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~~ 199 published studies and contains 396 ~~371~~ sea-level datapoints (sea-level index points and marine or terrestrial limiting points) and 401 ~~304~~ associated dated samples. The database follows the standardized WALIS template and is available as Cerrone et al, 2021b (http://doi.org/10.5281/zenodo.5102943).

1 Introduction

In this paper, we describe the Last Interglacial (here broadly defined as Marine Isotopeic Stage, MIS, 5~~5.5 or 5e~~) sea-level database for the Western Mediterranean, which was ~~, that was~~ compiled from ~~standardizing~~ data and metadata contained in published scientific papers reporting geological evidence and dated samples related to Quaternary sea-level changes in the region. Information on sea-level proxies and dated samples was standardized using ~~. The database was created using~~ the WALIS interface, which is accessible (upon registration) at this link: https://warmcoasts.eu/world-atlas. ~~This interface allows standardizing data and metadata on Pleistocene relative sea-level indicators and associated ages.~~ From the interface, the ~~The~~ database ~~described in this study represents the output of a tool embedded within the WALIS interface, that allows~~ was ~~exporting~~ exported in ~~all data in~~ spreadsheet format and made t. ~~As a result, the Western Mediterranean database presented in this work is in .xls format, is~~ available as a multi-sheet excel file in Zenodo~~, and available~~ under a CC-BY license (Cerrone et al, 2021b, http://doi.org/10.5281/zenodo.5102943). Database field descriptions are also available in Zenodo ~~at the following link:~~ https://doi.org/10.5281/zenodo.3961544 (Rovere et al., 2020) and are synchronized with a read-the-docs website here: https://walis-help.readthedocs.io/en/latest/. In the supplement of this paper, we report a table summarizing elevation, age, reference(s), and quality scores for each relative sea-level (RSL) datapoint in the Western Mediterranean database.

30 The data and metadata compiled in this manuscript were extracted from 199 ~~179~~ studies (Figure 1~~Figure 1~~a), mostly~~.~~ ~~Most of these were~~ published in the last 40 years (Figure 1~~Figure 1~~c). The data compilation was done ~~, that were reviewed~~ between March 2020 and ~~January~~ June 2021 (Figure 1~~Figure 1~~b). Therefore, data contained in papers ~~that appeared~~ published during ~~after~~ this timeframe ~~is~~ may not be included in our database. ~~The majority of the studies we reviewed were published within the last 40 years (Figure 1c).~~ The database ~~includes~~ includes data from the ~~the~~ Mediterranean coasts of

35 Spain, France, Italy, Albania, Algeria, and Morocco. The coasts of Tunisia and Lybia, which ~~may be also considered as part of~~ lie at the transition between the ~~the~~ Western and the Eastern Mediterranean basins, 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). We did not include in the database cave deposits previously used as sea-level indicators in Mallorca Island (Spain) and Croatia, to avoid duplication of data within WALIS, as these deposits are part of another compilation (Dumitru

40 et al., 2021b~~0~~). Overall, the Western Mediterranean ~~Last Interglacial~~ database contains 328 ~~305~~ sea-level index points (for which paleo relative sea level can be calculated), 42 ~~43~~ marine limiting points (indicating that sea-level at the time of formation was above the reported facies), and 25 ~~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.
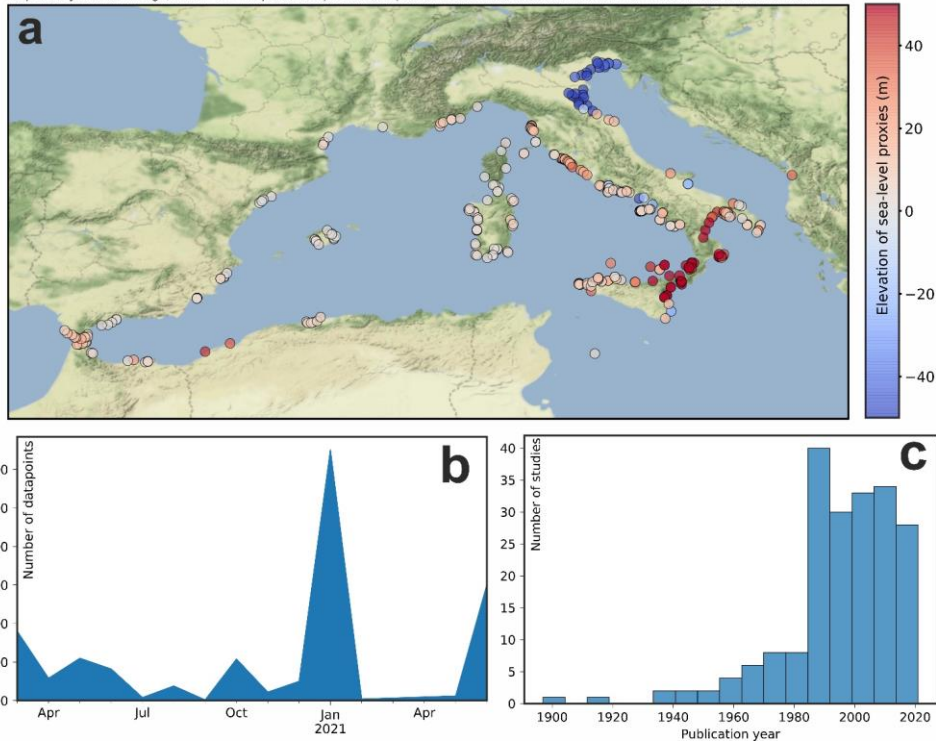
Figure 1: Overview of the Western Mediterranean database. a) Elevation of sites within the reviewed geographic area; b) Data ranges of database creation; c) Year of publication of reviewed studies.

In the following sections, we first give an overview of the classic literature describing the Last Interglacial sites in the Western Mediterranean. Many of these the older older studies mentioned in this section do not contain all the metadata necessary to meet the WALIS standards (i.e., they are missing key information such as on location, elevation, or age), they represent the foundations upon which 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 the database. We then turn to the description of the data points 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 physical geographers and geologists worked on both sides of the basin describing outcrops correlated to the then-called "Tyrrhenian" sea-level highstand (Issel, 1908; de Lamothe, 1911; Gignoux, 1913; Blanc, 1936), later identified with MIS 5. This "first wave" of authors was followed by a series of geologists geoscientists who detailed the first stratigraphic descriptions and uncovered explored new sites (e.g., Butzer and Cuerda, 1962; Ottmann, 1954; Bonifay and Mars, 1959). This "second wave" was supported by the development of dating techniques such as U-sSeries (Stearns and Thurber, 1965), which helped to strengthen previous chronological correlations, that were heretofore based almost uniquely on (bio)stratigraphic correlations.

These studies laid the foundation upon which, in the 1980s and 1990s, works 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 aAmino aAcid rRacemization to a vast number of Mediterranean sites. This work appeared ion 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 collects the results of the first applications of eElectron sSpin rResonance (ESR) dating on Western Mediterranean outcrops, that was pioneered by (Radtke et al. (1981), Radtke (1983), Brückner, (1986) and Brückner and Radtke (1986)).

The renewed interest stirred by the "Dating Mediterranean shorelines" volume is reflected in a large number of studies that appeared in the scientific literature during in the late 1990s and 2000s. Our Western Mediterranean database is largely based on these works (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;), alongside with detailed studies providing age and RSL information at sites in the Western Mediterranean basin.

3 Sea-level indicators

Within the Western Mediterranean context, we identified eleven types of sea-level indicators (Table 1Table 1). The most widespread sea level indicators ones are marine terraces, beach deposits (or beachrocks), and tidal notches (Figure 2: Types of sea-level indicators and number of sites where they are present within the Western Mediterranean database Figure 2). For each location where Last Interglacial shorelines were reported, we derived 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 elevations at which the same landforms/deposits occur along the modern shoreline. limits of the indicative

Commentato [AR1]: COMMENT BY H. BRÜCKNER:
Brückner (1980) carried out an in-depth research about the flight of marine terraces of Metaponto, bordering the Gulf of Taranto, using 14C, 230Th/234U, palaeomagnetics and a tephra layer as dating tools. He was the first to link a flight of marine terraces to the oxygen isotope stages as they were known by then. Among them he also found the MIS 5 terraces, which were later dated with luminescence techniques (Zander et al., 2006).

Brückner, H.: Marine Terrassen in Süditalien. Eine quartärmorphologische Studie über das Küstentiefland von Metapont. – Düsseldorfer Geographische Schriften, 14, 235 p., 1980, Düsseldorf (PhD thesis, monograph).
Zander, A., Fülling, A., Brückner, H., Mastronuzzi, G.: OSL dating of Upper Pleistocene littoral sediments: a contribution to the chronostratigraphy of raised marine terraces bordering the Gulf of Taranto, South Italy. – Geografia Fisica e Dinamica Quaternaria, 29 (1), 33–50, 2006.

Commentato [AR2R1]: In this section, we tried to highlight studies for the Western mediterranean, addressing different sites across the basin. We put this reference in the geographic descriptions below, where we think it fits better.

Commentato [AR3]: COMMENT BY H. BRÜCKNER:
Not mentioned in the bibliography.

Commentato [AR4R3]: Many thanks, we now inserted it.

Commentato [AR5]: COMMENT BY H. BRÜCKNER:
The first were Radtke et al. (1981)* on the coasts of Latium, Italy. Later, ERS dating was the backbone of Radtke's PhD thesis (Radtke 1983).**

*Radtke, U., Hennig, G. J., Linke, W., Müngersdorf, J.: Th-230/U-234 and ESR- dating of fossil shells in Pleistocene marine terraces (Northern Latium, Central Italy). Quaternaria, 23, 37-50, 1981, Rome.

**Radtke, U: Genese und Altersstellung der marinen Terrassen zwischen Civitavecchia und Monte Argentario (Mittelitalien) unter besonderer Berücksichtigung der Elektronenspin-Resonanz-Altersbestimmungsmethode. Düsseldorfer Geographische Schriften, 22, 179 pages, 1983, Düsseldorf (PhD thesis, monograph).

Commentato [AR6R5]: Thank you. We cited these references here.

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85 ~~meaning using While~~For this purpose, we used modern analog data whenever available. However, such data is not often reported, therefore ~~,~~ for the majority of data points we used the IMCalc tool (Lorscheid and Rovere, 2019)~~.~~, which allows extracting ex-situ values for the calculation of ~~reference water level and indicative range (i.e.,~~ the relationship between the dated facies and the contemporary mean sea~~-~~ level ~~(,~~ Shennan et al., 2015). Such relationship is commonly defined as the indicative meaning and is quantified via the indicative range and the reference water level, which are defined as,

90 respectively, the range occupied by a sea-level index point, and its midpoint (Shennan et al., 2015).

The most represented type of sea-level indicators in our compilation are marine terraces. ~~Studies on marine terraces~~Despite having a broad indicative range, marine terraces ~~sea level proxies in the Western Mediterranean.T~~have been widely used to assess ~~or deposits related to the Last Interglacial are very useful for the reconstruction of~~ late Quaternary vertical land movements, starting from an assumption of the "eustatic" sea level at elevations included between 3 and 9 meters above

95 present ~~. In fact, in the tectonically stable areas of the Mediterranean basin (e.g., Balearic Islands or Sardinia) the MIS 5e index points are situated at an elevation of 6 ± 3 m a.s.l.~~ (Ferranti et al., 2006 and references therein). However, recent work (Stocchi et al., 2018) showed that this approach should be used with caution due to the intrinsic uncertainties related to glacial and hydro~~al~~ isostatic adjustment and eustatic sea level.~~. Whenever paleoshorelines dated to MIS 5e are found at different elevation, subsidence or tectonic uplift occurred.~~

The other two widespread sea-level proxies are fossil beach deposits and tidal notches. For which concerns tidal notches, we only considered those forming on vertical cliffs at or close to the tidal level. We expressly excluded from our compilation abrasion notches, i.e., indentations on the cliff face caused solely by mechanical erosion exerted by waves mobilizing sediments (sand or pebbles), abrading against the rock. These can occur within a large elevational range, from above the

105 storm berm to well below sea level, and are generally considered poor sea-level indicators (Rovere et al., 2016).

Commentato [AR7]: COMMENT BY H. BRÜCKNER: Describe shortly the criteria, because it is fundamental (not just refer the reader to Shennan et al., 2015.

Commentato [AR8R7]: Done, we hope this answers the comment.

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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;

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

4 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 rods and is referred generally to as as a general "mean sea-level", with no additional information provided (Figure 3Figure 3a,b). Whenever the elevation measurement technique and datum was were not reported in the original study, we set the elevation error to 20% of the elevation value. If only the sea-level datum was not reported, we added set it to 5% to the reported elevation error. Also, wWe remark that the majority of studies do not report precise coordinates for the sites investigated. Therefore, we had at many sites, to reconstruct the geographic location of many sites we derived geographic coordinates for the site with the aid of location names identified in geolocation services (e.g., Google EarthMaps) or georeferencing maps from original publications in QGIS. This means that the location reported in the database is, for many sites, only indicative and may be off even by hundreds of meters or few kilometers (Figure 3Figure 3c).
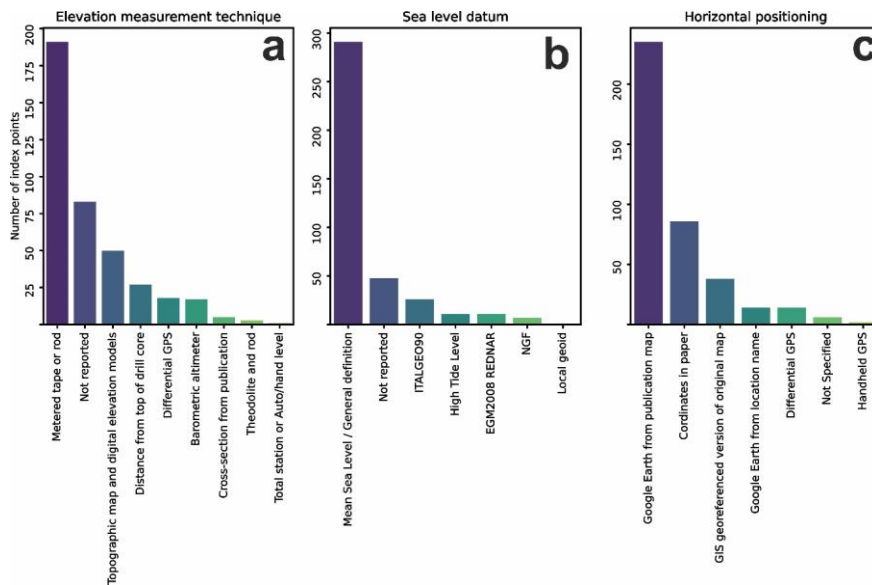
Figure 3: Elevation measurement (a), sea level datums (b), and ~~and~~ horizontal positioning (c) associated with sea-level indicators in the Western Mediterranean database.

5 Age attribution

In the Western Mediterranean, Last Interglacial sea-level indicators have been assigned an age through a large array of techniques (Figure 5Figure 5Figure 4). U-~~s~~Series dating was used to date corals preserved at several locations (Figure 5Figure 5Figure 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~~ one-third was dated via the older alpha-counting technique. We also included in the database 352 3 U-~~s~~Series ages on mollusks or corallineaceous algae (Figure 5Figure 5Figure 4b). ~~We remark that, d~~Due to issues with the open-system behavior of ~~mollusks and corallinaceous algae~~these fossils, WALIS only allows the attribution of a general Marine Isotopic Stage to mollusks and corallinaceous algae. This was 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 1b), 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 5 Figure 5 Figure 4c).

