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Markers of the last interglacial sea-level high stand along the coast of Italy: Tectonic implications

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Abstract

A compilation of the Marine Isotope Substage (MIS) 5.5 high stand (~125 Ka) sites spanning the coastline of Italy allows a picture of the vertical displacement pattern affecting the Central Mediterranean coasts since the Late Pleistocene to be drawn. For each of the 246 listed sites, the accurate elevation of the high stand is defined through well-known markers. Coupled with a refined age assessment locally supported by new radiometric dating, these markers provide robust constraints on deformation. Significant alongshore differences in site elevation between +175 and −125 m a.s.l. resulted from the interplay of regional and local tectonic processes, including faulting and volcanic deformation. Whereas most of Sardinia's coasts and the northern Tyrrhenian Sea coasts are tectonically stable, the central Tyrrhenian Sea coasts display stable promontories, subsiding plains, and localized centres of weak uplift. Subsidence of the plains is related to extensional faulting locally enhanced by volcano-tectonic collapse, and weak uplift arising from magmatic processes. Rapid uplift of southern Calabria, northeast Sicily and the Jonian sea coasts probably reflects the extent of deep crustal delamination. The central Adriatic Sea shows weak thrust-related uplift, but foreland flexure in northern Adriatic and possibly southwestern Sicily results in locally intense regional subsidence. The rapidly uplifting regions are well correlated with the sectors of higher seismic release and surface horizontal motion documented by geodetic velocities. In this light, the MIS 5.5 marker indicates with a relatively high spatial resolution the vertical component of tectonic displacement and provides insight into the long-term tectonic processes of the Central Mediterranean orogen.

1. Introduction

The Marine Isotope Substage (MIS) 5.5 coincides with the last interglacial, and its geochronology is based on orbital tuning of high-resolution deep-sea oxygen isotope stratigraphy. According to this stratigraphy the

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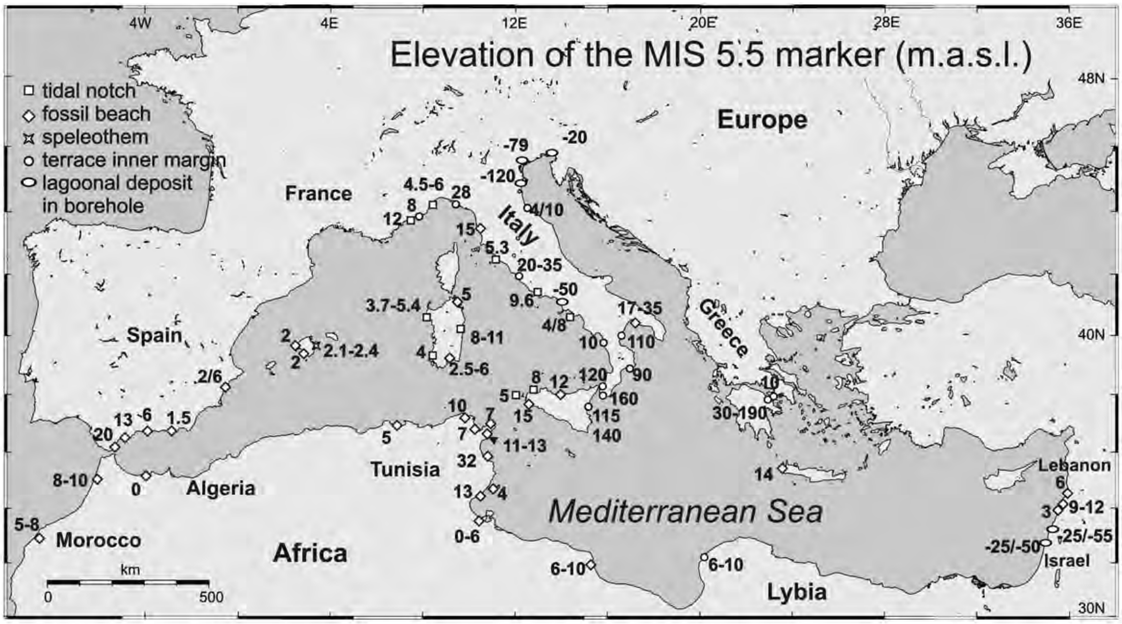


Fig. 1. Generalized elevation distribution of the MIS 5.5 marker in the Mediterranean Sea. Only representative sites and site elevation (metres a.s.l.) are shown. Slightly modified after Lambeck et al. (2004a).

geochronological subunit MIS 5.5 occurred between Termination II (end of MIS 6) and the onset of MIS 5.4, spanning between 132 and 116 ka (Shackleton et al., 2003).

During this last interglacial period the global sea-level rose higher than the modern one (Shackleton, 2000; Waelbroeck et al., 2002; Siddall et al., 2003). Sea-level curves, however, vary according to the location as a result of glacio-isostasy related to ice-sheet loading cycles, which can result in several metres height difference (Lambeck and Chappell, 2001; Potter and Lambeck, 2004). At the Mediterranean coasts, the average level attained by the sea during the MIS 5.5 is inferred to be $\sim 6 \pm 3$ m (Lambeck et al., 2004a).

In the Mediterranean, a large number of sites show markers of interglacial sea-level high stands. Attributing these markers to particular interglacial periods offers valuable information on the vertical displacement and displacement rate, which occurred along the coastlines of the tectonically mobile plate interface between Europe and Africa. Markers attributed to the last interglacial are represented by notches, marine terraces, beach deposits, speleothem concretions and boreholes of molluscs living in the spray zone of rocky cliffs (Fig. 1). In terms of timing, they have been identified with variable degree of accuracy.

In the western and central Mediterranean area, in Spain (Hearty, 1986; Zazo et al., 1999; Vesica et al., 2000; Rodriguez-Vidal et al., 2004), Morocco (Gigout, 1960) and Algeria (Stearns and Thurber, 1967; Hearty, 1986), and further east in Tunisia (Paskoff and Sanlaville, 1983; Hearty, 1986; Jedoui et al., 2003; Bouaziz et al., 2003) and Libya (Hey, 1956), the high stand is represented by marine terraces and raised beaches, which, apart from the Gibraltar area, commonly lay close to the predicted eustatic elevation (Fig. 1). Less is known about the French coast, where limited unpublished evidence suggests tectonic stability (Dumas, pers. comm.). In contrast, in the eastern Mediterranean the high stand markers are tectonically displaced, but the database is small as distribution and elevation of the high stand markers are known from a few sites only (Fig. 1; e.g. Greece: Keraudren and Sorel, 1987; Armijio et al., 1996; Pirazzoli et al., 1996; Westaway, 2002; De Martini et al., 2004; Crete: Hearty, 1986; Lebanon: Fleish, 1956; Stearns and Thurber, 1965; Fleish et al., 1981; Israel: Sivan et al., 1999; Porat et al., 2003; Sivan et al., 2004).

In the central Mediterranean area, at the coasts of the Italian peninsula and its islands the recognized altitude variability of the markers was attributed to tectonic processes, which resulted in differential displacements relative to the predicted eustatic sea-level (Cosentino and Gliozzi, 1988; Westaway, 1993; Bordoni and Valensise, 1998). These pioneering studies on tectonic displacements have dealt with part of the Italian coastline only, namely with central-southern Italy, where displacement rates are higher. In addition, uncertainties provided in the mentioned papers are poorly constrained.

The central Mediterranean area is characterized by belts of active tectonic deformation, which surround the northern, western and eastern margins of the Adriatic block. Based on seismicity and Global Positioning System (GPS) velocities, the southern part of Italy appears to be affected by seismic deformation and displacements at higher rates than its northern counterpart (Oldow et al., 2002; Oldow and Ferranti, 2005). The southern part of peninsular Italy is located above a lithospheric slab, which is considered responsible for the long-term and the recent uplift of the coastline (Cosentino and Gliozzi, 1988; Westaway, 1993). However, an interplay of regional and local tectonic processes is needed to explain the large variability in amplitude and wavelength of the elevation pattern in different parts of southern and central Italy (Bordoni and Valensise, 1998). Moreover, the record of active deformation in recent marine terraces of the northern Italy coasts is poor.

