78, 169-187, 2013. Htpps://doi.org/10.1016/j.quascirev.2013.08.006

Romano, P., Santo, A. and Voltaggio, M.: L'evoluzione geomorfologica della piana del fiume Volturno (Campania) durante il tardo Quaternario (Pleistocene medio-superiore-Olocene), Il Quaternario - Italian Journal of Quaternary Sciences, 7(1), 41–56 [online] Available from: http://www.aiqua.it/images/directory/1327339013QuaternarioVol.7Fasc.1pag.41-56.pdf, 1994.

Romeo, R.: Studio geofisico integrato ad alta risoluzione dei depositi marini e della struttura del substrato della riviera di Miramare (Golfo di Trieste), PhD thesis, University of Trieste, 2009.

Rovere, A., Ryan, D., Murray-Wallace, C., Simms, A., Vacchi, M., Dutton, A., Lorscheid, T., Chutcharavan, P., Brill, D., Bartz, M., Jankowski, N., Mueller, D., Cohen, K. and Gowan, E.: Descriptions of database fields for the World Atlas of Last Interglacial Shorelines (WALIS), doi:10.5281/zenodo.3961544, 2020.

Rovere, A., Raymo, M. E., Vacchi, M., Lorscheid, T., Stocchi, P., Gomez-Pujol, L., Harris, D. L., Casella, E., O'Leary, M. J. and Hearty, P. J.: The analysis of Last Interglacial (MIS 5e) relative sea-level indicators: Reconstructing sea-level in a warmer world, Earth-Science Reviews, 159, 404–427, 2016.

Ruggieri, G. and Unti, A.: Una malacofauna del Tirreniano di Birgi Nuovo (Trapani), Il Naturalista Siciliano, XII, 19–32, 1988.

Ruggieri, G., Unti, A., Unti, M. and Moroni, M. A.: La Calcarenite di Marsala (Pleistocene Inferiore) e i terreni contermini, Bollettino Società Geologica Italiana, 93, 723–733, 1975.

Ruggieri, G. and Buccheri, G.: Una malacofauna Tirreniana dell'isola di Ustica (Sicilia), Geologica Romana, VII, 27–58, 1968.

Ruggieri, G.: Il terrazzo marino presiciliano della Penisola di Crotone, Giorn. Geol. serie 3, 20, 39–62, 1948.

Santangelo, N., Romano, P., Ascione, A. and Ermolli, E. R.: Quaternary evolution of the Southern Apennines coastal plains: a review, Geologica Carpathica, 68(1), 43–56, doi:10.1515/geoca-2017-0004, 2017.

Santangelo, N., Ciampo, G., Di Donato, V., Esposito, P., Petrosino, P., Romano, P., Russo, E. E., Santo, A., Toscano, F. and Villa, I.: Late quaternary buried lagoons in the northern campania plain (southern Italy): Evolution of a coastal system under the influence of volcano-tectonics and eustatism, Italian Journal of Geosciences, 129(1), 156–175, doi:10.3301/IJG.2009.12, 2010.

Santoro, E., Mazzella, M. E., Ferranti, L., Randisi, A., Napolitano, E., Rittner, S. and Radtke, U.: Raised coastal terraces along the Ionian Sea coast of northern Calabria, Italy, suggest space and time variability of tectonic uplift rates, Quaternary International, 206(1-2), 78–101, doi:10.1016/j.quaint.2008.10.003, 2009.

Saoudi, N.: Pliocène et Pléistocène inférieur et moyen du Sahel d'Alger, ENAL, Alger, 1989.

Schwarcz, H. P., Bietti, A., Buhay, W. M., Stiner, M. C., Grun, R. and Segre, A.: On the reexamination of Grotta Guattari: uranium-series and electron-spin-resonance dates, 1991a.

Schwarcz, H. P., Buhay, W., Grün, R., Stiner, M., Kuhn, S. and Miller, G. H.: Absolute dating of sites in coastal Lazio, Quaternaria Nova, 1, 51–67, 1991b.

Sechi, D., Andreucci, S., Stevens, T. and Pascucci, V.: Age and significance of late Pleistocene Lithophyllum byssoides intertidal algal ridge, NW Sardinia, Italy, Sedimentary Geology, 400, 105618, 2020.

Segre, A. G.: Geologia, In: Zavattari, E. (Ed.), Biogeografia delle isole Pelagie. Rendiconti Accademia Nazionale Lincei, XL, 115–162, 1960.