Optically sStimulated lLuminescence (OSL), tThermo Lluminescence (TL), iInfrared stimulated lLuminescence (IRSL), and eElectron sSpin rResonance (ESER) techniques were used to date coastal deposits at several locations, mostly in Italy (Figure 5 Figure 5 Figure 4d,f). Much more widespread is the use of aAmino aAcid rRacemization (AAR) on mollusks (Figure 5 Figure 5 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-sSeries at sites where mollusks and corals were found in within the same deposit (Hearty et al., 1986a).

In general, only samples dated with U-series (corals or speleothems), luminescence, and ESR have been assigned radiometric ages and associated 2σ uncertainties. Overall, the ages in the database cover most of MIS 5 (Figure 4 Figure 4a,b), but MIS 5a, MIS 5c, and MIS 5e peaks cannot be easily distinguished (Figure 4 Figure 4a). This indicates that most radiometric ages in the Western Mediterranean have large error bars, making it challenging to distinguish between MIS 5 peaks only based on dating.

In general, only samples dated with U-series (corals or speleothems), luminescence and ESR have been assigned radiometric ages and

Chronostratigraphic and bio-stratigraphic correlations among sites are very common in throughout the Western Mediterranean (Figure 5 Figure 5 Figure 4g). Among these, one of the most widespread is related to the presence, embedded within Pleistocene deposits, of "Senegalese fauna" (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, Tritonium ficoides, Natica lactea, N. turtoni, Mytilus senegalensis, Arca Geissei, Cardita senegalensis,* and some other minor species, present in minor percentages (Gignoux, 1913). The name "Senegalese fauna" derives from the fact that its most representative species, *P. latus* (Figure 6 Figure 6 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.

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

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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 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 (namely, MIS 5a and MIS 5c). We also remark note that, at many sites where Senegalese fauna was described, independent datings (e.g., AAR, Luminescence, U-sSeries) confirmed the MIS 5 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 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 the now obsolete designation *Strombus bubonius*. We remark that the living depth range of "Senegalese fauna" is rather wide. Added to the fact that, in Western Mediterranean deposits, the faunal remains are often found not in situ and fragmented (i.e., they have been likely transported in the littoral zone), the best practice is to identify the association with paleo RSL through the characteristics of the deposit (i.e., cross-bedding, grain size) rather than with the paleo living range of these faunal remains. This is the approach we followed in our review.

A second particular type of chronostratigraphic attribution is the one related to tidal notches (Antonioli et al., 2018). Tidal notches (Figure 7Figure 6) are sea-level indicators that have a very narrow indicative range, but that cannot be dated directly due to 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 constraints is are 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 5Figure 5Figure 4h), e.g., limiting radiocarbon dates or Argon / Argon ages for which there is no standard template within WALIS.
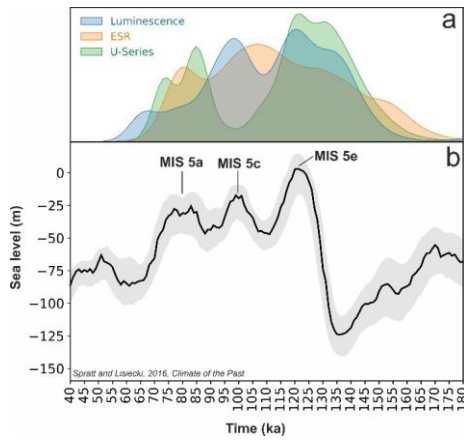
Figure 4: a) kernel density estimate plots for Luminescence, ESR and U-series samples for which a radiometric age is available in the Western Mediterranean database. This plot has been obtained by a Monte Carlo sampling (n=100000) the normal distribution of each dated sample in the Western Mediterranean database and plotting the resulting age distributions; b) Late Pleistocene sea-level from Spratt and Lisiecky, 2016.

Map tiles by Stamen Design, CC BY 3.0 -- Map data (C) OpenStreetMap contributors
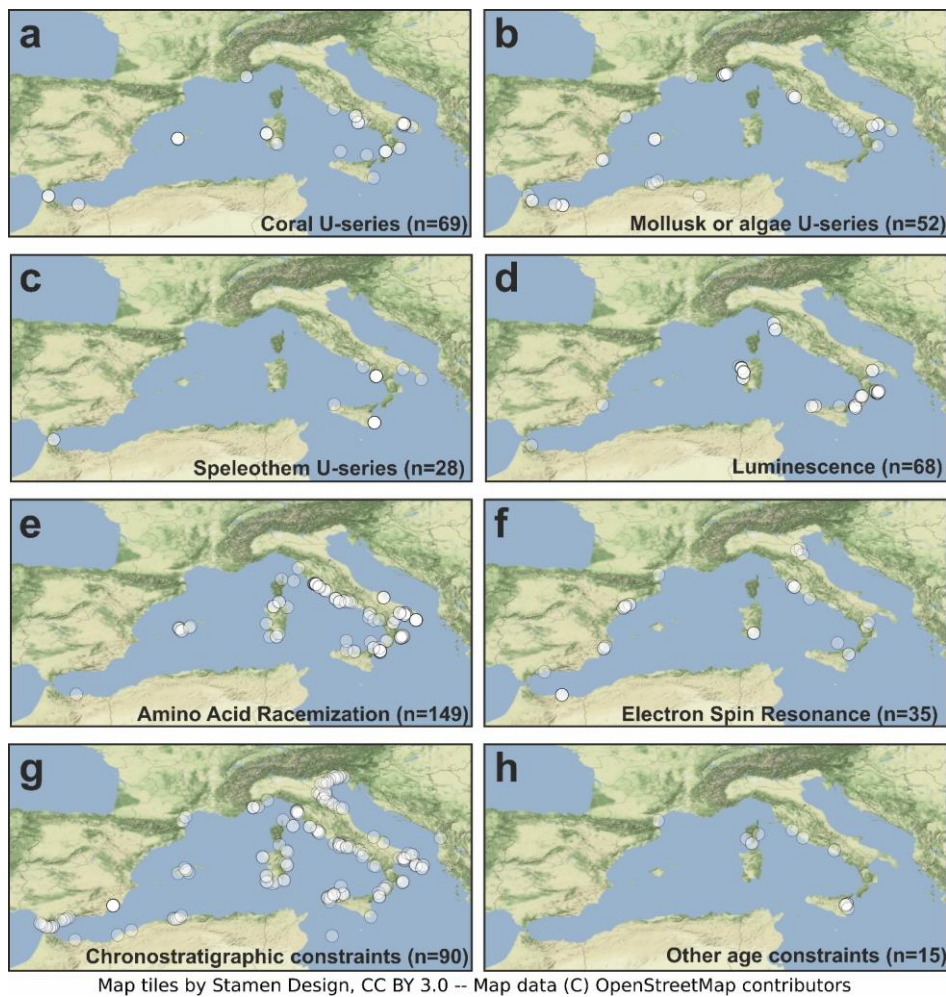
Figure 5: Geographic location of dated samples (or chronostratigraphic attributions), divided by type of analysis.

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Figure 6: 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

Figure 7: Bioerosive T~~t~~idal notch on the Orosei cliffs, Sardinia, Italy. Note the modern notch carved at present sea level. Photo by
230 **A. Rovere.**

6 Quality of sea level and age determinations

Within the WALIS interface, 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 documentation (Rovere et al., 2020), which are and reported verbatim in Table 2Table 2.

235 In general, if a site was dated only with one among U-sSeries 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. In the long stratigraphic cores, the age determination has been ranked to "Aaverage", while is defined as "Ggood" when is based on pollen chronozones and as "Eexcellent" in the rare cases that ESR dating is also available. Tidal notches are a particular case, as they can be dated only indirectly. For these indicators, the age information quality was
240 systematically set to "Poor". We remark that this is a conservative choice, as the quality of the 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.

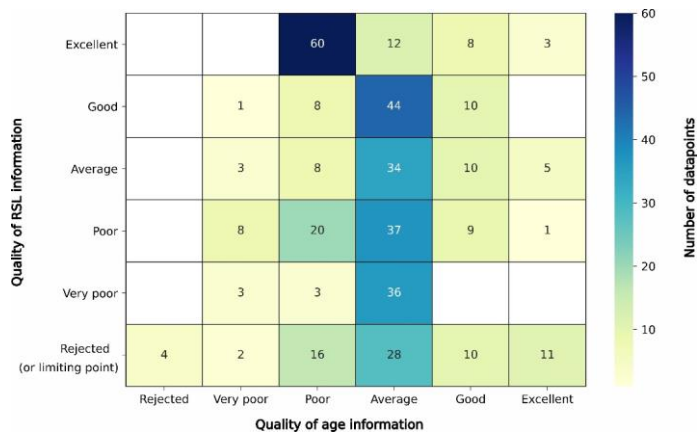
Overall, nearly 40% of points in the database have above average quality for both age and RSL information, with only three
245 sites reaching an excellent score in both categories (Figure 8Figure 7). Among these, two are located in Sardegna and one in Campania (Italy). Sites attaining very high scores are also present in Toscana (Italy) and the Balearic Islands (Spain). It is worth noting that more than 30% of the sites in our compilation ranks high (good to excellent) for which concerns sea-level information but low (average to poor) for age information.-

250 **Figure 8:** 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. The color of each cell represents the number of sites for each category.

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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 5e (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.

7 Relative sea-level data

In the following sections, we describe the data points inserted in the Western Mediterranean database. We, starting start from the coasts of Spain and proceeding proceed 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 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.

7.1 Spain (Mediterranean Coasts and Gibraltar Strait)

Along the Mediterranean coasts of Spain, Last Interglacial sea-level proxies have been preserved mostly as relic beaches or 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~~ several other sites rely on chronological constraints given by ~~aAmino aAcid rRacemization~~ AAR (e.g. Hearty, 1987), U-Series on mollusk shells (e.g., Hillaire-Marcel et al., 1996), ESR (e.g., Brückner, 1986) 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~~ five regions: Andalucía, Murcia, Comunidad Valenciana (Alicante province), Cataluña, and Islas Baleares (Mallorca). ~~, the southern tip of the Comunitat 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), no.~~ XX ~~on Figure 8. As we were not able to retrieve the original papers in this area, these data points were not included in WALIS.~~

7.1.1 Andalucía

The Andalucía region includes sites that are located both in the Mediterranean and on the Atlantic coast, west of the Gibraltar Strait (Figure 9~~Figure 9Figure 8~~). Despite this review is focussed on the Western Mediterranean, these Atlantic sites are here reported for completeness. In ~~this region~~Andalucía, studies on Pleistocene shorelines date back to the late 1980s /1990s (Zazo, 1980; Brückner, 1986; Brückner and Radtke, 1986; 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 (from ~~nonos.: 114 to no~~ to .-14 ~~on~~in Figure 9~~Figure 9Figure 8). (no. 15 on (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 points in WALIS as marine terraces, with a broader indicative range than beach deposits. East of Malaga, one site named (*Cerro Juan*, RSL ID 4001, no. 15 in Figure 9) was described by Brückner and Radtke, 1986 and was dated with ESR to MIS 5e (117.3 ka). More towards the east, in the ~~sourroundings~~surroundings of the city of Alméria (not shown in Figure 9), Bruckner (1986) reported several sites that were dated to MIS 5 / MIS 5e with ESR and U-series on mollusks. The author refers to earlier papers by Goy and Zazo (1982), Baena et al. (1981), and Bernat et al. (1978) for the description and further ages on these sites. As we were not able to retrieve the first two papers and the third one (Bernat et al., 1978) contains only dating metadata, we did not insert any datapoint for this portion of the Andalucía coast on WALIS.

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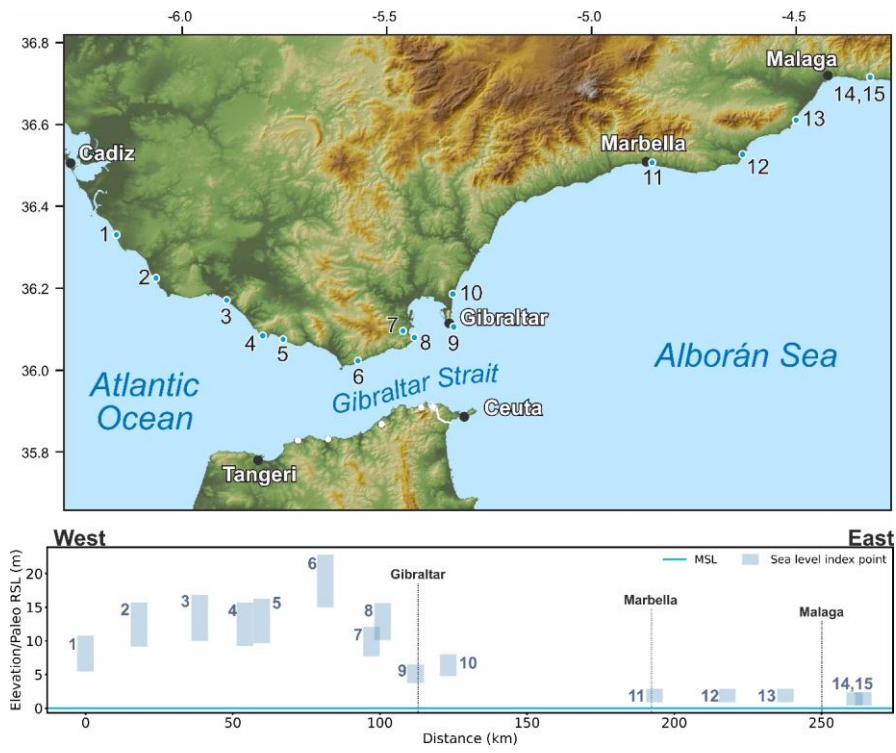
Figure 9: ~~Last Interglacial~~MIS 5 **sea level data for Andalucía (Spain). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) 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**
310 **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); 15:** *Cerro Juan* **(RSL ID 4001).** ~~The topography has been obtained from the Shuttle Radar Topography Mission void-filled DEM (Farr et al., 2007), free NASA dataset.~~

7.1.2 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 Almería and Alicante were used to give an age to these deposits. Within the sites in the so-called Cope Basin, the most complete in terms of stratigraphic descriptions and ages was reported from a location called *Casa de Renco* (RSL ID 750, no.1 in Figure 10), where marine conglomerates outcrop up to 5.2 m a.s.l. Bardají et al. (2015) describe the lowermost sedimentological units in 11 outcrops along the Cope Basin (RSL IDs 740-750, nos. 1 to 11 in Figure 10, see map in the inset). 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 5e age for this unit, as its age attribution is based solely on the presence of *P. latus* and other warm-water faunas. For this reason, In 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. It is worth noting that, in a short stretch of coast (2.5 km), the MIS 5 shoreline appears deformed by tectonics, raising from ~2 to ~12 m a.s.l.

7.1.3 Comunitat Comunidad Valenciana (Alicante province) and Cataluña

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, nos. 12 and 13 in Figure 10), where they found evidence for an MIS 7 terrace (dated using U-sSeries on *Cladocora* corals). Immediately above this terrace, U-sSeries 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. Few kilometres kilometers north of this area, in correspondence of *Cabo Santa Pola* and *Cabo Huerta*, three beach deposits were dated (although with large uncertainties) to MIS 5 by Brückner, 1986. Their elevation is 2-3 meters a.s.l. (RSL IDs 4079, 4080, 4081, nb. nos. 14 to 16 in Figure 10).