By reviewing and updating the MIS 5.5 markers, which can be used to broadly outline the vertical component of orogenic displacement, this study aims to verify the tectonic models regarding coastal deformation in Italy in the last ~130 ka and provide accurate vertical displacement rates. Benefiting from local expertise, we compiled the altitude distribution of the MIS 5.5 marker along the entire Italian coastline, based on published papers, to which the reader is referred for more details, and new work. Particular criticism was devoted to standardize the type of markers that were used for database compilation and to stipulate the uncertainty associated with altitude and age estimate of the markers. The database was used to generate the maps presented in this work, which outline a differential altitude distribution of the MIS 5.5 marker as a result of regional and local tectonic processes.

2. The MIS 5.5 substage in Italy

The "Tyrrhenian" of Issel (1914) was introduced by Gignoux (1913) as a chronostratigraphic subunit and later formalized as Eutyrrhenian by Bonifay and Mars (1959). The beach deposit exposed at Cala Mosca in Sardinia (Fig. 2) was proposed as stratotype of this Eutyrrhenian subunit (*Couches a Strombe* of Gignoux, 1913). The term "Tyrrhenian/Eutyrrhenian" is based on observations of exposed coastal features indicating the sea-level high stand during the last interglacial. The obvious coincidence between the Eutyrrhenian coastal sea-level high stand observations, occasionally supported by radiometric dating, and the MIS 5.5 sea-level data allowed to define that the MIS 5.5 substage covers the same time period of the Eutyrrhenian subunit.

During the MIS 5.5, a warm faunal assemblage known as "senegalaise fauna" (Gignoux, 1913), and mainly represented by mollusks (i.e. *Strombus bubonius, Conus testudinarius, Cardyta calyculata senegalensis, Hyotissa hyotis*) progressively colonized the Mediterranean shelves. The "senegalaise fauna" includes the index fossil *S. bubonius* LMK, which entered the Mediterranean Sea from Gibraltar and spread over the southern and western coasts of the Mediterranean, where hundreds of individuals were found in single outcrops (e.g. Ravagnese and Taranto in Italy; Dai Pra et al., 1974; Dai Pra, unpublished data, Fig. 3). On the northern Mediterranean coast only a few individuals of *S. bubonius* were found (Federici and Pappalardo, this volume).

Fig. 2. MIS 5.5 marine deposit at Cala Mosca, Sardinia (Site 1 in Fig. 4). The inset shows details of fossils incorporated in the deposit. See Fig. 4 for site location.

Uncertainty surrounds the biostratigraphic duration of *S. bubonius* in the Western Mediterranean (e.g. Hillaire-Marcel et al., 1996; Zazo et al., 1999), but in the central Mediterranean the fossil was only attributed to the MIS 5.5 highstand. In Italy, the occurrence of *S. bubonius* is restricted to the coasts of the Tyrrhenian and Jonian (= Ionian in English language publications) Sea to the east and southwest, whereas it was not found at the Adriatic Sea coast (Fig. 3). Thus, different palaeoceanographic conditions occurred between the Adriatic and the Tyrrhenian–Jonian Sea (e.g. Selli et al., 1979) involving either one or a combination of SST (Capotondi, 2004), deep cool water production and upwelling.

The lithologic setting of the coast controls the development and preservation of the MIS 5.5 markers. The Tyrrhenian, Sardinian and southern Adriatic coasts are mostly rocky promontories (Fig. 3), where erosional\chemical markers (notches, Table 1) were preserved. Loose or weakly cemented Neogene rocks form the central-northern Adriatic coastline and the coastal plains of the Tyrrhenian Sea, and, consequently, MIS 5.5 markers are poorly preserved.

The determination of the sea-level position during the Last Interglacial is not straightforward. Due to different effects of glacio and hydro-isostasy associated with water volume transfer between ice sheets and oceanic waters (Esat et al., 1999; Potter and Lambeck, 2004), the

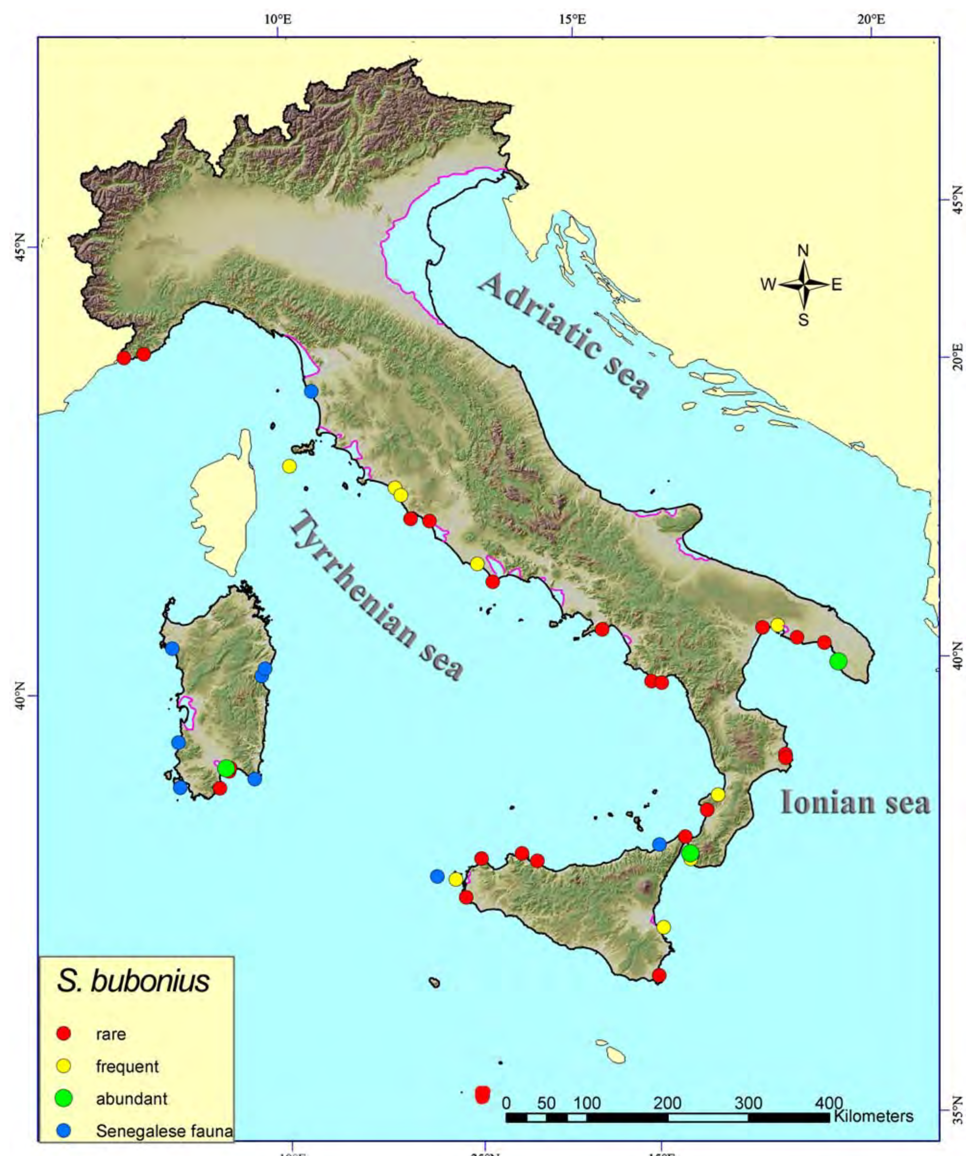


Fig. 3. Distribution of MIS 5.5 marine deposits bearing *S. bubonius LMK,* or Senegalaise fauna plotted on a Digital Elevation Model (DEM) of Italy. A qualitative estimation of the site abundance of *Strombus bubonius* specimens is indicated by the different dot fill. The black and pink lines indicate the present-day and the MIS 5.5 highstand shoreline, respectively.