Segre, A. G.: Tracce di morfologia subaerea sul fondo marino litoraneo del Lazio meridionale, Historia naturalis, 3(1), 1–3, 1949.

Selli, R.: Le Quaternarie marin du versant Adriatique-Jonien de la Pèninsule italienne, Quaternaria, 6, 391–413, 1962.

Sivan, D. and Galili, E.: The last interglacial sea-level record of the Israeli coastline - WALIS database of sea-level indicators, doi:10.5281/zenodo.4274178, 2020.

Stearns, C. E. and Thurber, D. L.: Th230/U234 dates of late Pleistocene marine fossils from the Mediterranean and Moroccan littorals, Progress in Oceanography, 4, 293–305, doi:10.1016/0079-6611(65)90056-x, 1965.

Stocchi, P., Vacchi, M., Lorscheid, T., Boer, B. de, Simms, A. R., Wal, R. S. W. van de, Vermeersen, B. L. A., Pappalardo, M. and Rovere, A.: MIS 5e relative sea-level changes in the Mediterranean Sea: Contribution of isostatic disequilibrium, Quaternary Science Reviews, 185, 122–134, doi:10.1016/j.quascirev.2018.01.004, 2018.

Surić, M., Richards, D. A., Hoffmann, D. L., Tibljaš, D. and Juračić, M.: Sea-level change during MIS 5a based on submerged speleothems from the eastern Adriatic Sea (Croatia), Marine Geology, 262(1-4), 62–67, doi:10.1016/j.margeo.2009.03.005, 2009.

Tosi, L., Rizzetto, F., Bonardi, M., Donnici, S., Serandrei Barbero, R., Toffoletto, F. (Eds.): Note illustrative della Carta Geologica alla scala 1:50.000, foglio 128 Venezia. APAT - Regione Veneto, 164 pp., 2007a.

Tosi, L., Rizzetto, F., Bonardi, M., Donnici, S., Serandrei Barbero, R., Toffoletto, F. (Eds.): Note illustrative della Carta Geologica alla scala 1:50.000, foglio 129 Chioggia–Malamocco. APAT - Regione Veneto, 164 pp. 2007b.

Tuccimei, P., Onac, B. P., Dorale, J. A., Ginés, J., Fornós, J. J., Ginés, A., Spada, G., Ruggieri, G. and Mucedda, M.: Decoding last interglacial sea-level variations in the western Mediterranean using speleothem encrustations from coastal caves in Mallorca and Sardinia: A field data–model comparison, Quaternary international, 262, 56–64, 2012.

Tuccimei, P., Ginés, J., Delitala, M. C., Ginés, A., Gràcia, F., Fornós, J. J. and Taddeucci, A.: Last interglacial sea level changes in Mallorca island (Western Mediterranean). High precision U-series data from phreatic overgrowths on speleothems, Zeitschrift für geomorphologie, 1–21, 2006.

Ulzega, A. and Hearty, P. J.: Geomorphology, stratigraphy and geochronology of Late Quaternary marine deposits in Sardinia, Z. Geomorphol. NF, Suppl. Bd, 62, 119–129, 1986.

Ulzega, A. and Ozer, A.: Comptes-rendus de l'excursion, Table ronde sur le Tyrrhénien de la Sardaigne. INQUA, 3–112, 1980.

Vacchi, M., Ghilardi, M., Melis, R. T., Spada, G., Giaime, M., Marriner, N., Lorscheid, T., Morhange, C., Burjachs, F. and Rovere, A.: New relative sea-level insights into the isostatic history of the Western Mediterranean, Quaternary Science Reviews, 201, 396–408, 2018.

Vacchi, M., Ghilardi, M., Spada, G., Currás, A. and Robresco, S.: New insights into the sea-level evolution in Corsica (NW Mediterranean) since the late Neolithic, Journal of Archaeological Science: Reports, 12, 782–793, doi:10.1016/j.jasrep.2016.07.006, 2017.

Vacchi, M., Marriner, N., Morhange, C., Spada, G., Fontana, A. and Rovere, A.: Multiproxy assessment of Holocene relative sea-level changes in the western Mediterranean: Sea-level variability and improvements in the definition of the isostatic signal, Earth-Science Reviews, 155, 172–197, 2016.

1795 Vannoli, P., Basili, R. and Valensise, G.: New geomorphic evidence for anticlinal growth driven by blind-thrust faulting along the northern Marche coastal belt (central Italy), Journal of Seismology, 8(3), 297–312, doi:10.1023/b:jose.0000038456.00574.e3, 2004.