Further North, in the Cataluña region, Zazo and Goy, (1989) report overlapping marine levels near the Ebro Delta. These are located up to a few meters a.s.l. One site, called *Morro del Gos* (RSL ID 4002, nb. no. 17 in Figure 10Figure 10Figure 9) was dated with ESR by Brückner and Radtke (1986), yielding ages of 105±21 ka and 105±21 ka and 137±27.4 ka. Similar

large age spans, always coherent with an MIS 5e attribution were found at three other sites north of *Morro del Gos* (RSL IDs 4082 to 4084, nb. nos. 18 to 20 in Figure 10Figure 10Figure 9).

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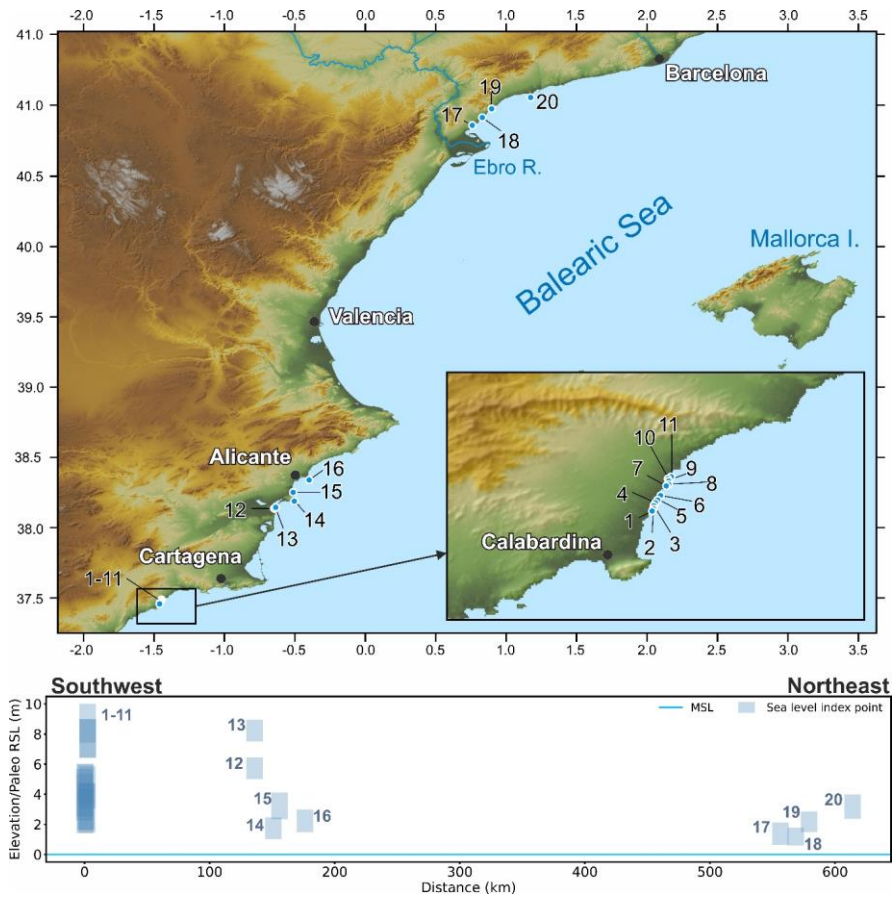


Figure 10: MIS 5 sea level data for Murcia, Comunidad Valenciana and Cataluña. Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, NASA dataset). Lower panel: Distance/Elevation graph from Southwest (left) to the Northeast (right). Sites list: 1: *Cope Basin - Point 11 Unit D* **(RSL ID**

750). 2: *Cope Basin - Point 10 Unit D* (RSL ID 749). 3: *Cope Basin - Point 9 Unit D* (RSL ID 748). 4: *Cope Basin - Point 8 Unit D* (RSL ID 747). 5: *Cope Basin - Point 7 Unit D* (RSL ID 746). 6: *Cope Basin - Point 6 Unit D* (RSL ID 745). 7: *Cope Basin - Point 4 Unit D* (RSL ID 743). 8: *Cope Basin - Point 5 Unit D* (RSL ID 744). 9: *Cope Basin - Point 3 Unit D* (RSL ID 742). 10: *Cope Basin - Point 2 Unit D* (RSL ID 741). 11: *Cope Basin - Point 1 Unit D* (RSL ID 740). 12: *La Marina - El Pinet Section B, Terrace T8* (RSL ID 738). 13: *La Marina - El Pinet Section A, Terrace T8* (RSL ID 751). 14: *South of Torre de Enmedio* (RSL ID 4079). 15: *Calabasi* (RSL ID 4080). 16: *Cabo de las Huertas* (RSL ID 4081). 17: *Morro del Gos* (RSL ID 4002). 18: *Cala del Torrent del Pi* (RSL ID 4084). 19: *Cala de Gestell* (RSL ID 4083). 20: *Cabo de Salou Cala Font* (RSL ID 4082).

7.1.4 Islas Baleares (Mallorca)

The island of Mallorca (Figure 11~~Figure 11~~~~Figure 9~~) has arguably preserved some of the most prominent Last Interglacial sea-level proxies ~~for the~~ within 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-~~s~~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, ~~nno. 2 on~~ in Figure 11~~Figure 11~~~~Figure 9~~), which is also referred to in the literature 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 12~~Figure 10~~), with U-~~s~~Series (Hillaire-Marcel et al., 1996; Muhs et al., 2015; Zazo et al., 2003) or ~~a~~Amino ~~a~~Acid ~~r~~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-~~s~~Series on mollusks and ~~a~~Amino ~~a~~Acid ~~r~~Racemization. This apparent age difference has been recently ruled out by Muhs et al., 2015, who dated ~~nine~~ several *Cladocora* sp. coral samples from the (supposed) MIS 5a unit at Camp de Tir, and obtained ages spanning the range 112 - 119~~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~~best described MIS 5e outcrop in Mallorca, but it is not the only one. Re-assessing sites 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), which would place ~~The most recent~~ MIS 5e ~~datum~~sea level at ~~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 11~~Figure 11Figure 9~~) in Mallorca as reported in Lorscheid et al., 2017, associating them with 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-~~s~~Series on cave deposits (Dumitru et al., 2020).

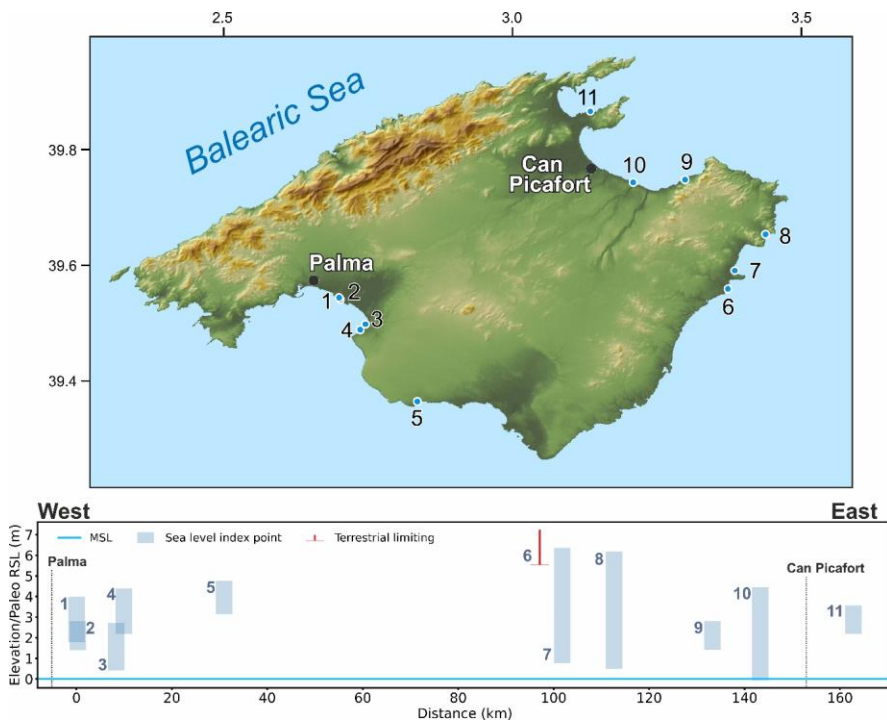



Figure 11: ~~Last Interglacial~~ MIS 5 sea-level data for Mallorca (Islas Baleares, Spain). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007,~~, free~~ NASA dataset). Lower panel: Distance/Elevation graph, 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).

395 **Figure 12: General overview of the *Camp de Tir* outcrop in Mallorca (RSL ID 357, ~~no.~~no. 2 on Figure 11~~Figure 11~~~~Figure 9~~), Balearic Islands, Spain. The upper part of the outcrop is composed by shallow water beach sands of Last Interglacial age. Photo by A. Rovere.**

7.2 Mainland France

The study of the marine Pleistocene deposits along the Mediterranean coast of France dates back to the 1950s (Masurel,
400 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 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
405 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.

7.2.1 Languedoc-Roussilion

The Languedoc-Roussilion coast extends from the border with Spain to the Rhone Delta (Figure 13~~Figure 13~~~~Figure 11~~). Ambert (1999) compiled the most recent review of the Last Interglacial shorelines in this region. These are generally

410   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, nnoo. 4 ion Figure 13Figure 13Figure 11), Leucate (RSL ID 385 and 1316, nnoso. 1 and 2 respectively ion Figure 13Figure 13Figure 11), and Port la Nouvelle (RSL ID 384, nnoo. 3 ion Figure 13Figure 13Figure 11) are characterized by abundant faunal remains rich in *Tapes dianae,* which is considered the key species for the local "Euthyrrenian" stage. The single chronological constrain is provided by an ESR age on a shell

415   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 at *La Franqui* (RSL ID 1316, noo. 2 onin Figure 13Figure 13Figure 11) which placed the RSL at 3 ± ±2.5 m a.s.l. This deposit was dated with

420   both radiocarbon and U/Th techniques but both ages were not considered reliable (Ambert, 1999), therefore they only point to a minimum age (the deposit is older than Holocene). The faunal assemblage is also not very peculiar, with the sole presence of *Spondylus gaederopus*.

ha formattato: Tipo di carattere: Corsivo

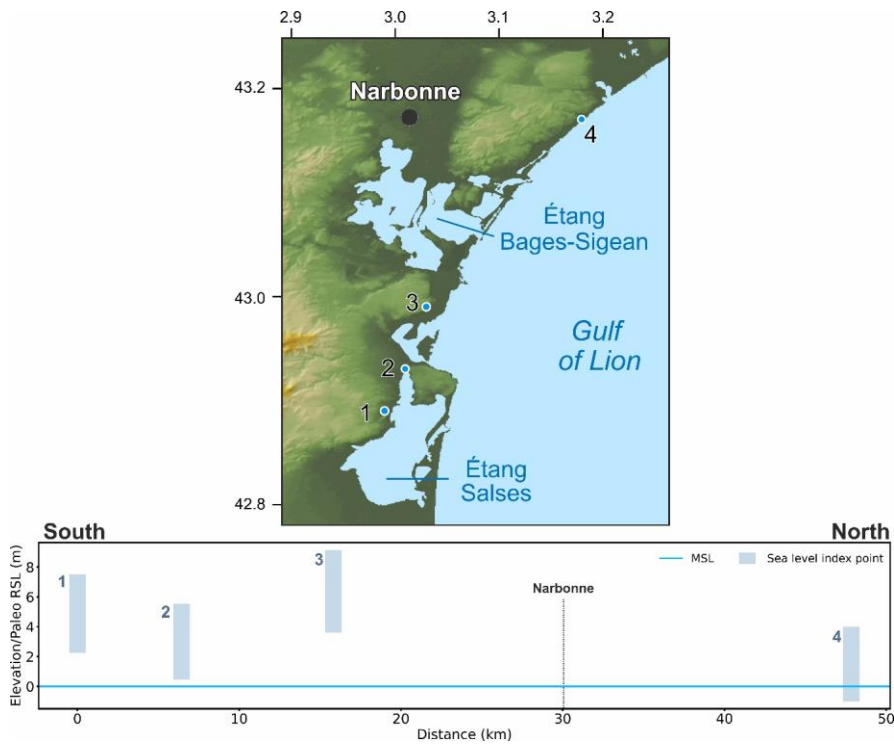



Figure 13: ~~Last Interglacial~~ MIS 5 **sea-level data for Languedoc-Roussilion (France). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007~~), free~~ NASA dataset). Lower panel: Distance/Elevation graph, from 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).**

7.2.2 Provence-Cote d'Azur

This portion of the Mediterranean French coast extends from the Rhone Delta to the border with Italy (Figure 14~~Figure 12~~).
In his review, Ambert (1999) reports a large elevation variability of the Last Interglacial shorelines which ranges from ~3 to
~22 m 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, no. 1 in Figure 14). 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.

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

440 82 ka. This variability is likely related to issues of dating mixed shell remains with U-Series (Stearns and Thurber, 1965).

More recently, Dubar et al. (2008) performed some U/Th dating (U-Series ID 1719 to 1725) on marine mollusc 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, no. 3 in Figure 14) and at 10.3 ±1.3 m a.s.l. (RSL ID 451, no. 4 in Figure 14). The variability of the last-interglacial shoreline in this area elevation was explained by differential tectonic

445 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, constrains the paleo seal-level above ~6 m a.s.l. during MIS 5e.

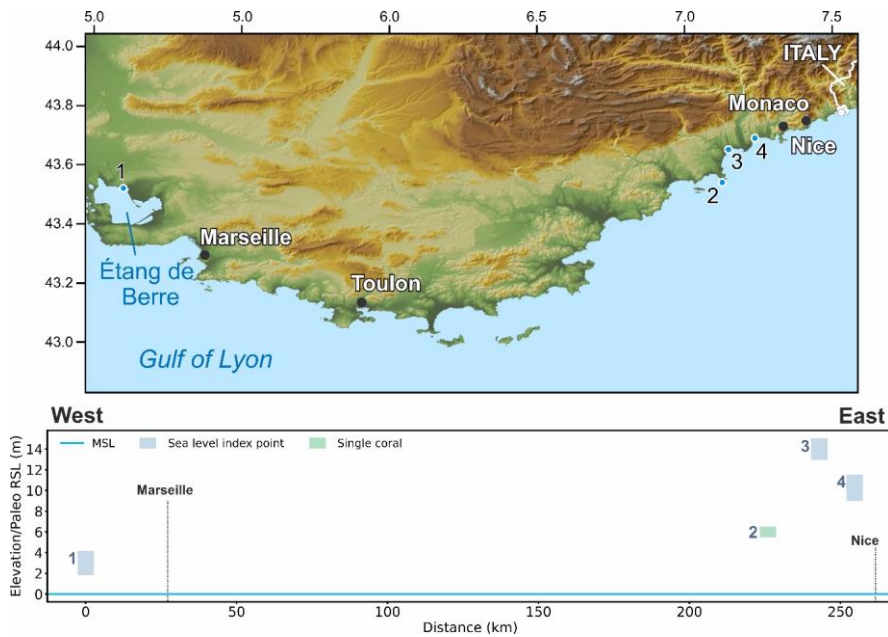



Figure 14: ~~Last Interglacial~~MIS 5 **sea-level data for Provence-Cote Azur (France). Upper panel: Map of sites. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007)~~;, free~~NASA dataset). Lower panel: Distance/Elevation graph, from 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).**

7.3 Mainland Italy

The coasts of the Italian peninsula (including the two main islands, Sardinia and Sicily) have preserved evidence of MIS 5 sea-level changes at several locations. These were the subject of previous Italian-wide compilations, namely those of Bordoni and Valensise (1999) and Ferranti et al. (2006). In our work, we retrieved the original manuscripts cited in these two papers whenever possible. When not possible, we retrieved the data reported by these compilations and inserted them into the WALIS template.