Table 1
Type of markers of the MIS 5.5 highstand, including the estimated uncertainty in the related paleo-sea level location and the assigned quality factor

Depositional marker
1. Beach/lagoon deposits
Uncertainty: −2 m. Quality: 1
2. Backshore/foreshore deposits
Uncertainty: ±5 m. Quality: 2/3
Erosional
3. Inner margin of marine terrace
Outcropping: uncertainty: +3 m. Quality: 1
Concealed beneath continental deposits: uncertainty: −20 m. Quality: 3
4. Marine terrace
Uncertainty: +20 m. Quality: 3
5. Tidal notch
Uncertainty: ±0.1 m. Quality: 1
Biological marker
6. Top of lithophaga hole-band
Uncertainty: +2 m. Quality: 1
7. Dendropoma reef
Uncertainty: ±0.2 m. Quality: 1

MIS 5.5 sea-level high stand was at different positions in different parts of the world. Thus, the eustatic datum for individual regions must be defined using independent observational data. In the central Mediterranean the marker shoreline in southern Sardinia (Fig. 4) is commonly used to define the shoreline position during the sea-level high stand. This shoreline is situated at a coast which is considered to be tectonically stable since the Early Miocene (Patacca et al., 1990; Gueguen et al., 1998), and unaffected by crustal loading and unloading during a glacial–interglacial cycle (Lambeck et al., 2004b). The mean altitude of the MIS 5.5 marker at the Sardinian sites is 6±3 m and is here adopted as the average eustatic reference datum for Italy.

3. Quaternary tectonics of Italy

The deviation of the MIS 5.5 marker elevation from the expected eustatic elevation is used to elucidate the pattern of vertical motion experienced by Italian coasts.

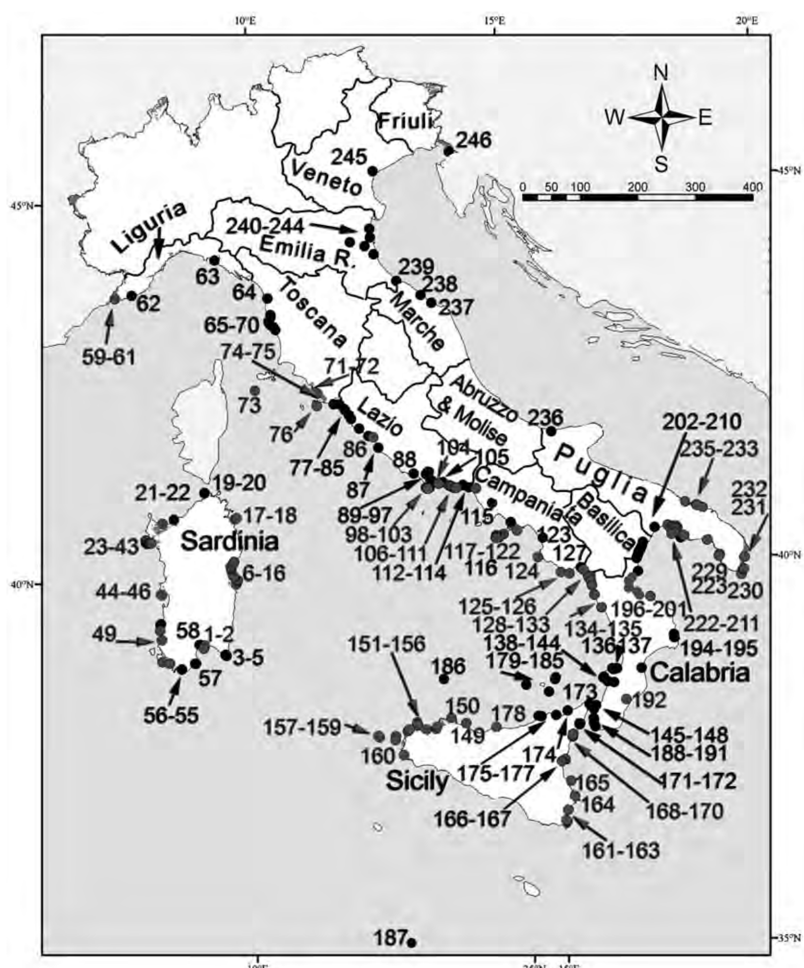


Fig. 4. Distribution of the MIS 5.5 exposures in Italy; numbers refers to site numbers listed in Additional table. Outlines and names of Italy administrative regions are shown.

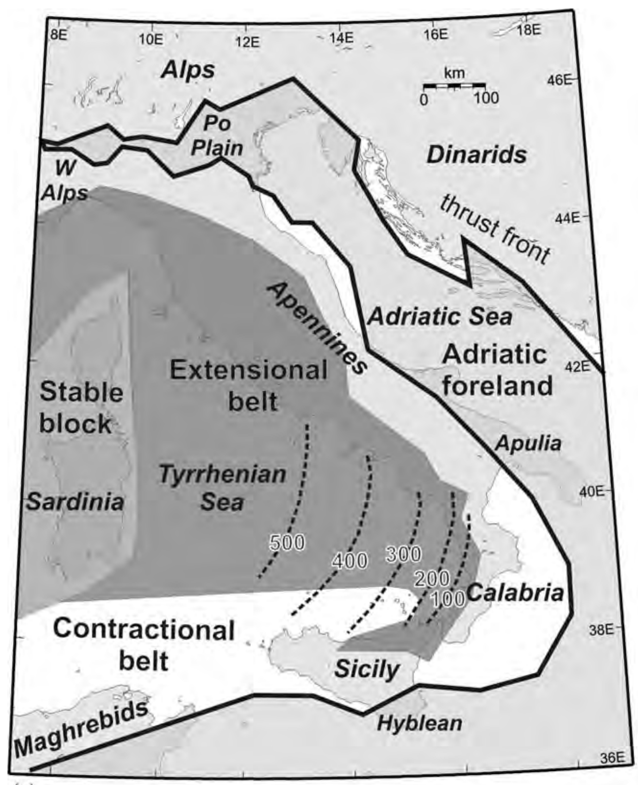
Many of the existing MIS 5.5 markers in Italy are marine terraces and notches, and are found in areas of uplift. On the other hand, where subsidence prevails, markers are buried under more recent deposits and thus exposures are not available.

Since vertical and horizontal tectonic displacements are often contemporaneous, assessment of the vertical displacements must be framed in the regional orogenic setting. The Neogene tectonic evolution of Central-Southern Italy is characterized by paired belts of contraction and extension that advanced towards the Adriatic foreland in mainland Italy, and the Hyblean foreland in Sicily (Fig. 5a; Patacca et al., 1990; Gueguen et al., 1998). The growth of the Apennines thrust belt to the east and of the Tyrrhenian back-arc basin to the west has been controlled by westward subduction and eastward roll-back and delamination of the Adriatic–Jonian slab (Malinverno and Ryan, 1986; Royden et al., 1987; Channell and Mareschal, 1989; Doglioni, 1991). Today, seismic tomography and deep earthquakes beneath the southeastern Tyrrhenian Sea identify the subducted Jonian slab (Fig. 5a; Cimini and Amato, 1993; Selvaggi and Chiarabba, 1995).