Verri, A. and De Angelis D'Ossat, G.: Cenni sulla geologia di Taranto, Bollettino della Società Geologica Italiana, XVIII, 179–210, 1899.

1800 Vicens, D., Gràcia, F. and Ginés, A.: Quaternary beach deposits in Mallorca: paleontological and geomorphological data, Ginés, A.; Ginés, J.; Gomez-Pujol, L, 55–84, 2012.

Vicino, G.: La spiaggia tirreniana dei Balzi Rossi nei recenti scavi nella zona dell'ex-Casinó, Atti XVI Riunione Scientifica Istituto Italiano di Preistoria e Protostoria, 75–84, 1974.

Vita, S. de, Laurenzi, M. A., Orsi, G. and Voltaggio, M.: Application of Ar Ar and U, Quaternary International, 47/48, 117–
1805 127, 1998.

Vita-Finzi, C.: Late Quaternary alluvial chronology of northern Algeria, Man, 2(2), 205–215, 1967.

Yokoyama, Y., Nguyen, H., Shen, G. U. A. N. J. U. N., Quaegebeur, J. P. and Koumba, N. Z. I. E. N. G. U. I.: Datation par les méthodes des familles de l'uranium et la résonance de spin électronique (ESR) du remplissage de la grotte des Ramandils à Port-la-Nouvelle (Aude, France), Cypsela: revista de prehistòria i protohistòria, (6), 151–154, 1987.

1810 Zanchetta, G., Bonadonna, F. P., Marcolini, F., Ciampalini, A., Fallick, A. E., Leone, G. and Michelucci, L.: Intra-Tyrrhenian cooling event deduced by non-marine mollusc assemblage at Villa S. Giorgio (Livorno, Italy), 2004.

Zazo, C., Goy, J. L., Dabrio, C. J., Lario, J., González-Delgado, J. A., Bardají, T., Hillaire-Marcel, C., Cabero, A., Ghaleb, B., Borja, F. and others: Retracing the Quaternary history of sea-level changes in the Spanish Mediterranean–Atlantic coasts: Geomorphological and sedimentological approach, Geomorphology, 196, 36–49, 2013.

1815 Zazo, C., Goy, J. L., Dabrio, C. J., Bardají, T., Hillaire-Marcel, C., Ghaleb, B., González-Delgado, J.-Á. and Soler, V.: Pleistocene raised marine terraces of the Spanish Mediterranean and Atlantic coasts: records of coastal uplift sea-level highstands and climate changes, Marine Geology, 194(1-2), 103–133, doi:10.1016/s0025-3227(02)00701-6, 2003.

Zazo, C., Silva, P. G., Goy, J. L., Hillaire-Marcel, C., Ghaleb, B., Lario, J., Bardaji', T. and González, A.: Coastal uplift in continental collision plate boundaries: data from the Last Interglacial marine terraces of the Gibraltar Strait area (south
1820 Spain), Tectonophysics, 301(1-2), 95–109, doi:10.1016/s0040-1951(98)00217-0, 1999.

Zazo, C. and Goy, J. L.: Hoja Vejer de la Frontera (no 1073= 1076), Plioceno superior y Cuaternario. Mapa Geológico de Espana, 1(50.000), 2o, 1990.

Zazo, C. and Goy, J. L.: Sea-Level Changes in the Iberian Peninsula During the Last 200,000 Years, in Late Quaternary Sea-Level Correlation and Applications: Walter S. Newman Memorial Volume, edited by D. B. Scott, P. A. Pirazzoli, and C. A. Honig, pp. 27–39, Springer Netherlands, Dordrecht., 1989.

Zazo, C.: El Cuaternario marino-continental y el límite Plio-Pleistoceno en el litoral de Cádiz, PhD thesis, Universidad Complutense de Madrid., 1980.

Zecchin, M., Civile, D., Caffau, M. and Roda, C.: Facies and cycle architecture of a Pleistocene marine terrace (Crotone, southern Italy): A sedimentary response to late Quaternary, high-frequency glacio-eustatic changes, Sed. Geol., 216, 138–157, 2009.

Zecchin, M., Nalin, R. and Roda, C.: Raised Pleistocene marine terraces of the Crotone peninsula (Calabria, southern Italy): facies analysis and organization of their deposits, Sedimentary geology, 172(1-2), 165–185, 2004.

Zomeni, Z.: Last interglacial (MIS 5e) sea-level proxies in Cyprus, Eastern Mediterranean, doi:10.5281/zenodo.4438721, 2021.

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1835