7.3.1 Liguria

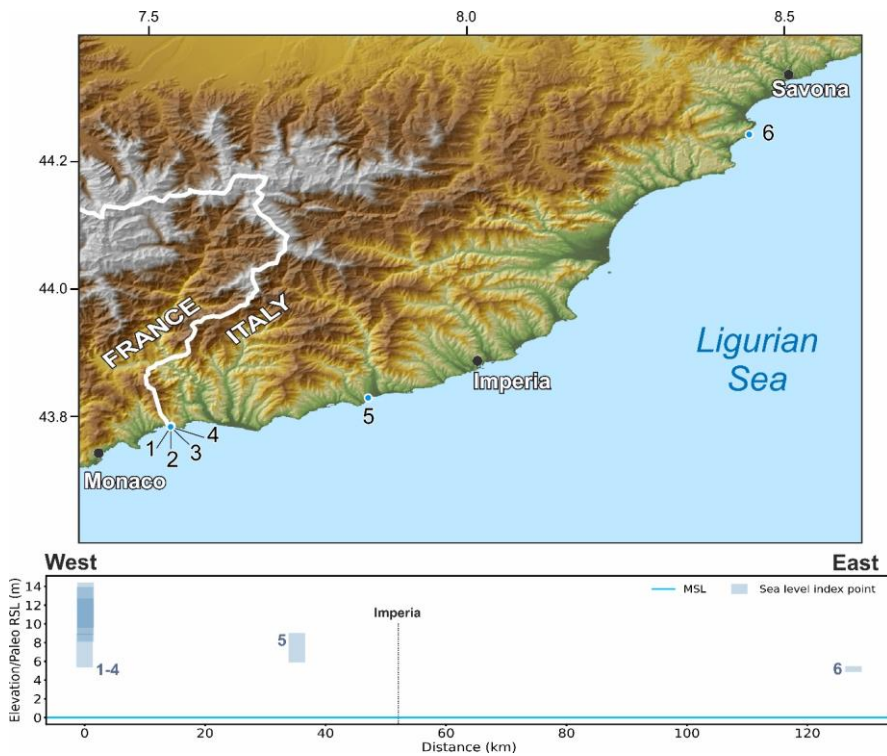
East of the French border, Quaternary shorelines (in particular the Last Interglacial ones) are preserved at few locations along the coast of Liguria (Figure 15), mostly on limestone rocky coasts, and in coastal caves. The most recent review on MIS 5e shorelines in this region was written by Federici 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. Here, four caves (*Ex Casino*, *Barma Grande*, *Bausu da Ture*, *Grotta del Principe*, RSL IDs 233, 237, 239, 240, nos. 2, 4, 3, and 1 respectively in Figure 15) have preserved Last Interglacial deposits. Further to the East, similar deposits are found in the *Madonna dell'Arma* cave (RSL ID 242, no. 5 in Figure 15) (Vicino, 1974; De Lumley, 1969; Isetti et al., 1962). This cluster of data was attributed to the Last Interglacial due to the 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, no. 6 in Figure 15) give a chronologic constraint to a well-preserved upper band of *L. lithophaga* (date mussel) boreholes (Figure 16) at ~6 m 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 28 m 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.

475

Figure 15: Last Interglacial sea-level data for : MIS 5 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.The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, 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 Marina di Bergeggi* (RSL ID 246).

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Figure 16: Close-up of *L. lithophaga* boreholes at ~~ca. ~~~6 m above modern sea level in the *Grotta Marina di Bergeggi*, Liguria, Italy (RSL ID 246, ~~no.~~no.6 in Figure 15~~Figure 15Figure 14~~). Each borehole has a diameter of approximately 2-3 cm. Photo by A. Rovere.

7.3.2 Toscana

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). Compared to this previous compilation, here ~~In WALIS,~~ we standardize the calculation of the indicative range for many of the previously reported sites, also re-analyzing original works (Figure 17~~Figure 17Figure 15~~). We report, where available, also details on their dating. Starting from the North of 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 terrace of the site named *Quercianella* (RSL ID 255, ~~nno~~o. 6 i~~o~~n Figure 17~~Figure 17Figure 15~~, 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. 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 the presence of 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 and 326, nos. 7 and 8 respectively in Figure 17) and *Baratti* (RSL ID 327 and 328, nos. 10 and 11 respectively in Figure 17), albeit obtaining only limiting ages (*Buca dei Corvi* >10 ka, *Baratti* >100 ka). 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 at *Cala dei Turchi* (RSL ID 330, nos. 13 in Figure 17 and Figure 18), 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 (~6 to 9 m a.s.l., RSL ID 331, no. 12 in Figure 17) on the cliff. Stocchi et al. (2018) provide differential GPS measurements of these two features 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 separate age constraints to the *L. lithophaga* boreholes and erosional features on the cliff. The same issue applies to a tidal notch at *Talamone* (RSL ID 335, no. 14 in Figure 17), 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, no. 15 in Figure 17, 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 10-13 m a.s.l. and attributed to MIS 5e with AAR.
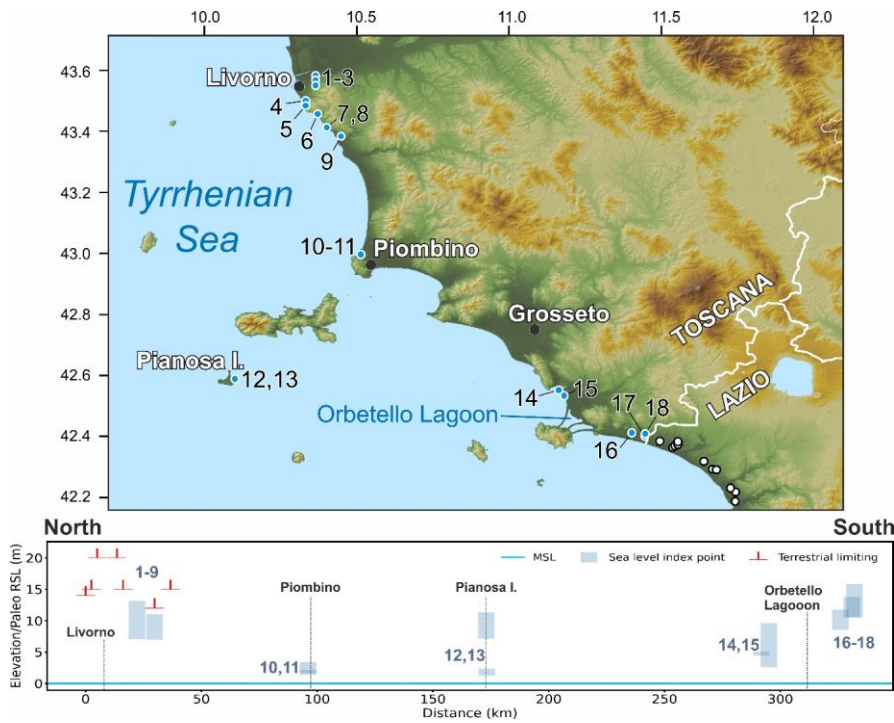
Figure 17~~: Last Interglacial sea-level data for~~ : MIS 5 sea-level data for Toscana (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, 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 1* ~~Upper notch and lithophaga boreholes~~ (RSL ID 331). 13: *Pianosa - Cala dei turchi 2*~~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).

Figure 18: Shelly-rich Last Interglacial deposit at Pianosa, Tuscany, Italy, at 1.7 m above present sea level (RSL ID 330, ~~no.~~no. 13 ~~on~~in Figure 17~~Figure 17Figure 16 Figure 15~~). Photo by A. Rovere.

7.3.3 Lazio

The border between Toscana and Lazio (Latium) administrative regions (Figure 19~~Figure 19Figure 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, most of them containing Senegalese fauna. Some of these deposits were already ~~identified~~ known 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 km 103* site (RSL ID 483, ~~nnoo.. 98 i~~on Figure 19~~Figure 19Figure 17~~). 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, ~~no.~~nos. 109, ~~10 and~~ to12~~1~~ respectively ~~in~~on Figure 19~~Figure 19Figure 17~~). Sixteen kilometers southwards, ~~, then~~they rise ~~in only 16 km near Civitavecchia up~~ to 35 m a.s.l. near Civitavecchia, at *Monna Felice* (RSL ID 494, ~~no.~~no. 15~~2~~ on Figure 19~~Figure 19Figure 17~~). In the same area, ESR ages associated (in some cases) with facies descriptions of the deposits were reported by Radtke (1983) and Radtke (1986). While these two studies report several mollusk~~s~~e samples dated with ESR and U-series in the stretch of coast between Civitavecchia and Monte Argentario, in the database only three sites were reported for which elevation, facies, and dating information is readily available (RSL IDs 4070, 4071, 4072, nos. 7,13 and 14 in Figure 19).

Hearty and Dai Pra (1986) report only two beach deposits dated to MIS 5e southwards, towards the city of Rome (RSL IDs 495-496, no. 16 and 17 respectively in Figure 19). At *Cava Rinaldi* (RSL ID 529, no. 185 in Figure 19), 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 $\pm$ 2 ka) with $^{40}Ar/^{39}Ar$ thanks to the presence of an intercalated 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, no. 196 in Figure 19), at 11 m a.s.l. The ESR sample gave an age of 79 $\pm$ 7 ka, while the U-Series one yielded an age of 198 $\pm$ 8 ka, 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 ~23 m a.s.l and MIS 5e attained much higher levels, at around 35 m a.s.l. 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, nos. 17 and 18 respectively in Figure 19) 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, nos. 19 to 24 in Figure 19), 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 Latina), Antonioli et al. (1988) report MIS 5e deposits down to 6 m b.s.l (RSL ID 508, no. 31 in Figure 19). 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-MIS5e. 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.
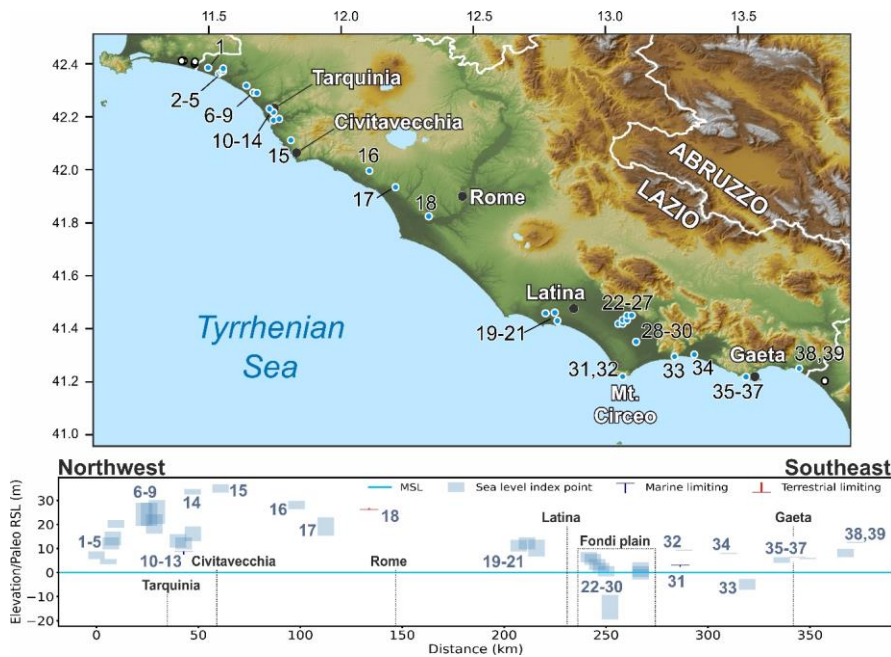
Figure 19: ~~Last Interglacial sea level data for~~ : MIS 5 sea-level data for Lazio (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~ The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, NASA dataset). **Lower panel: Distance/Elevation graph, from Northwest (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:** *Riva dei Tarquini,* (RSL ID 4070). **8:** ~~7:~~ *Between Arrone and Mignone rivers* (RSL ID 481). **9:** ~~8~~ *Aurelia km 103* (RSL ID 483). **10:** ~~9~~ *Northwest of Tarquinia railway station* (RSL ID 484). **11:** ~~10~~ *F. delle Serpe* (RSL ID 479). **12:** ~~11~~ *Casale Olivastro* (RSL ID 480). **13: Km17-1(k) (RSL ID 4071); 14:** *Casal San Vincenzo* (RSL ID 4072). **15:** ~~12~~ *Monna Felice* (RSL ID 494). **16:** ~~13~~ *Monteroni - Cerveteri* (RSL ID 495). **17:** ~~14~~ *Casale di Statua* (RSL ID 496). **18:** ~~15~~ *Cava Rinaldi (point d)* (RSL ID 529). **19:** ~~16~~ *Quadrato* (RSL ID 527). **20:** ~~17~~ *Borgo Santa Maria, west of Latina* (RSL ID 497). **21:** ~~18~~ *Borgo Sabotino* (RSL ID 498). **22:** ~~19~~ *Pontinia I* (RSL ID 513). **23:** ~~20~~ *Pontinia II* (RSL ID 514). **24:** ~~21~~ *Pontinia III* (RSL ID 515). **25:** ~~22~~ *Pontinia IV* (RSL ID 516). **26:** ~~23~~ *Pontinia V* (RSL ID 517). **27:** ~~24~~ *Pontinia VI* (RSL ID 518). **28:** ~~25~~ *Borgo Vodice I* (RSL ID 519). **29:** ~~26~~ *Borgo Vodice II* (RSL ID 520). **30:** ~~27~~ *Borgo Vodice III* (RSL ID 521). **31:** ~~28~~ *Torre Rossa* (RSL ID 499). **32:** ~~29~~ *Circeo (Grotta delle Capre)* (RSL ID 522). **33:** ~~30~~ *Terracina (Pisco Montano)* (RSL ID 523). **34:** ~~31~~ *Fondi plain core ATP4* (RSL ID 508). **35:** ~~32~~ *Torre Capovento* (RSL ID 500). **36:** ~~33~~ *Sperlonga (Sant'agostino)* (RSL ID 524). **37:** ~~34~~ *Gaeta (Grotta del Turco)* (RSL ID 525). **38:** ~~35~~ *Marina di Minturno* (RSL ID 501). **39:** ~~36~~ *Minturno (Monte d'Argento)* (RSL ID 526).

7.3.4 Campania

600 South of Lazio, Last Interglacial sea-level records in Campania have been reported both from the subsurface (in the Garigliano and Campana coastal plains) and on surface outcrops (mainly along the Cilento promontory, Sele Plain, Sorrento Peninsula, and Capri island) (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-

605 Series age on fragments of *C. caespitosa* (126 ±11 ka, USeries ID1964) found in the *San Marcellino core* (RSL ID 722, no. 2 in Figure 18, Romano et al., 1994, see below).

In the Garigliano Plain, at *Masseria Transitiello* (near the Cellole Aurunci village, RSL ID 3624, no. 1 in Figure 18), 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, no. 36 in Figure 17, see the previous section). Six specimens of *Glycimeris glycimeris* from *Masseria Transitiello* have been dated

610 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, no. 2 in Figure 18) (Romano et al., 1994).

615 Last Interglacial sea-level proxies were also found at c. 18 m b.s.l. in the *San Marco Evangelista* core (Santangelo et al., 2010), near the city of Caserta, about 28 km inland from the modern coastline (RSL ID 739, no. 3 in Figure 18). In this core, the deposits associated to the Last Interglacial transgression (labeled as *Upper fossiliferous Unit*) constrained by the integration of tephra-stratigraphic and radiometric analyses ($^{40}Ar/^{39}Ar$) on volcanic layers. In particular, the *Upper fossiliferous Unit* (between 27.00 to

620 17.4 m b.s.l.) is located by Santangelo et al. (2010) between a tephra layer (Strat ID 65) at the top, which was correlated to an eruption dated 105 ka (Allen et al., 1999), and an older tephra at the bottom (WALIS Other Dating ID 53) dated ($^{39}Ar/^{40}Ar$ on sanidine crystals) 150 ±10 ka.