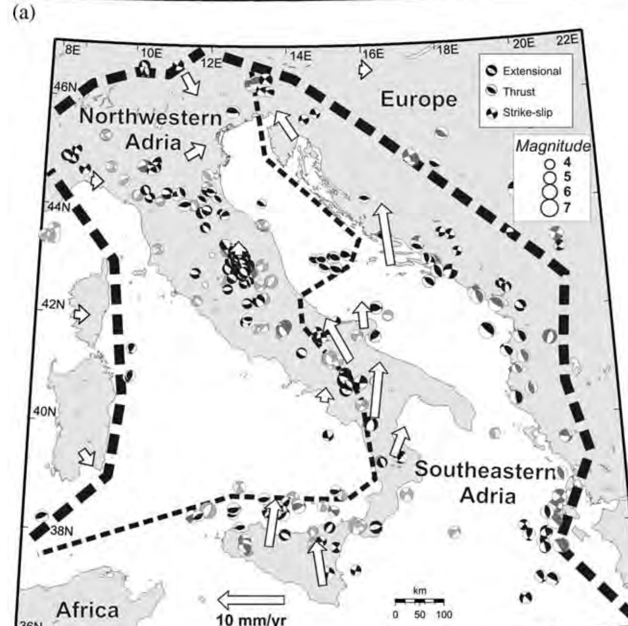
During Pliocene–Quaternary, contractional structures of the western part of the Apennines, Calabria and eastern Sicily were superimposed by extensional faults causing displacements normal to the orogen (Fig. 5a). Most areas of the Tyrrhenian coast experienced extension in a back-arc setting, which was accompanied by volcanism on the young continental margin and in the basin (Beccaluva et al., 1989). The displacement along the faults articulated the Tyrrhenian coast of Italy in a complex alternation of subsiding basins and uplifting rocky promontories (Mariani and Prato, 1992; Cinque et al., 1993; Tortorici et al., 1995). The transition between the thrust belt to the east and the extensional belt to the west runs across the mountain belt and roughly outlines the front of crustal delamination (Ferranti and Oldow, 2005a, b; Oldow and Ferranti, 2005).

In contrast, the Adriatic, Jonian and southern Sicilian coasts overlie the frontal part of the Apennines orogen and foreland including the active frontal part of the Dinaric and Southern Alps system in the northern Adriatic (Fig. 5a). The transition between the Apennines and Western Alps occurs in the Ligurian Sea (Fig. 5a).

The islands of Sardinia and Corsica are a detached fragment of the Alpine foreland and orogenic belt (Patacca et al., 1990). The western and eastern side of Sardinia and Corsica have been effected by intense extensional tectonics related to the Oligocene–Miocene



(a)



(b)

Fig. 5. Tectonic setting of Italy. (a) Major tectonic domains: Adriatic foreland, contractional and extensional belts, and stable block, indicated by light grey, white, dark grey and medium grey, respectively. Dashed lines in southern Tyrrhenian sea indicates the depth (in km) of the Benioff zone (Giardini and Velonà, 1988). (b) Active deformation including: focal solutions of $M>4$ earthquakes (black: 1976–2004 Harvard and 1997–2004 Mednet CMT catalogues, available at http://www.seismology.harvard.edu/CMTsearch.html, and http://mednet.ingrm.it/, respectively; light grey: Gasparini et al., 1985; medium grey: Anderson and Jackson, 1987); generalized GPS site velocity (arrows) with respect to stable Europe; and boundaries of tectonic domains in the central Mediterranean (thin and thick dashed line indicate intra-Adria and Africa–Europe–Adria boundaries) defined by GPS velocities and regional seismicity (Oldow et al., 2002).

Ligurian–Balearic and Miocene–Pliocene Tyrrhenian sea rifting, respectively (Cherchi and Montandert, 1982; Burrus, 1984; Rossi et al., 1996; Assorgia et al., 1997). Today, both islands appear tectonically stable (Fig. 5a; Boschi et al., 1997).

The present-day pattern of regional deformation is recognized through crustal seismicity and GPS velocity fields (Fig. 5b). The earthquake focal mechanisms record northeast–southwest extension along the axis of the Apennine chain and northeast–southwest to north–south contraction and transpression in several segments of the Adriatic foreland of the Apennines, southern Alps and Dinarids (Gasparini et al., 1985; Montone et al., 1997). GPS velocities together with regional seismicity (Fig. 5b) indicate that the southern part of Italy experiences larger horizontal velocities than its northern counterpart as both parts converge towards stable Europe (Oldow et al., 2002; Oldow and Ferranti, 2005).

4. Data compilation

4.1. Sea-level indicators

Based on field observations, a list of the MIS 5.5 highstand markers (Table 1 and Fig. 6) was established. The list includes seven types of markers grouped in three classes (Table 1). Two classes are composed of *depositional* and *erosional/chemical* indicators of the eustatic sea-level. In addition, we introduce a third class of *biological* indicators, which are destructive or constructional organisms living at sea-level. According to its nature, each marker was assessed its specific uncertainty regarding sea-level positioning. We consider markers with definable (and preferentially small) uncertainty as reliable.

4.1.1. Depositional indicators

4.1.1.1. Beach/lagoon transition deposit. Lagoonal deposits (silty and clayey sediments) frequently bear the bivalve *Cerastoderma glaucum* and the gastropods *Bittium* sp., *Rissoa* sp. and *Hydrobia* sp. This fauna assemblage is characterized as "Euryhaline and Eurythermal in brackish water (LEE)" (Peres and Picard, 1964). It indicates the mean sea-level with an uncertainty of 2 m.

4.1.1.2. Backshore/foreshore deposit. These deposits are typically composed of litho- and bioclasts forming ridges and wedges, but they may be related to a shoreline with variable uncertainty. In general, the uncertainty for both backshore and foreshore deposits may be 10 m if lateral facies transition or biofacies are not established. When facies analysis allows correlation of beach deposits with adjacent foreshore and backshore sediments, the palaeo-sea-level position might be identified with an uncertainty of 6 m.

4.1.2. Erosional/chemical indicators

4.1.2.1. Inner margin of marine terraces. The inner margin of a terrace indicates the position of the palaeo-shore line. In hard rock it appears as a step between the wave-cut platform and the former cliff. In soft rock, it is covered by colluvial deposits and can hardly be identified. An uncertainty of 3 m was attributed to well-exposed inner margins and 20 m to the masked ones, the latter being only evidenced by a knickpoint in the topographic profile.

4.1.2.2. Marine terrace. Terraces are today usually degraded and their inner margin is destroyed. The maximum height of the terrace was therefore taken as the indicator of palaeo-sea-level with an uncertainty of 20 m.

4.1.2.3. Tidal notch. The notch is a common intertidal feature at coasts with moderate tidal range. The maximum concavity is formed by the neap tide range and is, thus, a precise measure of the mean sea-level position with assigned uncertainty of 0.2 m.

4.1.3. Biological indicators

4.1.3.1. Top of lithophaga hole band. The pelecypod *Lithophaga lithophaga* colonizes the first 20 m below the sea-level of calcareous rocky coasts, but it is statistically very frequent in the first 2 m below mean sea-level. From the upper limit of the burrows a sub-horizontal line is defined, which is considered as a reliable marker of a past mean sea-level position (Stiros et al., 1992), provided that fossil specimens of *L. lithophaga* are found in some of the rock-bored holes. The assigned uncertainty on this marker is 2 m.

4.1.3.2. Dendropoma reef. One of the most valuable indicators of sea-level are in situ bioconstructions of some calcareous algae (*Lithophyllum lichenoides, Neogoniolithon notarisii*) living alone or in symbiosis with the gastropod vermetids *Dendropoma petraeum* (Antonioli et al., 1999a). The lower limit of the bioconstruction corresponds to the mean low tide level (Laborel and Laborel Deguen, 1994). The narrow zonation of these organisms yields an indication of sea-level with an uncertainty of 0.2 m. Unfortunately, Dendropoma markers, although frequent in present-day reefs, are rare as fossil reefs due to their fragile nature and are only known from sheltered caves of Sicily (Antonioli et al., this issue).

4.2. The uncertainty of sea-level constraints

The uncertainty of sea-level positioning is constrained by the precision with which the position of the indicator with respect to the palaeo-sea-level is determined and precision of the age of the indicator.