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

625 species *Sylvestra seminis* (RSL ID 790, no. 4 in Figure 18).

In the area close to the town of Cancello, 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,

Commentato [AR29]: COMMENT BY H. BRÜCKNER: Were the deposits in the borehole dated, and if so, what was the outcome? The transgession starts after the peak of the MIS 6 regression and goes to the peak of MIS 5.5. At a depth of -18 m I presume an age older than ca. 135 ka BP (in a tectonically relatively stable region).

Commentato [CC30R29]: The marine succession (top at - 18 m) are not directly dated, but it is placed between two dated tephra layers (150 ka at the bottom of the marine succession and 105 ka at the top of it). The Campania Plain is not tectonically stable but in subsidence as evidenced by the position of the MIS 5e deposits

described above. However, a recent work (Cerrone et al., 2021c) 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 side, at elevations comparable with those recorded in other tectonically stable areas of the Tyrrhenian Sea. In particular, at *Cala di Ieranto* (RSL ID 721, no. 29 in Figure 18) and *Conca dei Marini* (RSL ID 720, no. 34 in Figure 18) 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 Uranium uptake 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 to identify three distinct Last Interglacial sea-level peaks, with a double notch at 6.5 m (RSL ID 766, no. 33 in Figure 18) and ~8 m a.s.l. (RSL ID 3565, no. 36 in Figure 18) and another tidal notch at 3.5 m a.s.l. (RSL ID 767, no. 32 in Figure 18). 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 side of Sorrento Peninsula (RSL ID 3623, no. 35 in Figure 18). 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 Capri Island. The 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 U-Series ages on *C. caespitosa* from the bay of Ieranto, at the southern side of the Sorrento Peninsula (RSL IDs from 800 to 822, nos. 6 to 28 in Figure 18, see a photo of one of the notches in 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 MIS 5c (RSL ID 770, no. 38 in Figure 18), whereas the *Ponte Barizzo ridge* site, reaching an elevation of 25 m a.s.l., to MIS 5e (RSL 769, no 37 in Figure 18).

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 *Ogliastro Marina* (RSL ID 592, no. 42 in Figure 18), *Sapri* (RSL ID 791-792, no. 54 and 55 in Figure 18), and Palinuro (*Lido Ficocella*, RSL ID 593, no. 43 in Figure 18).

The age provided 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, no. 44 in Figure 18) 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. (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 reconstruction of the *Riparo degli Infreschi* outcrop (RSL IDs 3568 to 3576, no. 45 to 53 in Figure 18) based on new U-Series dating and tephra correlations. The new U-Series dates were performed on speleothems and calcite-filled *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 correlated to MIS 5e (RSL ID 3568, no. 45 in Figure 18).
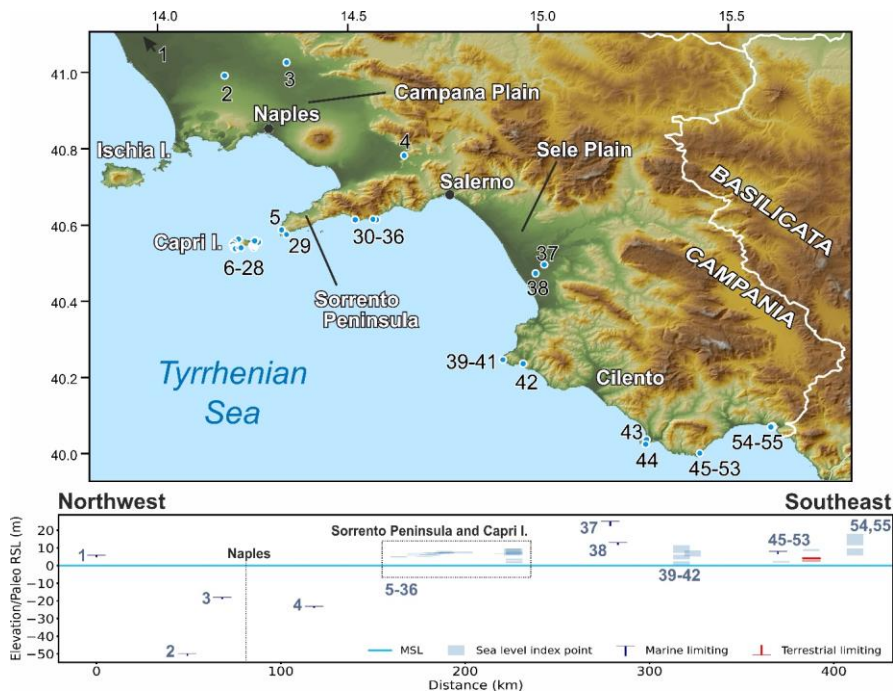
Figure 20: ~~Last Interglacial~~MIS 5 **sea level data for Campania (Italy). Upper panel: Map of sites.** ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~ The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, 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~~ *well* **(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 21: Tidal notch at Capri Island, *a Vascio Funno* site (RSL ID 815, ~~no.~~no. 23 in ~~Figure 20~~Figure 20~~Figure 19~~). Photo by A. Ascione

7.3.5 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 22~~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-~~s~~Series and AAR dating on *C. caespitosa* and Bivalvia respectively. However, ~~recently~~ a recent work by 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-~~s~~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~~ reach up to some tens of meters in elevation. This data is not yet included in WALIS.

The promontory of Capo Vaticano (RSL ID 267 to 270, 314 to 316, 3430, and 3431, ~~no.~~nos. 1 to 8 ~~in~~ Figure 22~~Figure 20~~) has been deeply investigated in the last decades and many dating constraints (OSL, TL, and U-~~s~~Series) have been provided.

However, 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 MIS 5c terrace of Bianca et al. (2011) reaches 175 m a.s.l. at *Capo Vaticano* (RSL ID 269, no. 5 in Figure 22). 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, no. 1 in Figure 22), 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.

In the Reggio Calabria area, Gignoux (1913) reported the presence of *P. latus* and Senegalese fauna in the *Bovetto* (RSL ID 306, no. 12 in Figure 22) and *Ravagnese* areas (RSL ID 304, no. 10 in Figure 22) at elevations up to ~130 m a.s.l. This area was later investigated by Hearty et al. (1986 a-b), Dumas et al. (1987, 1988), and Balescu et al. (1997), who dated the deposits with AAR and TL to MIS 5e. Another terrace, at Altibano (RSL ID 313, no. 18 in Figure 22), was tentatively 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. In Nocella (Figure 22), Dumas et al. (1987) report the highest occurrence of *P. latus* along the whole Mediterranean coast at 157 m a.s.l. This point has been related to a marine terrace reaching up to 166 m a.s.l. (RSL ID 1378, no. 16 in Figure 22). It is worth noting that Dumas et al. (1988) report the presence of *P. latus* at 105 m a.s.l. (RSL ID 4062, no. 13 in Figure 22) and 157 m a.s.l. in Nocella. These elevations are correlated to two distinct paleo shorelines (labelled VI and VII in Dumas et al., 1988) that were both associated to MIS 5e by the original authors. The authors hypothesized that these paleo shorelines corresponds to two different peaks of MIS 5e. However, in doing this, they arise an elevation gap problem that is not easy to justify. The age of these two paleo shorelines (VI and VII in Nocella) could not be differentiated by AAR geochronology (Dumas et al. 1988) or TL (Balescu et al., 1997). The issue, hence, is still open. The Bovetto-Ravagnese, Nocella, and Altibano terraces are geomorphologically separated but their chronological order cannot be easily untangled. However, based on the available data, and in particular considering as key-spot the Bovetto-Ravagnese terrace, an uplift rate of ~1 mm/yr for the Last Interglacial may be calculated for this area (Dumas et al., 1987, 1988, Ferranti et al., 2006). The uplift in Reggio Calabria varies in space and time.
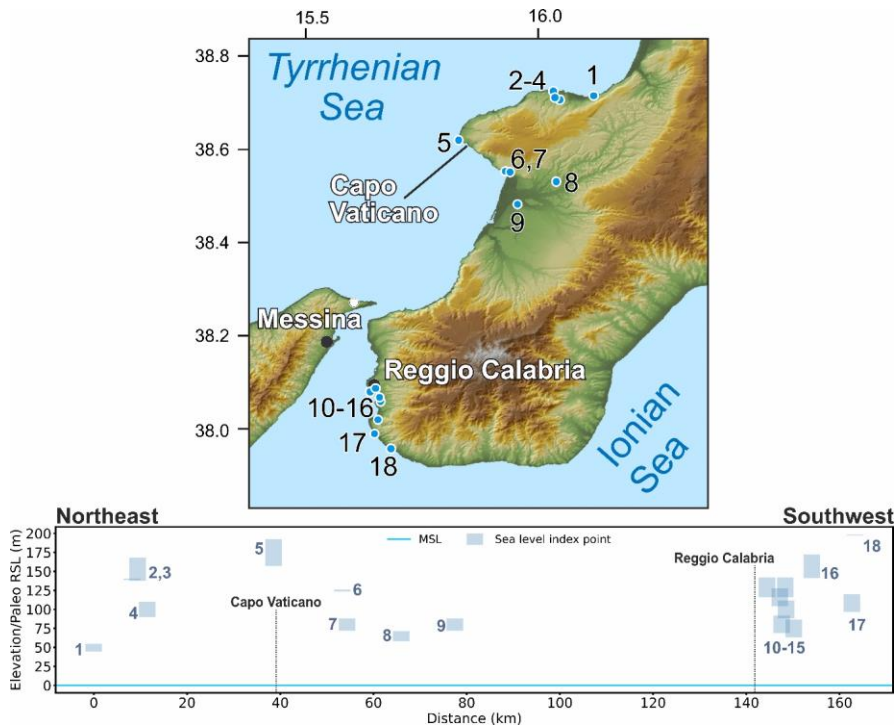
Figure 22: ~~Last Interglacial~~ MIS 5 **sea-level data for the Tyrrhenian side of Calabria and Basilicata (Italy). Upper panel: Map of sites.** ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~ The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, 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: *Trombaca II* (RSL ID 4065). 14: *Traietta* (RSL ID 4066). 15: *Rione Branca* (RSL ID 4067). 16: *Nocella Pellaro* (RSL ID 1378). 17: *Nocella II* (RSL ID 4062). 18: *Altibano* (RSL ID 313). ~~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: trombaca II, 14 Traietta, 15 rione branca 136: Nocella Pellaro (RSL ID 1378). 17 Nocella II 184: Altibano (RSL ID 313).~~

7.3.6 The Ionian coast of Calabria and Basilicata

Along the Ionian Sea coasts of Calabria and Basilicata (Figure 23Figure 23Figure 21) wewe identified several reports studies onreporting the presence of of the Last Interglacial shorelines. The Pleistocene marine terraces in Crotone and Isola di Capo Rizzuto (RSL ID 563 to 5656, 1379, 3428, no.nos. 1, 6, 5, 8 and 7 onin Figure 23Figure 23Figure 21), were first reported by Cortese (1895), and have been deeply studied in details by successive authors (Gignoux, 1913; Cosentino and Gliozzi, 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, among others). The Crotone peninsula has been considered the "*locus typicus of the Crotonian stage*" (Belluomini et al., 1988 and references therein), i.e., an area where an old nomenclature to indicate the Middle Pleistocene is particularly well-represented. The most recent review of the RSL indicators in the Crotone Peninsula is contained in Nalin et al. (2020), who provided also new infrared stimulated luminescence IRSL dating. 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, bBased on such dating, the *Capo Colonna* Terrace (RSL ID 3634, no.no. 9 onin Figure 23Figure 23Figure 21) has been correlated either to 5eto MIS 5 thanks to the , for the presence of deposits with *P. latus* (Nalin et al., (2012;) and Palmentola et al., (1990)). An AAR age of these deposits points to, or MIS 5a (AAR ID 161). 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 reported by Bracchi et al. (2011) and Nalin et al. (2012), in in addition to those already reported at addition to the presence of *P. latus* in Campolongo 33 site and Senegalese fauna in Campolongo 34Campolongo area (Gliozzi, 1987) and in Bosco Soverito site (Palmentola et al., 1990). SuchThese sites have not been included in the database, as there is not enough information to derive RSL index points. but only the index points related to the Last Interglacial. The age provided to constrain the *Isola di Capo Rizzuto* site (RSL ID 565, no.no. 5 onin Figure 23Figure 23Figure 22Figure 21) may be interpreted as a minimum age due to saturation problems of quartz and feldspar minerals. In the Nalin et al., 2020 review, it is includedreported as MIS 7.

In *Trebisacce* (RSL ID 324, no.no. 11 onin Figure 23Figure 21), at the northern border of the Sibari coastal plain, Cucci (2004) attributed dated to an MIS 5e age (AAR IDs 97 and 98) to a 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 in elevation 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 being this the only location where a direct age constraint has been provided.

A fFew kilometers northeast from of *Trebisacce*, in *Vaccarizzo* site (RSL ID 442, no.10 onin Figure 23Figure 21), 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).

Commentato [AR39]: COMMENT BY H. BRÜCKNER: Brückner 1980, in German, not quoted; Palmentola et al. 1990, in Italian, quoted

Commentato [CC40R39]: We added the main outcomes of Brückner, 1980

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Even if a very well-developed staircase 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, no. 12 in Figure 23), near the town of Nova Siri, the marine terrace, which inner edge was reported at 90 m 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 for the terrace, it is not included in the database.

The Metaponto area has been studied since the works of Gignoux (1913, 1960) and Vezzani (1967), with several interpretations proposed regarding the age and number of the marine terraces forming the flight sequence in the northern part of the Taranto Gulf. Brückner (1980) identified 11 marine terraces orders, which were constrained by integration of magnetostratigraphy, tephrostratigraphy, and U-series dating on molluscs. According to Brückner (1980), the Terrace T1 (up to 22 m a.s.l.) is correlated to MIS 5a (RSL ID 4060, no. 13 in Figure 23) and the Terrace T2 (up to 42 m a.s.l.) is correlated to MIS 5e (RSL ID 4061, no. 14 in Figure 23). Such interpretation is further supported by Zander et al. (2006) and Sauer et al. (2010) based on OSL and soil analyses respectively. The correlation of Terrace T2 with MIS 5e is confirmed by correlation with the presence of *P. latus* in *Ponte del Re* site (RSL ID 355, no. 1 in Figure 24), in Puglia, constrained via AAR and deposits with *P. latus* site (RSL ID 355, no. 1 on Figure 22).

Figure 23~~: Last Interglacial sea-level data for~~ : MIS 5 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.~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, NASA dataset). Lower panel: Distance/Elevation graph, from Southwest (left) to Northeast (right). Sites list: 1: *San Leonardo di Cutro* (RSL ID 563). 2: Campolongo (RSL ID 4068). 3: *Le Castella* (RSL ID 4069). 4: *Manca della Mozza* (RSL ID 566, out of bounds at 240m a.s.l., dated to Marine Isotope Stage 7). 5: *Isola di Capo Rizzuto* (RSL ID 565). 6: *Capo Rizzuto* (RSL ID 564). 7: *Crotone (II)* (RSL ID 3428). 8: *Crotone* (RSL ID 1379). 9: *Capo Colonna Terrace* (RSL ID 3634). 10: *Vaccarizzo* (RSL ID 442). 11: *Trebisacce* (RSL ID 324). 12: *Piano San Nicola* (RSL ID 416). 13: *Metaponto* (RSL ID 4060). 14: *Metaponto (II)* (RSL ID 4061) ~~2: Manca della VMozza. (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).~~

7.3.7 Puglia

Along the Ionian coasts of Puglia (Figure 24), near the border with Basilicata, at *Ponte del Re-Castellaneta* site (RSL ID 355, no. 1 in Figure 24) a marine terrace up to 40 m a.s.l. was correlated with MIS 5e due to the presence of Senegalese fauna with *P. latus* (Boenzi et al., 1985). The correlation was later detailed to MIS 5e 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, nos. 9, 4, 5, 16, 6, 12, 1, 18, 19, 3, 14, 11, 15, 13,8, 17, 10, 2 and 7 respectively in Figure 24) that confirm their MIS 5 age.

In particular, the section cropping out at *Il Fronte* (RSL ID 230, no. 2 in Figure 24, near the city of Taranto) has been recently analyzed in detail 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 five 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 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, no. 2 in Figure 24).

South of Taranto, specimens of *P. latus* were reported in *Torre Castelluccia* (RSL ID 705, no. 17 in Figure 24), *Torre Castiglione* (RSL ID 696, no. 19 in Figure 24), 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, MIS 5a according to Hearty and Dai Pra, 1992), while deposits containing *P. latus* were located at 28 m a.s.l. in the surroundings of *Lizzano* (RSL ID 695, no. 18 in Figure 24). The MIS 5e terrace in *Torre Castiglione* (RSL ID 696, no. 19 in Figure 24) has been reported at 2.5 m a.s.l. (Dai Pra and Stearns 1977). Moreover, at *Gallipoli* (RSL ID 3625, 3267, and 3268, no. 20 to 22 in Figure 24), *Glycymeris* specimens sampled at 8-10 m a.s.l. were constrained with AAR to MIS 5e (Dai Pra and Hearty 1988).
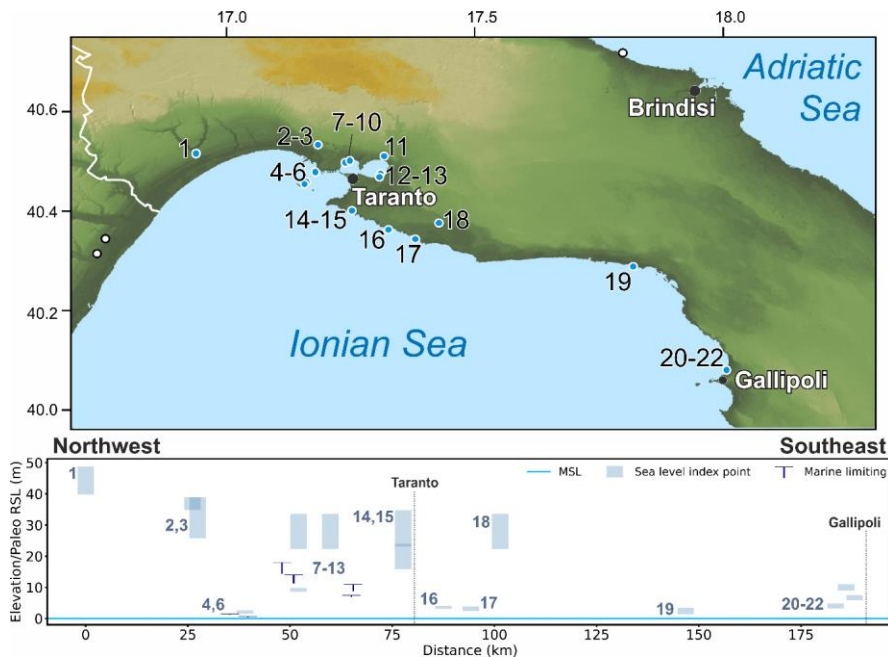
Figure 24: ~~Last Interglacial sea level data for~~ : MIS 5 sea level data for the Ionian side of Puglia (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, 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: *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).

Towards the Adriatic Sea side of Puglia (Figure 25~~Figure 25Figure 23~~), at the bottom of *Grotta Romanelli* (RSL ID 1319, ~~no.~~no. 3 ~~i~~on Figure 25~~Figure 25Figure 23~~), a marine deposit containing Senegalese fauna (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). Mastronuzzi et al. (2007), though, report that these deposits do not contain ~~These authors, though, wrongly reported the presence of~~ *P. latus*~~.~~, as

855 reported by earlier works. The same authors studied a series of sea caves along the southern coasts of Salento, at elevations from 0 up to 10 m a.s.l. (RSL IDs 1319, 1320, 1323 and 1324, 3635, nos. 3, 4, 2, 1, in Figure 24). Based on stratigraphic correlations and U-series dating of flowstones, Mastronuzzi et al. (2007) argue that these caves were reshaped by the sea during MIS 9c, MIS 5e, and MIS 5a. We included in

860 the database only the speleothem (USeries ID 2958) providing a limiting age (younger than 77 ka) at 3 m a.s.l. at *Grotta del Diavolo* (RSL ID 3635, nb 1 in Figure 24) because the others samples of Mastronuzzi et al. (2007) dated older than MIS 5. Overall, according to the evolution modelling proposed by Mastronuzzi et al. (2007), the fact that these caves have been reshaped by the sea during the MIS 5e is proof of the tectonic stability of the area. In this context, the data

865 points reported in Ferranti et al. (2006) from Parroni and Silenzi (1997), placing a marine terrace at an elevation of 25±15 m a.s.l. in *Marina di Novaglie* (RSL IDs 1323, 1324, nos. 2 and 3 in Figure 25), would need to be re-assessed with more precise measurements and dating, to assess if their attribution to MIS 5 is correct.

In the Apulian Tavoliere plain, the dating of *Glycymeris sp.* with AAR from the *MM4 borehole* (De Santis et al. 2010)

870 allowed to include in the database three marine limiting datapoints (RSL ID 452 to 454, nos. from 8 to 10 in Figure 23). 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 lower Holocene plain (Mastronuzzi et al. 1989). This site has been inserted in the database as a terrestrial limiting point (RSL ID 1317, no. 11 in Figure 23).

875 A synthesis regarding the Quaternary evolution of the Puglia region is included in Mastronuzzi and Sansò (2003).

Figure 25: Last Interglacial sea-level data for : MIS 5 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. The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, NASA dataset). Lower panel: Distance/Elevation graph, from Southwest (left) to Northeast (right). Sites list: 1: *Grotta del Diavolo* **(RSL ID 3635). 12:** *Marina di Novaglie Southern Site* ~~*of Marina di Novaglie*~~ **(RSL ID 1324). 32:** *Marina di Novaglie Northern Site* ~~*of Marina di Novaglie*~~ **(RSL ID 1323). 43:** *Grotta Romanelli* **(RSL ID 1319). 54:** *Grotta delle Striare* **(RSL ID 1320). 65:** *Torre Mattarelle - Torre Guaceto* **(RSL ID 1321). 67:** *Torre Santa Sabina* **(RSL ID 1322). 78:** *Villanova-Monopoli* **(RSL ID 1318). 89:** *MM4 borehole Unit 13* **(RSL ID 452). 910:** *MM4 borehole Unit 11* **(RSL ID 453). 1011:** *MM4 borehole Unit 10* **(RSL ID 454). 121:** *Fortore River* **(RSL ID 1317).**

7.3.8 Molise, Abruzzo and Marche

The coastal sector from Molise to the southern boundary of Romagna Plain (Figure 26Figure 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

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Commentato [AR45]: COMMENT BY H. BRÜCKNER: The extraordinary length of the first column (no. 1) must be explained. How can it reach from ca. 5 to ca. 35 m asl.?

Commentato [AR46R45]: This is from previous literature, it is just a very high error range put by the original authors. We highlighted that it should be re-assessed in the main text.

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890 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.

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
895 Marche region have been attributed to the Last Interglacial. ~~Anyhow~~However, the surveys carried out in the framework of the new geological map of Italy (Guerrara and Tramontana, 2011) and other recent investigations did no'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 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.

900 **7.3.9 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 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. However~~Anyhow~~, in Emilia -
905 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 26~~Figure 24~~). The database has been mainly produced in the framework of the new geological map (CARG project) but has been also 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
910 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 previous alluvial units, generally dating to MIS 6 (an example is reported in Figure 27~~Figure 25~~). The marine transgression expanded on the plain and induced the progressive shifting to lagoonal, beach, and marine environments. These deposits
915 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 RSL index points ~~of 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*, *Loripes* sp., *Hydrobia* sp., *Bittium* sp., *Abra* sp, and *Cerithium* sp.

The marine transgression flooded 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 26). 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 recognized in the cores in northern Adriatic, representing a major tool for stratigraphic correlation. Worthy of note, it is not a synchronous surface, but it is time-transgressive (Massari et al., 2004; Amorosi et al., 2008a-b).

Mollusk faunal associations is not chronological markers per se, but biostratigraphic markers if there are distinctive species present (e.g., Senegalese fauna with *P. latus*. However, the paleobotanical analyses carried out in few selected cores recognized the pollen associations related to warm temperate climate, characterized by broad-leaved trees 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, no. 8 in Figure 26), *240-S8*, near Milano Marittima (RSL ID 1308, no. 6 in Figure 26), and *223-S17*, at the southern boundary of Valli di Comacchio (RSL ID 1326, no.10 in Figure 26), 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, no. 6 in Figure 26), *222-S2* (112.5 m b.s.l., RSL ID 1310, no. 10 in Figure 26) and *205-S10* (85.5 m b.s.l., RSL ID 1309, no. 16 in Figure 26). 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 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 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 ann 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 subsidencemovements. 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 extent 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 26 Figure 24 and Figure 28Figure 28Figure 26).

965 **Figure 26: Last Interglacial sea level data for : MIS 5 sea-level data for Marche and Emilia Romagna (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.The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, 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**
970 **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 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**
975 **1314). 16: *205-S10 Comacchio Core S10* (RSL ID 1309). 17: *Core F187_S1 Valle Giralda* (RSL ID 1307). * Sites 1, 2, and 3 are rejected (see text for details) but inserted here for reference.**

7.3.10 Veneto

In the Venetian Plain (Figure 28Figure 28Figure 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 Last Interglacial (Figure 27Figure 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, no.no. 2 ion Figure 28Figure 28Figure 26), in the 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, no.no. 5 ion Figure 28Figure 28Figure 26), where 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 lagoonal, 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.

In Venice, the reference stratigraphy for Pleistocene is the core *VE-1* and *VE-1bis* (RSL ID 1303, no.no. 4 in Figure 28Figure 27Figure 26), 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 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, was 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.

1010 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 5e from the alluvial plain to the marine facies (Figure 27 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, no. no. 8 in Figure 28 Figure 28 Figure 26), to core *PRA* (RSL ID 793, no. no. 7 in Figure 28 Figure 28 Figure 26), to the coast (core *TdM*, RSL ID 1295, no. no. 6 in Figure 28 Figure 28 Figure 26,

1015 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

1020 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. Accordinggly to this setting, also the coastline of MIS 5e reached a more landward position (Figure 27 Figure 25 and Figure 28 Figure 28 Figure 26), as in core *TdM*, where the coastal

1025 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, no. no. 10 in Figure 28 Figure 28 Figure 26) and *VV* (RSL ID 1293, no. no. 11 in Figure 28 Figure 28 Figure 26).

Figure 27: a) Stratigraphic section of the -Venetian Friulian Plain, from AZX Azzano core (RSL ID 1301, ~~no.~~no. 8 in Figure 28Figure 28Figure 27) ~~viato~~ PRA Belfiore core (RSL ID 793, ~~no.~~no. 7 in Figure 28Figure 28Figure 27) to TdM Torre di Mosto core (RSL ID 1295, ~~no.~~no. 6 in Figure 28Figure 28Figure 27) (modified from Fontana et al., 2010). Trace of section is indicated in Figure 28Figure 28Figure 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.

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Commentato [AR54]: COMMENT BY H. BRÜCKNER:
See my remark on line 777. Here you can calculate:

uppermost lagoonal deposits ca. 45 m bsl., coring site 4 m asl.
45 m - 2 m (presumed glacio-isostatic sea level at 125 ka) - 4 m (elevation of coring site) = 39 m
39 : 125 --> ca. 0.3 m/ka subsidence
It makes sense that to the north of the Venice lagoon near the mountains the subsidence rate is smaller than further towards Venice.

Commentato [AR55R54]: Same reasoning as above, it would be a very rough estimate. Seems a bit too far-fetched to do here, with no sensitivity test on GIA or long-term subsidence oscillations.

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7.3.11 Friuli Venezia Giulia

Along the coastal plain, Veneto and Friuli Venezia Giulia are not separated by a physiographic boundary (Figure 28Figure 28Figure 26), so it is 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, no.no. 13 in Figure 28Figure 28Figure 26), 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 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, no.no. 14 in Figure 28Figure 28Figure 26), 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 ESR, butanyhow, 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, they seem not reliable. Recently, in the coast near Trieste, the geophysical investigations highlighted the occurrence of a buried flat surface, cut in the Flysch bedrock and often related to a basin ward coastal wedge. The surface has been interpreted as a marine terrace produced during the MIS 5e and, according to different wave velocity models, the top of the terrace is assessed at a depth ranging between 70-50 m b.s.l. (Romeo, 2009) and between 35-40 m b.s.l. (Zampa, 2014). As no geochronological constrains are available, eventually a generic MIS 5 age can be possibly assessed for the formation of this landform and the related sedimentary wedge. Moreover, it is worth noting that even in the shallower interpretation the elevation of these proxies for past marine level are rather comparable to the position of the of index points of MIS 5e documented in the Friulian Plain, but that area should have been affected by subsidence compared to the coast of Trieste in the last 125 ka.
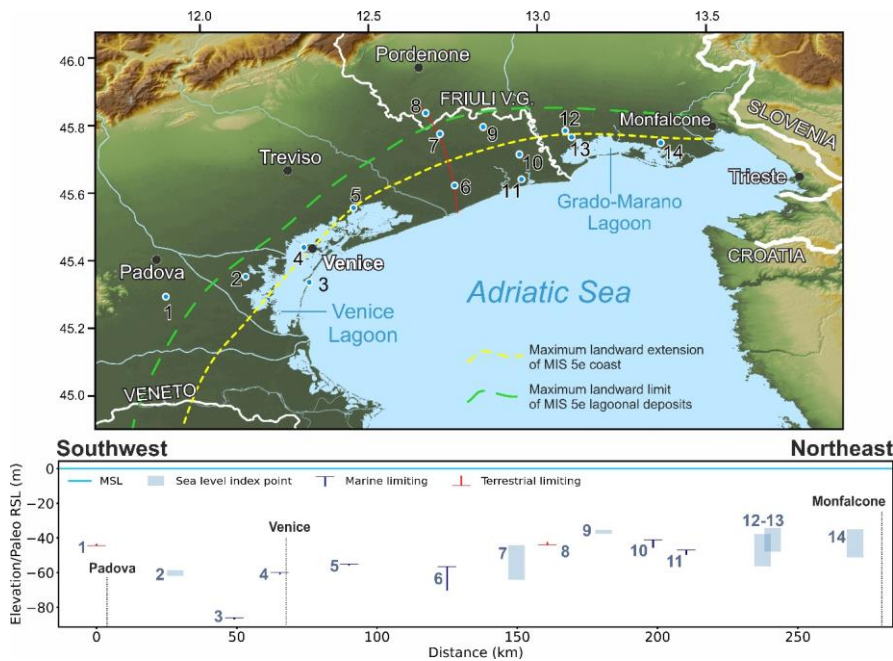
Figure 28~~: Last Interglacial sea-level data for~~: MIS 5 sea-level data for Veneto and Friuli Venezia Giulia (Italy). Upper panel: Map of sites. ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, NASA dataset). Lower panel: Distance/Elevation graph, from Southwest (left) to Northeast (right). The lines depicting the ~~most~~ innermost 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 27Figure 26Figure 25~~.