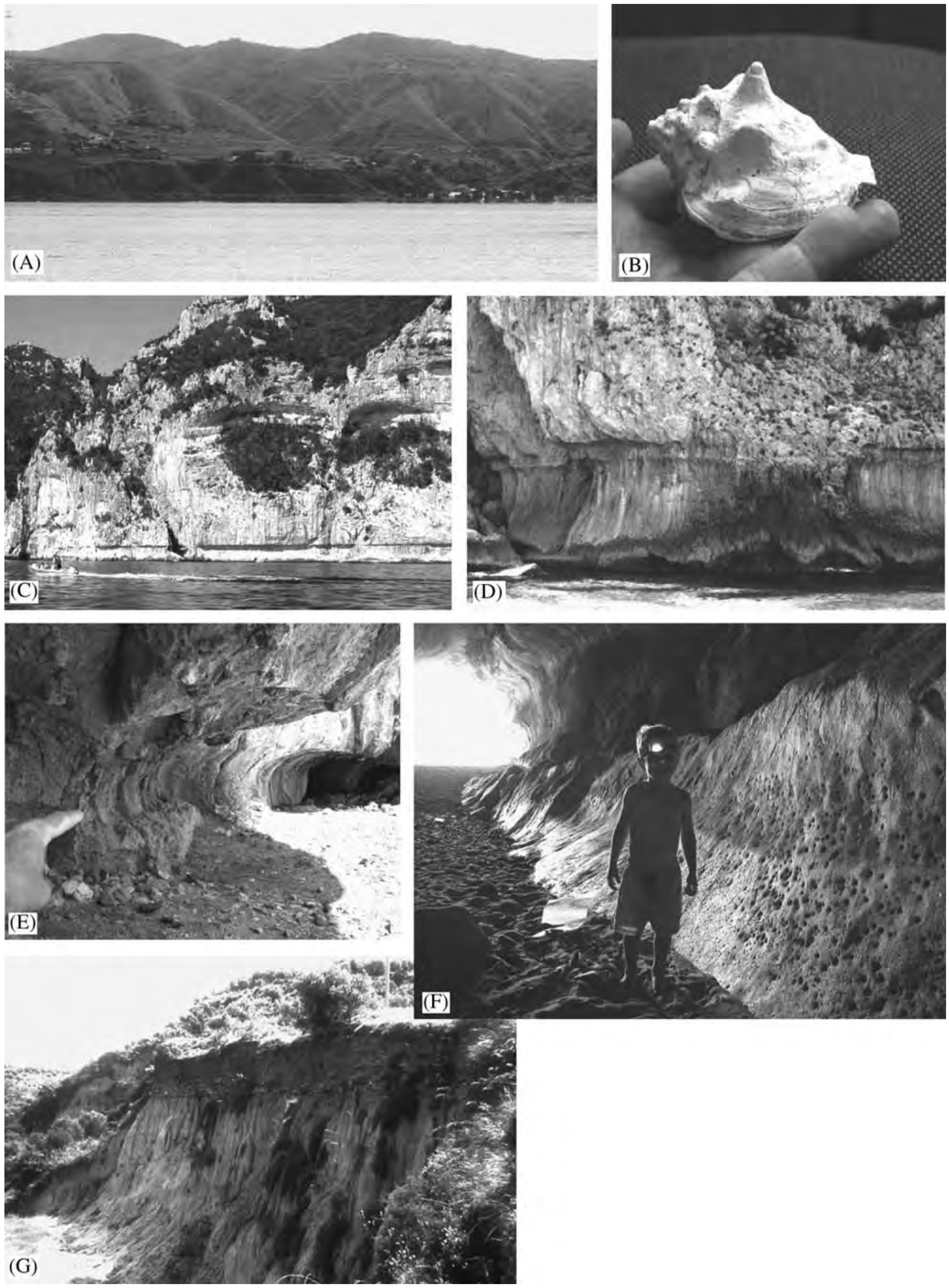


Fig. 6. Examples of some MIS 5.5 markers. Attribution of the markers to the MIS 5.5 is discussed in the text. (A) Marine terrace, whose inner margin is at 125 m a.s.l elevation at Scilla, Calabria (site 145, Fig. 4). (B) *S. bubonius* sampled at 140 m a.s.l. at Bovetto, Calabria (site 169, Fig. 4). (C) Tidal notch, Golfo di Orosei, Sardinia (site 12 Grotta del Bue Marino, Table 2). (D) Tidal notch at Capri, Campania (site 120, Fig. 4). (E) Into the tidal notch of Golfo di Orosei (site 15 Biddiriscottai, Fig. 4). (F) Lithophaga holes carved into the Cala Luna cave, Sardinia (site 11, Fig. 4). (G) Marine conglomerate on clay (site 138, Briatico, Fig. 4).

The precision of paleo-shoreline position depends on the type of markers (individual values are stipulated in Table 1) and by the precision of the measurement. At most sites we performed direct measurement of the shoreline height using a tape referenced to the mean sea-level, and in few cases geodetical stations were used. Due to the average tidal range of 0.5 m along Italy's coasts (the maximum tide of 1.1 m is found at Trieste in the northern Adriatic Sea), no tidal correction was employed.

Whereas positions can be established fairly precisely, ages determined by radiometric, ecostratigraphic and geomorphologic techniques suffer from lack of accuracy. The lack of datable material has resulted in very few radiometric age constraints. Ecostratigraphy relies on the index fossil *S. bubonius* and is less reliable when only barren "senegalaise fauna", which includes species still living today, occur. Many markers are "dated" using geomorphologic-stratigraphic criteria, and correlations with adjacent sites where age estimates are available.

Minor uncertainty sources are represented by corrections for crustal loading due to eustatic changes and ambiguity in marker identification due to tectonic displacement. Crustal loading during 120 m of eustatic sea-level variation is on the order of a few metres (e.g. Lambeck et al., 2004b) and in most cases, given the range of observed elevations up to over one hundred metres, contributes little to the total uncertainty. However, where the marker is close to the eustatic elevation, lack of compensation for crustal loading introduces a locally unknown error.

4.3. Database structure and uplift rate calculation

The complete dataset of the MIS 5.5 sea-level highstand in Italy is listed in an Additional Table provided on the web (.pdf file). Besides geographic coordinates and marker specification, the dataset includes the relevant faunal assemblage, the dating technique and available radiometric ages, and the derived uplift rate and its uncertainty.

Following Lambeck et al. (2004b), the uplift rate u and its variance σ_u^2 are given by

$$u = \frac{\Delta H}{T_{5.5}} \text{ and } \sigma_u{}^2 = \frac{\sigma_{\Delta H}{}^2}{T_{5.5}{}^2} + \left(\frac{\Delta H}{T_{5.5}{}^2}\right)^2 \sigma_{T_{5.5}}{}^2 \quad (1)$$

with eustatic and glacio-hydro-isostatic compensation given by

$$\Delta H = H_{5.5} - \boldsymbol{\delta} H_{5.5},$$

where $H_{5.5}$ is the height of the observed MIS 5.5 shoreline above mean sea-level and $\delta H_{5.5}$ is the height of this shoreline in areas of tectonic stability.

$T_{5.5}$ is the age of MIS 5.5 with the uncertainty $\sigma_{T_{5.5}}$ and $\sigma^2_{\Delta H}$ is the uncertainty of the tectonic uplift $(= \sigma^2_{H_{5.5}} + \sigma^2_{\boldsymbol{\delta} H_{5.5}})$. We adopt the following values: $T_{5.5} = 125$ ka, $\sigma_{T_{5.5}} = 5$ ka, $\delta H_{5.5} = 6$ m, $\sigma_{\boldsymbol{\delta} H_{5.5}} = 3$ m, the latter being the observational error of the Sardinia site. $\sigma_{\boldsymbol{\delta} H_{5.5}}$ is deduced from the estimated uncertainty of palaeo-sea-level, and mostly fall within 5 m (Table 1).