7.3.12 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).

1080   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.

HoweverAnyhow, 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.

1085   (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.

1090   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. HoweverAnyhow, this asymmetric evolution of the opposite sides

1095   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).

1100   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. HoweverAnyhow, 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

1105   proxy for the RSL of Last Interglacial.

7.4 Corsica, Sardinia and Sicily

7.4.1 Corsica

1110 Corse (Corsica) is the third-largest western Mediterranean Island and hosts a great number of Quaternary marine deposits (Figure 29) 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, no. 6 in Figure 29) and shallow coastal deposits (RSL ID 299, no. 5 on Figure 29, Figure 30) dominated by *Arca noe* and *Patella ferruginea* (Ottmann, 1954) seems to indicate that the maximal

1115 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 (AAR ID 93, Hearty et al., 1986a) which yielded an MIS 5e 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

1120 found in lagoonal facies (RSL ID 321, no. 2 in Figure 29) 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 Bonifacio (RSL ID 277, no. 1 in Figure 29, 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 infinite

1125 (19 to 40 ka) ages (Delibrias et al., 1972; Nesteroff, 1984).
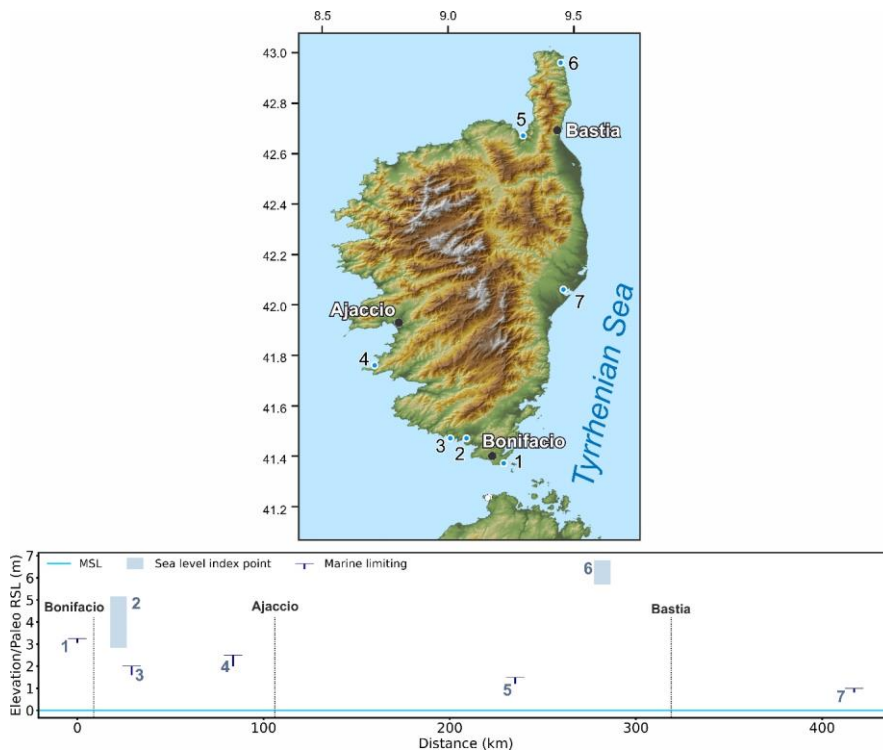
Figure 29~~: Last Interglacial sea-level data for~~ : MIS 5 sea-level data for Corsica (France). Upper panel: Map of sites. ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, 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).**

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Figure 30: Littoral deposits in *St Florent*, Corsica (RSL ID 299, ~~no.~~no. 5 in Figure 29~~Figure 29~~~~Figure 27~~). Photo by M. Vacchi.

7.4.2 Sardegna

Sardegna (Sardinia) ~~represents~~ is 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~~ in the 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., 2006; Ulzega and Hearty, 1986, Figure 31~~Figure 31~~~~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~~ at several sites, with some slight variability in its ~~showing variability in~~ elevation. In *Pedralonga* (RSL ID 432, ~~no.~~no. 1 in Figure 31~~Figure 31~~~~Figure 29~~) and *Capo Monte Santu* (RSL ID 435, ~~no.~~no. 2 in Figure 31~~Figure 31~~~~Figure 29~~), the notch ~~is placed at~~ has 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, ~~no.~~no. 3 in Figure 31~~Figure 31~~~~Figure 29~~). In the Northern portion of the East coast, the notch was observed both in *Capo Figari* (RSL ID 430, ~~no.~~no. 6 in Figure 31~~Figure 31~~~~Figure 29~~) and in *Tavolara Island* (RSL ID 431, ~~no.~~no. 5 in Figure 31~~Figure 31~~~~Figure 29~~) 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 level lies above a subtidal facies which was dated with AAR (AAR ID 90) yielding an~~n~~ ~~age of 120 ka~~ MIS 5e age (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 (Belluomini and Delitala, 1988).

The western coast of Sardinia hosts a large number of ~~LIG~~ MIS 5 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, ~~no.~~nos. 11 and 12 on Figure 31~~Figure 31~~~~Figure 29~~, Antonioli et al., 2018), beach deposits (RSL ID 388, ~~no.~~no. 10 in Figure 31~~Figure 31~~~~Figure 29~~, Casini et al., 2020), and fossil bioconstructions~~incrustations~~ (RSL ID 234-238, ~~no.~~nos. 13-19 in Figure 31~~Figure 31~~~~Figure 29~~, 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 32~~Figure 30~~) 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 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, ~~no.~~nos. 20, 26, 23, 24 and 22 in Figure 31~~Figure 31~~~~Figure 29~~). 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).

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 *Island* (RSL IDs 433,436 and 437, ~~no.~~nos. 30, 28 and 27 in Figure 31~~Figure~~

1180 31Figure 29, 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).

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

1185 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, no.no. 33 in Figure 31Figure 31Figure 29). This elevation is in agreement with the paleo-shoreline reconstructed in the Cagliari area (RSL IDs 132, 276, 1338, no.nos. 37, 38 and 36 in Figure 31Figure 31Figure 29) whose MIS 5e age was constrained by U-sSeries and AAR dating (Hearty et al., 1986a; Ulzega and Hearty, 1986).

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Commentato [AR64]: COMMENT BY H. BRÜCKNER:
You should mention in more detail the Cala Mosca site near Cagliari described by Ulzega (your no. 36). Ulzega even mapped the shorelines in the environs of Cagliari.
The Cala Mosca site supported the idea of a double-peaked MIS 5e.

By the way, the other famous site was Bovetto in Calabria, described by Dumas et al. (no. 12 in your Fig. 20).

In both cases the double-peaked MIS 5e is evidenced from the stratigraphy (one transgression on top of another, both dating from 5e); the peaks cannot be differentiated by dating since all the dating methods overlap within the 2 sigma range.

Commentato [AR65R64]: We know that these sites have received a lot of attention in the past, but we would refrain from reporting the interpretations of former authors on the double peak.
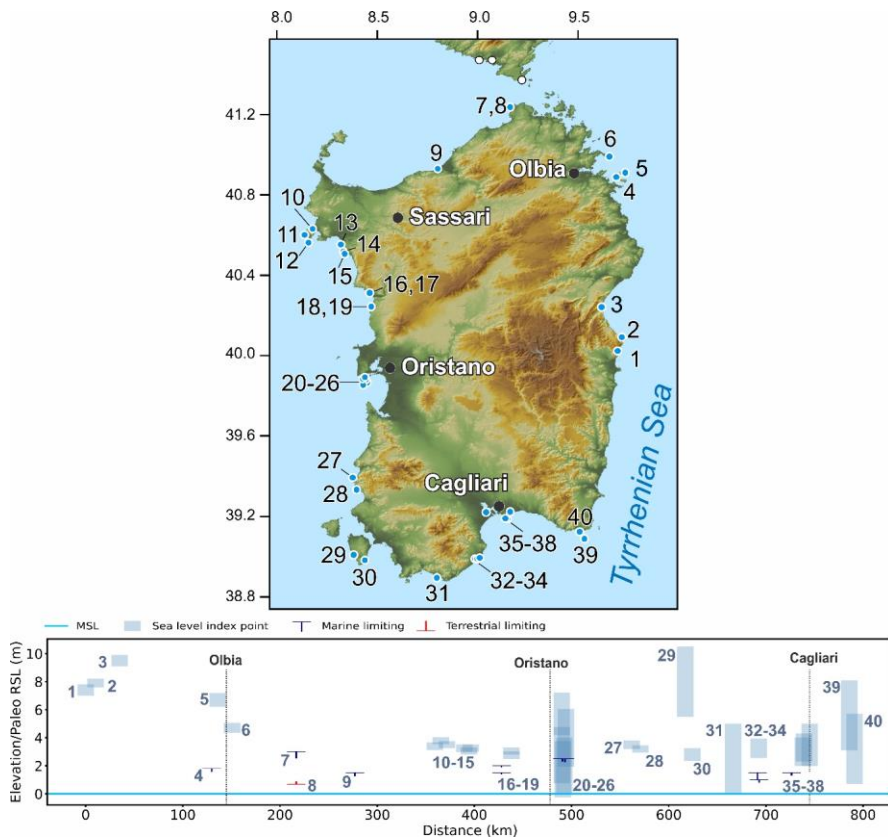
Figure 31: Last Interglacial sea-level data for : MIS 5 sea-level data for Sardegna (Italy). Upper panel: Map of sites. ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, NASA dataset). Lower panel: 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~~TLI* (RSL ID 289). 8: *Capo Testa, Santa Reparata ~~Marine limiting~~ MLI* (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 tró* (RSL ID 234). 14: *Punta Padre Bellu* (RSL ID 235). 15: *Baurantinu* (RSL ID 236). 16: *Bosa Sect.1* (RSL ID 241). 17: *Bosa Sect 2* (RSL ID 243). 18: *Bosa Sect 3* (RSL ID 244). 19: Porto Alabe (RSL ID 238). ~~19~~20: *San Giovanni del Sinis* (RSL ID 262). ~~19: Porto Alabe (RSL ID 238). 20~~21: *San Giovanni del Sinis*

(RSL ID 271). 2*21*: *San Giovanni del Sinis* (RSL ID 272). 2*32*: *San Giovanni del Sinis* (RSL ID 265). 2*43*: *Faro Capo San Marco* (RSL ID 266). 2*54*: *Capo San Marco* (RSL ID 261). 2*65*: *San Giovanni del Sinis* (RSL ID 263). 2627: *Buggerru* (RSL ID 437). 2728: *Masua* (RSL ID 436). 2829: *Sant'Antioco Cala Sapone* (RSL ID 296). 2930: *Sant'Antioco* (RSL ID 433). 3*10*: *Capo Malfatano* (RSL ID 295). 3*21*: *Nora* (RSL ID 1336). 3233: *Nora Is Fradis* (RSL ID 1337). 3334: *Nora-Is Fradis* (RSL ID 279). 3*54*: *Sa Illetta* (RSL ID 278). 3*65*: *Cagliari Marina Piccola* (RSL ID 1338). 3*76*: *Cagliari Cala Mosca* (RSL ID 132). 3*87*: *Is Arenas* (RSL ID 276). 3*98*: *Capo Carbonara Villasimius* (RSL ID 293). 3940: *Capo Carbonara Isola dei cavoli-Cala Ponente* (RSL ID 294).

Figure 32: Last Interglacial outcrop at San Giovanni del Sinis (RSL ID 262, no.no. 20 in Figure 31Figure 31Figure 29). In the photo, A. Rovere is pointing to the contact between subtidal (below) and intertidal (above) beds. Photo by E. Casella.

7.4.3 Sicilia

Antonioli et al., 2006 reviewed the elevation of RSL indicators of the Llast Iinterglacial 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 33) 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, nos. 16, 17 and 15 in Figure 33) by Malatesta (1957) and up to 12 m a.s.l. in Favignana (RSL ID 855, no. 3 in Figure 33) by Abate et al. (1992, 1996). Antonioli et al. (2002) measured the elevation of the tidal notches on Marettimo island at ~5-8 m a.s.l. (RSL ID 833 to 843, nos. 4 to 14 in Figure 33). 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, no 2 and 18 respectively in Figure 33). 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, no. 1 in Figure 33).

Northwest of Trapani, Mauz et al. (1997) surveyed Last Interglacial sea-level proxies in the Gulf of Castellammare and Capo San Vito (RSL IDs 822 and 823, no. 24 and 23, RSL IDs 826 to 829, no. 28 to 25, RSL ID 830, no. 21, RSL IDs 844 and 845, nos. 22 and 20 in Figure 33) 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, no. 23 in Figure 33) and a tidal notch up to 8 m a.s.l. (RSL ID 922, no. 24 in Figure 33), 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, nos. 32 and 31 in Figure 33) and nearby areas (Capo Gallo, RSL ID 897, no. 30 in Figure 33), 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 ~7 to ~10 m a.s.l. in the area of Cefalù (RSL ID 862, no. 34 in Figure 33) with AAR. This constraint allowed to correlate to MIS 5e a tidal notch in Cefalù promontory and *La Kalura* promontory (RSL ID 863, no. 35 in Figure 33) 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, no. 33 in Figure 33) it has been found at 7 m a.s.l. and constrained by AAR dating on *Arca* shells (Antonioli et al., 1994b).

1245
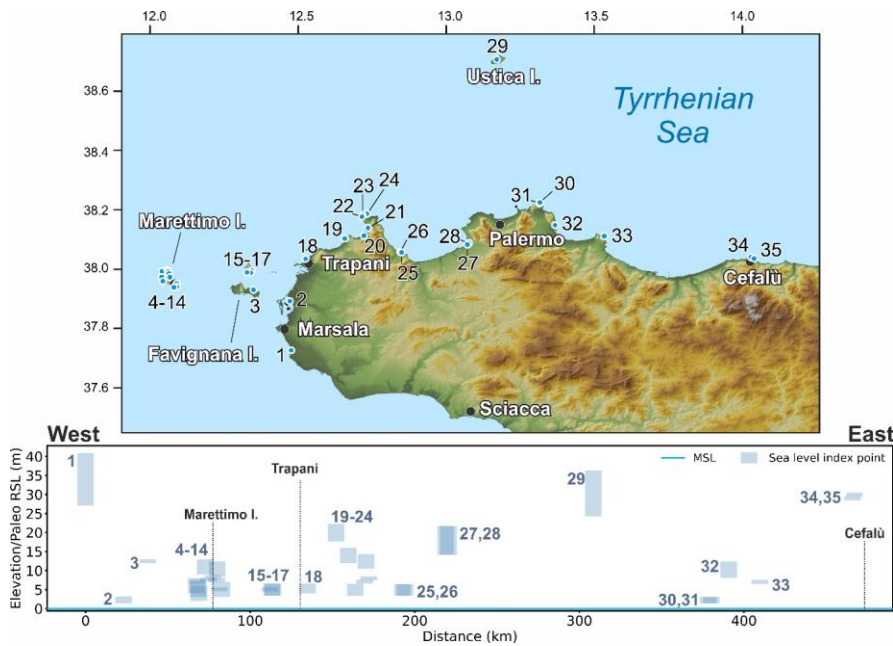
Figure 33~~: Last Interglacial sea-level data for~~ : MIS 5 sea-level data for Sicilia, sector 1 (Italy). Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, 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 between the towns of Pachino (to the South) and Monte Tauro (to the North). *P. latus* specimens embedded into a 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) mapped the marine terraces along the Syracuse coast by synchronous correlation method using as age constraints U-Series 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 ~30 up to ~70 m a.s.l. This estimate, which was based on ESR dating on mammal 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 MIS 5e terrace of Meschis et al. (2020) corresponds to the MIS 3c terrace of Bianca et al. (1999). 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 34), 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 of MIS 7 age (Gillot et al., 1994), which were successively incised by a marine terrace (Monaco et al., 2000). The 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, nos. 4 to 6 in Figure 34) and slowly decrease in elevation towards the south, reaching a maximum of 165 m a.s.l. in Catania (RSL IDs 849 to 851, nos. 1 to 3 in Figure 34).