Radiometric ages are drawn from existing reports, and additional ESR data are provided in this paper for the Po Plain sites. Based on the combined uncertainties derived from paleo sea-level positioning, age and altitude measurement, a quality factor ranging from 1 to 3 is attributed to each marker. This datum is presented in an Additional Table, available through the Corresponding Author.

5. Occurrence of the MIS 5.5 markers in Italy

The spatial distribution of the MIS 5.5 markers in Italy is shown in Fig. 3. Figs. 7–12 shows the altitude of the most reliable indicators according to their quality (indicated in the Additional Table). Sites, which lack reliable chronological constraints (e.g. Sarno in Campania, Trieste in Friuli, Fortore in Puglia) and sites, for which full consensus about their attribution to MIS 5.5 (e.g. Lipari and Taormina in Sicily, Crotone, Villa San Giovanni and Capo Vaticano in Calabria) were not achieved amongst the authors are listed in the Additional Table, but not included in Figures and in the discussion.

The altitude of the most reliable markers varies from −125 to +175 m with respect to modern sea-level. Whereas the lowest altitudes are shown at the northern Adriatic coast and at the large coastal plain in northern Campania (Figs. 7 and 10), the highest altitudes are recorded at the coasts of southern Calabria and eastern Sicily, and at the Jonian coast of Basilicata (Figs. 11 and 12)

The significant differences in altitude of the indicators originate from different regional tectonic settings associated with segments of the orogenic belt. In the following, the elevation pattern of the MIS 5.5 marker in specific regions named in Fig. 4 is discussed in light of the local tectonic processes, through a journey winding counterclockwise along the shores of Italy. Where Holocene deposits are present, we compare MIS 5.5 markers with Holocene markers to validate the tectonic interpretation drawn from the MIS 5.5 markers.

5.1. Sardinia

From Sardinia an extensive number (58) of MIS 5.5 sites are reported, with marker distribution mainly controlled by lithology since most notches are found on limestone promontories (Fig. 7). Inner margins are poorly identifiable at low laying coasts owing to the thick continental cover, which was not eroded due to the tectonically stable conditions of the island.

Sardinia is the only region in the Tyrrhenian Sea where the marker elevation has a very low variability of ~10 m. The elevation of many sites lies between 5 and 6 m, and therefore it was chosen as our reference site for the MIS 5.5 eustatic elevation.

Within this generally stable setting, minor but consistent patterns of vertical motions at metre scale may be recognized in local areas owing to the accurate sea-level positioning and excellent lateral exposure of the tidal notch (Fig. 7). For instance, at Capo Caccia, located on the NW side of the island, the marker altitude decreases from east to west across different rock promontories from an eustatic elevation of 5.5 to 4 m and 3.5 m (Fig. 7, inset). The subsidence towards the

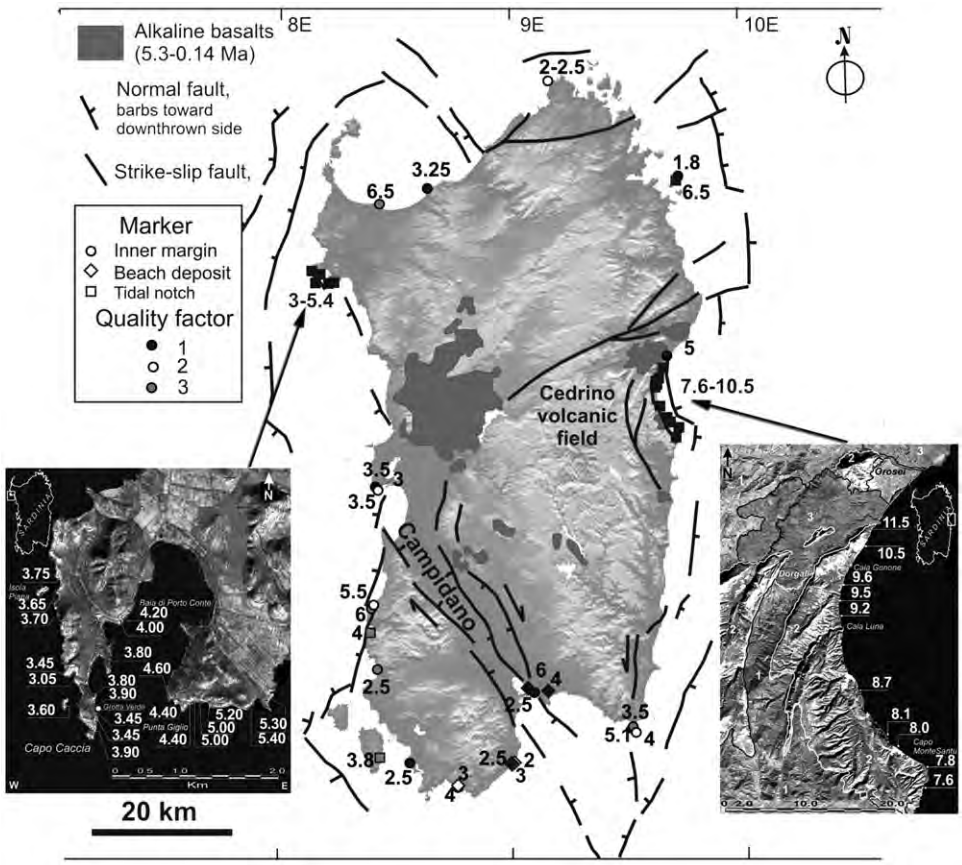


Fig. 7. Elevation of the MIS 5.5 markers, indicated by numbers in black in metres with respect to modern s.l., plotted on a DEM of Sardinia. Markers type and quality factor as listed in Additional Table are indicated. Grey patches indicate the latest Miocene–Quaternary volcanics. Main faults from the Structural Model of Italy CNR (Bigi et al., 1992). The two insets show details of the elevation pattern in the Capo Caccia promontory and Golfo di Orosei area.

west is indicative of minor block motion possibly accommodated by faults associated with the continental margin of the Western Mediterranean Sea.

In the central segment of the eastern coast, a remarkably well-developed tidal notch is exposed for over 70 km, and its elevation increases to the north from 7.6 to 10.5 m (Fig. 5 and inset in Fig. 7; Carobene and Pasini, 1982; Antonioli and Ferranti, 1992), whereas further to the north it appears at 5 m a.s.l. The small amplitude bulge outlined by the marker elevation changes might be associated with the residual activity in the nearby Pliocene–Quaternary Cedrino volcanic field (Fig. 7), whose activity reportedly ended at 140 ka, before MIS 5.5 (Bigi et al., 1992).

5.2. Liguria

Sites showing good evidence of a MIS 5.5 highstand are very few along the Ligurian coast (see Federici and Pappalardo, this volume). In Eastern Liguria a beach deposit, whose terrace displays an inner margin at 28 m a.s.l (Fig. 8), was attributed to the MIS 5.5 based on OSL dating. Other scattered outcrops in eastern Liguria place the MIS 5.5 shoreline at 20 m, but at places, the same marker might appear at sea-level (Fig. 8). In Western Liguria, an notch and an associated deposit containing a faunal assemblage with *S. bubonius* present inside two caves (sites 59–60) indicates sea-level at 12 m. Slightly eastward, the same faunal assemblage was found at sites 61–62, but here the notch is not preserved.

Taken at face value, a different vertical behaviour between eastern and western Liguria is apparent, with the marker being slightly uplifted in the western area and remaining at eustatic value in the eastern one (Fig. 8).