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 *Venerupis* shells, provided by Antonioli et al. (2006) at 115 m a.s.l. (RSL ID 903, no. 8 in Figure 34), whereas Bonfiglio (1981) reports a tidal notch with serpulids in a cave at 130 m a.s.l. (RSL ID 3626, no. 7 in Figure 34).

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, no.no. 2 in Figure 34Figure 34Figure 32) by Antonioli et al. (2004) and at 125 m a.s.l. by Catalano and Guidi (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 (Milazzo Cape) area, at ~ca. 90 m a.s.l. (RSL ID 921, no.no. 10 in Figure 34Figure 34Figure 33). Worthy to note, in Capo Milazzo (Fairbridge, 1973) were located the stratotype site (Depéret, 1918) at ~c. 60 m a.s.l. for the Middle Pleistocene (old definition of Quaternary, Gibbard and Head, 2010), *Milazziano* time, according to the outdated terrace system of Fairbridge, (1973).

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, no.no. 17 in Figure 34Figure 34Figure 32). 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 5e.5 spans from 40 m a.s.l. in Filicudi (RSL ID 913 914, no.no. 16 in Figure 34Figure 34Figure 32 Lucchi et al., 2004a, b), 45 m a.s.l. on Lipari Island (RSL IDs 909 to 911, no.nos. 13 to 15 in Figure 34Figure 34Figure 32), and 115 m a.s.l. in Panarea Island (RSL IDs 917-918, no.nos. 11 and 12 in Figure 34Figure 34Figure 32 ,Radtke, 1986).

Figure 34: ~~Last Interglacial~~MIS 5 **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.~~**The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, 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).

7.5 Algeria

One of the earliest reports of Pleistocene deposits in Algeria (Figure 35) 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 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.

7.5.1 Tipasa

In the Tipasa province, Authemayou et al. (2016) identified six sites from which cross-sections were extracted and beach 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, no. 17 in Figure 35) and gives an age of 67 ka. Age ID n. 21 was taken from the profile *AT3* (Boun Haroun, RSL ID 6, no. 20 in Figure 35) and gives an age of 102 ka. Age ID n. 48 was taken from *AT5* (Ain Benian, RSL ID 9, no. 22 in Figure 35) 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, nos. 18 and 19 on Figure 35) and were published by Stearns and Thurber (1965). They report U-Series ages of 140 ± 10 ka (sample L-779a) and 125 ± 10 ka (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-Quaternary beach deposits*".

Maouche et al., 2011 suggested that the "Terrace 1" in the area of Tipasa is located at 175-185 m 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.

7.5.2 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, no. 16 and 15 respectively in Figure 35). 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.

7.6 Morocco

The Quaternary marine terraces cropping out along the Mediterranean Moroccan coasts (Figure 35) testify to the uplift of this region during the Quaternary (El Gharbaoui, 1977). However, they have not been studied deeply as their counterparts 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 constrained to the Last Interglacial (120±10 ka) by U-Series on mollusk shells by Stearns and Thurber (1965). One of the first attempts to date the marine terraces along the Mediterranean coast of Marocco was performed by Brückner (1986) by integration of U-series, AAR, TL, and ESR dating.

7.6.1 The Dhâda terrace

The *Dhâda* terrace (RSL ID 248-249, nos. 2 and 3 in Figure 35) has been identified between 13 and 15 m a.s.l. and was characterized 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 for the *Dhâda* terrace must be considered as a minimum age because of the high $^{234}U/^{238}U$ activity ratio of the dated corals. The Uranium ratio indicates that the coral samples have been rejuvenated. 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 uranium uptake. Such dating (USeries ID 546 to 549), allowed El Abdellaoui et al. (2016) to stratigraphically correlate the *Zhâra* (RSL ID 3598, no. 4 in Figure 35) and *Hejar-Lasfar* (RSL ID 3599, no. 1 in Figure 35) marine terraces, located respectively few kilometers eastward and westward of the *Dhâda* terrace, to the MIS 5e. The inner edge of the *Zhâra* and *Hejar-Lasfar* terraces is in the 13-14 m elevation range.

7.6.2 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, no 6 in Figure 35~~Figure 33~~). 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 U-series ~~been~~ dated ~~constrained by U-Series dating on~~ flowstones covering marine sediments~~-~~. The data from Abad et al. (2013) ~~data allow to constraining~~ provide a ~~a~~both a minimum elevation (marine limiting point (RSL ID 259, ~~no.~~no. 6 in Figure 35~~Figure 33~~)) for the ~~the~~ MIS 5e highstand at ~14 m a.s.l., and ~~to help~~ ~~correlate~~ to correlate a tidal notch (RSL ID 260, ~~no.~~no. 5 in Figure 35~~Figure 33~~) for the MIS 5e and ~~to~~ 5a respectively at ca. 14 m a.s.l. (RSL ID 259) and at ~10 m a.s.l. to MIS 5a~~, respectively~~(RSL ID 260). ~~In particular~~We remark that, ~~T~~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).

Southeasternward from Cape Leona, in Laskrine and Auchtame sites (RSL ID 4073 and 4074, no~~s~~. 7 and 8 in Figure 35~~Figure 35~~~~Figure 34~~), the MIS 5e has been constrained by Brückner (1986) based on the integration of U-series an~~d~~ TL dating between 4 and 6 m a.s.l.

7.6.3 Al-Hoceima

The Al-Hoceima region is situated at the eastern edge of the Mediterranean ~~Morocco~~Moroccan coasts. At ~~the~~ *Al-Hoceima site* (RSL ID 929~~,~~ ~~no.~~no. 9 in Figure 35~~Figure 33~~), 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~~,~~ ~~no.~~no. 10 in Figure 35~~Figure 33~~). Such correlation is based on U-~~s~~Series dating on corals (USeries ID 2952 and 2953) and *P. Latus* (U-~~S~~series IDs 2954 and 2955) from the MIS 7 marine terrace. However, it is worth noting that the samples of Poujol et al. (2014) are affected by chemical weathering.

Few kilometres eastwards from Al-Hoceima site, Brückner (1986) reports the presence of *P. latus* and Senegalese fauna up to 5 m a.s.l. at *Beni Said* (RSL ID 4075, no. 11 in Figure 35~~Figure 35~~~~Figure 34~~) and *Ifri Ifounassene* (RSL ID 4076, no. 12 in Figure 35~~Figure 35~~~~Figure 34~~) sites. The correlation of such terraces with MIS 5e is confirmed also by a~~n~~ ESR dating on a snail in *Ifri Ifonaussene (III)* (RSL ID 4078, no. 14 in Figure 35~~Figure 35~~~~Figure 34~~), while U- series dating on snail allowed

Brückner (1986) to correlate the marine terrace up to 3.75 m in *Ifri Ifounassene (II)* (RSL ID 4077, no. 13 in ~~Figure 35~~Figure 35Figure 34) to MIS 5a.

1410
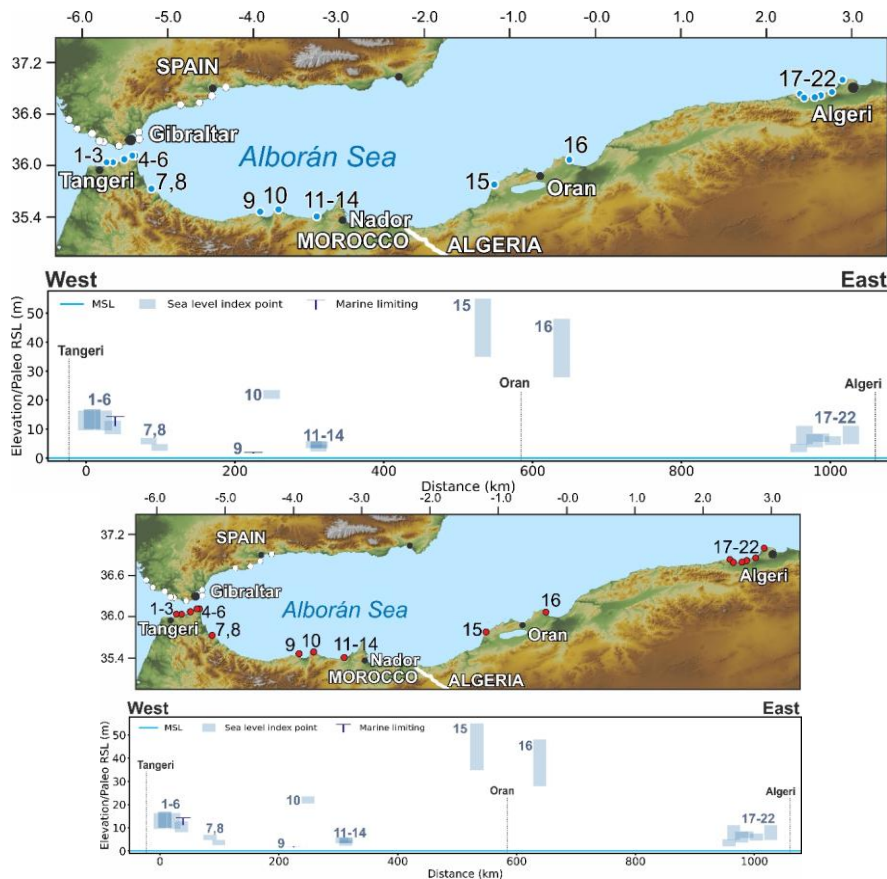
Figure 35: Last Interglacial sea level data for Algeria and Morocco. Upper panel: Map of sites. Red dots are sites in the region of interest, white dots are other sites within the Western Mediterranean compilation. ~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007), free NASA dataset.~~The topography has been obtained from the Shuttle Radar Topography Mission (SRTM) void-filled DEM (Farr et al., 2007, NASA dataset). **Lower panel:**

1415

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:** *Laskrine* **(RSL ID 4073). 8:** *Aouchtame* **(RSL ID 4074). 9:** *Al Hoceima* **(RSL ID 929). 10~~8~~:** *Rastarf Cape Al-Hoceima* **(RSL ID 3622). 11:** *Beni Said* **(RSL ID 4075). 12:** *Ifri Ifounassene* **(RSL ID 4076). 13:** *Ifri Ifounassene (II)* **(RSL ID 4077). 14** *Ifri Ifounassene (III)* **(RSL ID 4078). 9~~15~~:** *Cap Figalo* **(RSL ID 12). 16~~0~~:** *Arzew* **(RSL ID 11). 11~~7~~:** *Chenoua Transect AT1* **(RSL ID 4). 12~~8~~:** *Tipasa Transect AT2* **(RSL ID 5). 13~~9~~:** *Tipasa Transect AT2'* **(RSL ID 7). 20~~14~~:** *Bou Haroun Transect AT3* **(RSL ID 6). 21~~5~~:** *Mazafran Transect AT4* **(RSL ID 8). 22~~16~~:** *Ain Benian Transect AT5* **(RSL ID 9).**

8 ~~Final~~ Concluding remarks

Our database and the regional descriptions associated with it show that 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 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. In uplifting and subsiding coastal tracts, the RSL information we compiled might support the definition of long-term vertical motion rates, albeit we remark that these should be calculated accounting for two main potential issues. One is the underlying assumption that any land motion rate calculated from Last Interglacial RSL proxies is necessarily assumed to be continuous, which might not be the case in areas affected by high seismicity (e.g. along the southern coasts of Italy) or subsidence (e.g., the Po coastal plain). The second is that, to calculate land motion rates from Last Interglacial sea-level proxies, large uncertainties are stemming from both Last Interglacial global mean sea level estimates and glacial isostatic adjustment processes, which have to be accounted for before calculating long-term rates.

Areas that are traditionally considered tectonically stable, such as the islands of Sardinia (Italy), Corsica (France), and Mallorca (Spain) might provide benchmarks to evaluate glacial isostatic adjustment models and Last Interglacial global mean sea level scenarios for the Western Mediterranean region. Overall, MIS 5e proxies at these sites seem to indicate paleo RSL included between 3 and 9 meters above present-day.

~~Even if it was not the main aim of this work, the compilation of the database allows to better define the areas affected by recent vertical movements. In particular, as evidenced in Figure 1a, the mainland Italy present a very different tectonic behaviour between the NE part, which is affected by strong subsidence, and the Southern Italy, which, on the contrary, shows uplift up to some mm/yr. The central western Mediterranean may be considered tectonically stable, while mild uplift is recorded in southern Spain, Algeria, Mediterranean Morocco and central Italy.~~

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. Based on different dating techniques and a volcanic ash layer, Brückner (1980) assigned the staircased marine terraces bordering the Gulf of Taranto to the interglacials MIS 1 to MIS 19. Recent studies on cave deposits in Mallorca allowed placing important benchmarks on Early Pleistocene and Pliocene highstands (Dumitru et al., 2021a; 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 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 many Western Mediterranean MIS 5 sites are often characterized by geological units with narrow indicative ranges (which is also reflected by the relatively high number of sites that were assigned above-average RSL quality scores during the compilation, 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 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 key requirement for future studies is the re-assessment of modern analog landforms and deposits near the Last Interglacial ones. In our compilation, we used in large part the *ex-situ* values extracted from the IMCalc software (Lorscheid and Rovere, 2019), but these cannot be considered as accurate as *in-situ* modern analogs.

Another issue that is common within Western Mediterranean MIS 5 proxies is the paucity of reliable ~~absolute~~ radiometric 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 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~~ aim~~ed~~ 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 the age of several ~~interesting~~ potentially relevant Last Interglacial outcrops ~~were~~ was 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. For which concerns the issue of differentiating between different sea-level peaks within MIS 5e, the scarcity of well-preserved corals and the high uncertainties associated with other dating methods make such an endeavor a very challenging one for the Western Mediterranean, leaving the differentiation of ages to the geological interpretation of co-occurring units within the same outcrop.

9 Data availability

The Western Mediterranean –sea–level database is available open access and kept updated as necessary at this link: http://doi.org/10.5281/zenodo.5102943 (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. A summary of all sea-level data points included in the database is annexed to this paper. 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 data entries and the text for southern Italy and the southern portion of the Western Mediterranean (Algeria and Morocco). M. Vacchi curated data entries and text curated the text for France, Corsica, and Sardinia. A. Fontana curated curated data entries and text the text for the Adriatic Sea. A. Rovere curated curated data entries and textthe text and data for Spain and Tyrrhenian Northern Italy.

Acknowledgments

The data used in this study were compiled in WALIS, a sea-level database interface developed by the ERC Starting Grant "WARMCOASTS" (ERC-StG-802414), in collaboration with PALSEA (PAGES / INQUA) working group. The database structure was designed by A. Rovere, D. Ryan, T. Lorscheid, A. Dutton, P. Chutcharavan, D. Brill, N. Jankowski, D. Mueller, M. Bartz, E. Gowan, and K. Cohen. The data points used in this study were contributed to WALIS by Ciro Cerrone, Matteo Vacchi, Alessandro Fontana, and Alessio Rovere. The authors acknowledge the National Aeronautics and Space Administration (NASA) for the free use of SRTM data.

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