5.3. Tuscany–Lazio

The northern part of Tuscany is characterized by the wide Versilia coastal plain, which is bordered by normal faults, whose recent activity was noted through geophysical exploration (Cantini et al., 2001; Carminati et al., 1999). Documentation of a moderate subsidence of the plain comes from the ENEA core (Nisi et al., 2003). Samples of *C. caespitosa* collected within a *Cerastoderma* lagoonal layer at −71 and −68 b.s.l. yielded mean ages

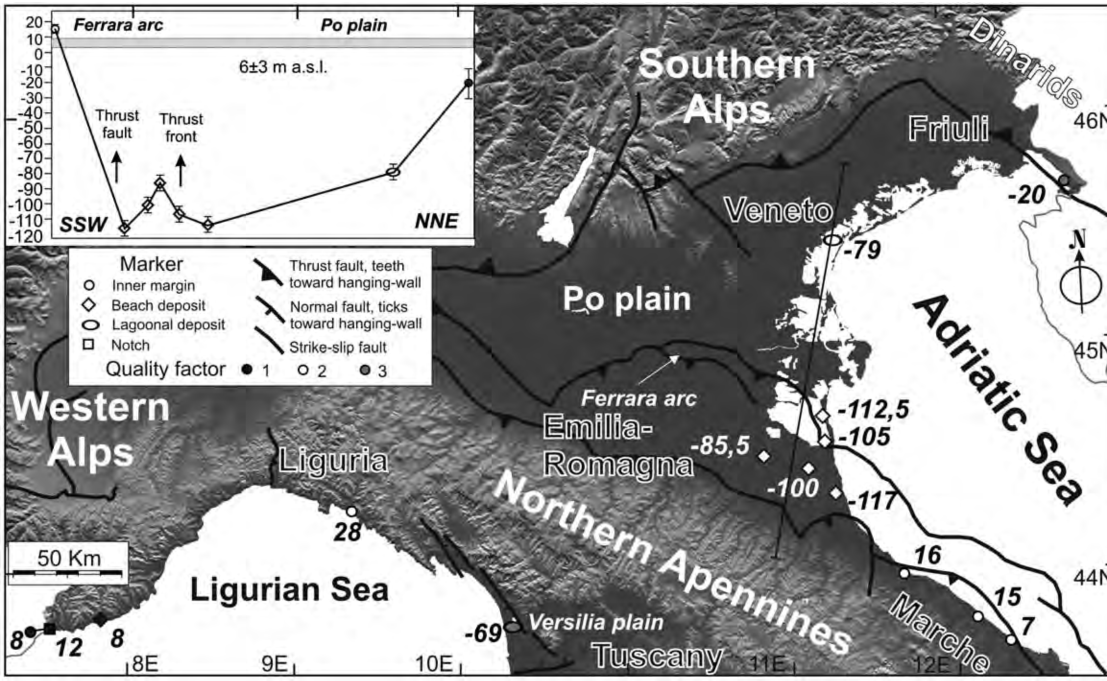


Fig. 8. Elevation of the MIS 5.5 markers, indicated by numbers in black in metres with respect to modern s.l., plotted on a DEM of Northern Italy. Markers type and quality factor as listed in Additional Table are indicated. Main faults from the Structural Model of Italy CNR (Bigi et al., 1992). Inset shows section of marker elevation across the front and foredeep of the Northern Apennines (trace indicated by thin solid line).

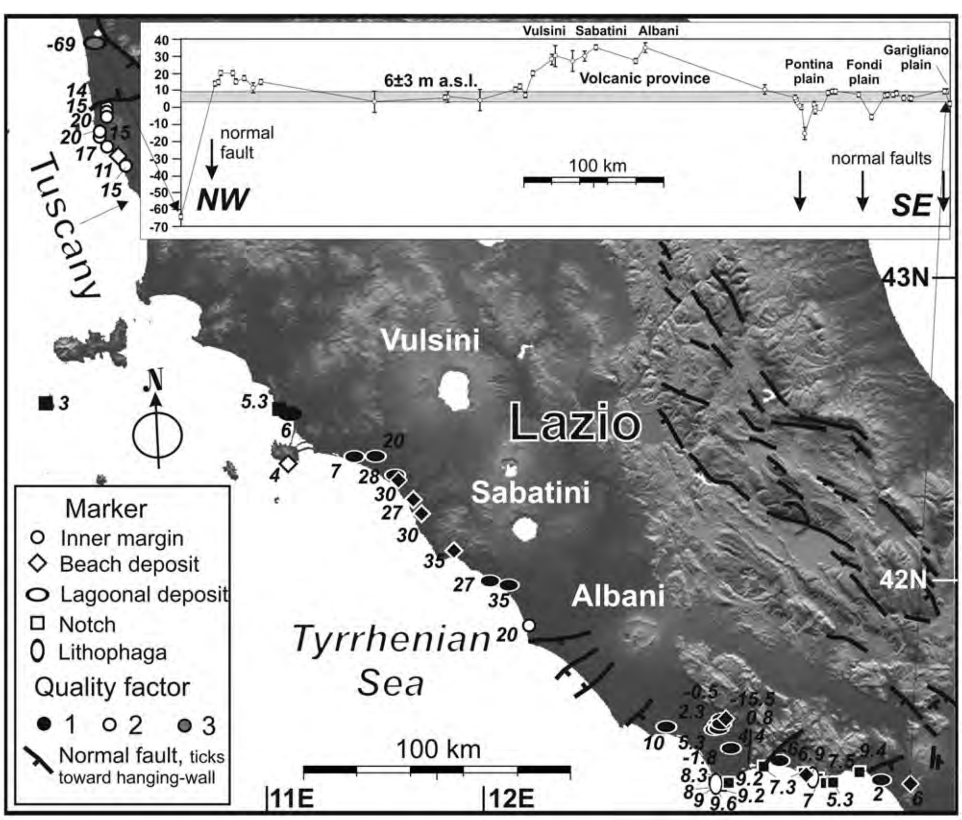


Fig. 9. Elevation of the MIS 5.5 markers, indicated by numbers in black in metres with respect to modern s.l., plotted on a DEM of southern Tuscany–Lazio. Markers type and quality factor as listed in Additional Table are indicated. Main faults modified from the Structural Model of Italy CNR (Bigi et al., 1992) and Mariani and Prato (1992). Inset shows coast-parallel section of marker elevation (partly redrawn from Nisi et al., 2003).

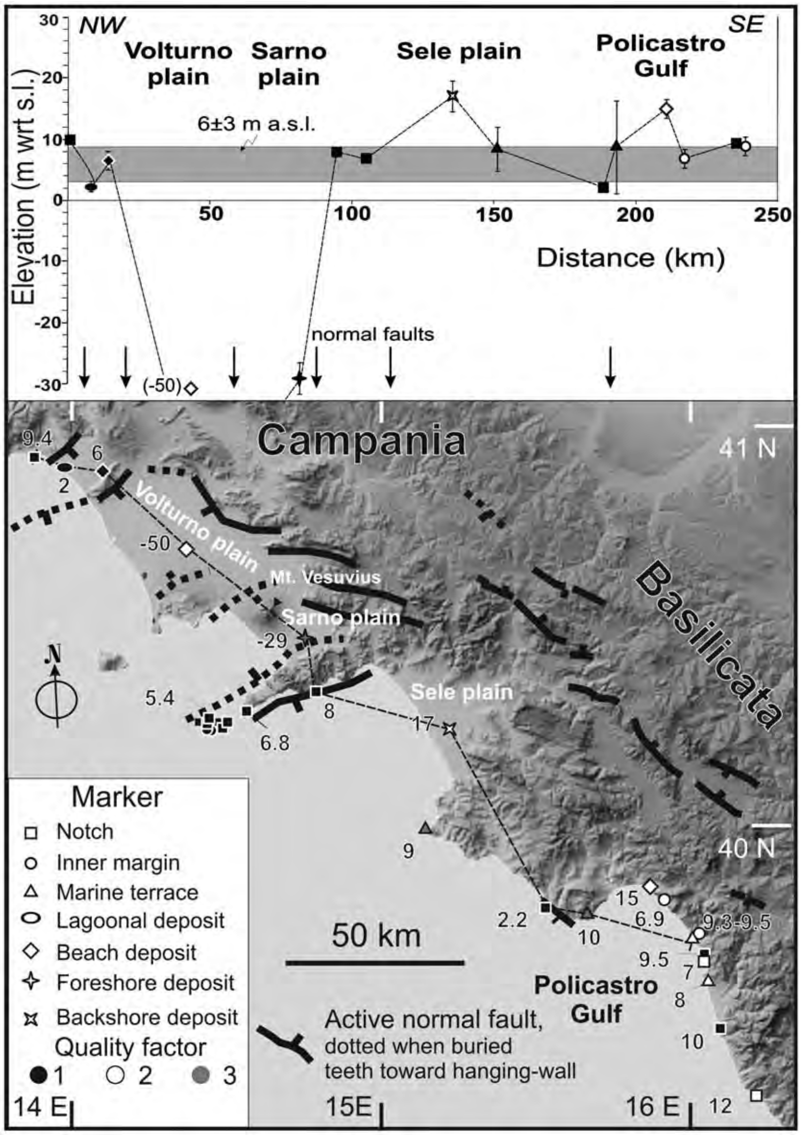


Fig. 10. Elevation of the MIS 5.5 markers, indicated by numbers in black in metres with respect to modern s.l., plotted on a DEM of Campania and Tyrrhenian Basilicata. Markers type and quality factor as listed in Additional Table are indicated. Active faults from unpublished data. Inset shows coast-parallel section of marker elevation (trace indicated by dashed line).

of 133 ± 15 and 129.5 ± 15 ka, respectively. Given the large uncertainty of the age, the amount of subsidence cannot be accurately determined, and the value used (-0.26 mm/a) is derived from a mean radiometric age of 131 ka. For this particular site, we consider a mean radiometric age, which is slightly older than the nominal MIS 5.5 age. In the same core, Holocene lagoonal deposits are encountered at the expected eustatic elevation (Lambeck et al., 2004b), but assessment of the relative contribution of subsidence and sediment supply is difficult.

In southern Tuscany and Lazio, the highstand is documented by marine terraces and locally by tidal notches. Immediately south of the Versilia plain (Fig. 9), the marine terraces are uplifted to ~20 m a.s.l. probably as a result of flexural unloading in the footwall of the normal fault system bordering the plain. Southwards, between the centre of uplift around Livorno and the Roman volcanic complex (around Sabatini complex, Fig. 9), the marker altitudes indicate tectonic stability. At the Roman volcanic complex, markers indicate a 150 km wavelength bulge which was related to magmatic injection beneath the >20 ka vents (Bordoni and Valensise, 1998; Karner et al., 2001; Nisi et al., 2003). We add here the observation that the bulge has spikes which can be attributed to the interference between the different volcanic complexes of Vulsini, Vico, Sabatini and Albani (Fig. 9), whose activity becomes younger to

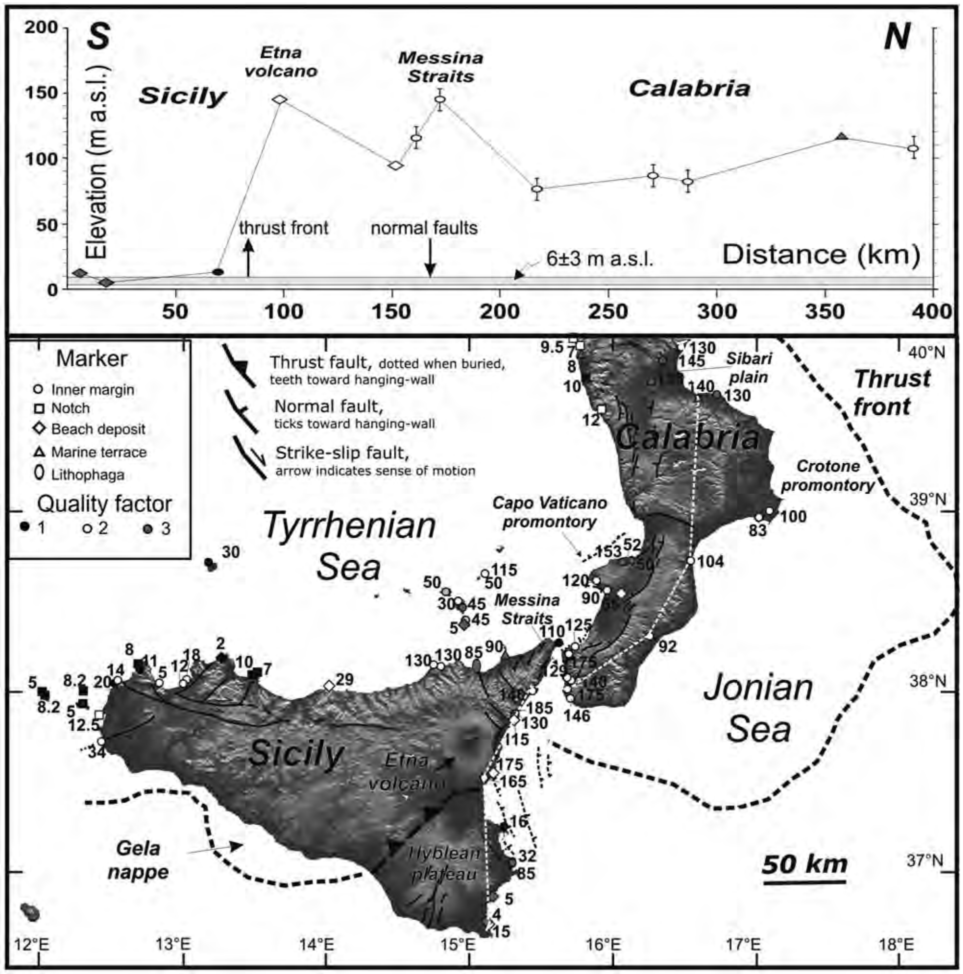


Fig. 11. Elevation of the MIS 5.5 markers, indicated by numbers in black in metres with respect to modern s.l., plotted on a DEM of Calabria and Sicily. Markers type and quality factor as listed in Additional Table are indicated. Major faults and the thrust front of the Apennines and Maghrebids are shown (partly adapted from Bigi et al., 1992; Tortorici et al., 1995; Catalano et al., 2003). White dashed lines is trace of cross-section portrayed above.

the south (Nappi et al., 1991; Barberi et al., 1994). South of the volcanoes, the pattern of subsidence in the plains and stability on the rocky promontories typical of the eastern Tyrrhenian coast returns (e.g. Nisi et al., 2003).

5.4. Campania and Tyrrhenian Basilicata

Along the rocky promontories of this region the MIS 5.5 marker represented by notches and marine terraces, locally associated with radiometrically dated deposits, is generally at the position of the MIS 5.5 sea-level (Fig. 10; Brancaccio et al., 1978; Romano, 1992). In contrast, in the Volturno plain (Fig. 10), the MIS 5.5 marker is recovered in a borehole at around −50 m (Romano et al., 1994), yielding an average subsidence rate of 0.45 mm/a. The subsidence of the plains is consistent with volcano-tectonic collapse following emplacement of the Campanian Ignimbrite around 37 ka ago (De Vivo et al., 2001). However, the depth at which MIS 3 marine deposits are found in the same core suggests a mean subsidence rate of 0.2–0.3 mm/a for the last 50 ka. AMS ^{14}C data of wood fragments found in lagoon deposits (Barra et al., 1996) indicate that the Volturno coastal plain was tectonically almost stable during the last 5 ka. Thus, the subsidence rate was higher for some 10 ka after the MIS 5.5, and decreased progressively since then.

Subsidence at a minor average rate since the last interglacial is found in the Sarno plain, south of Mt. Vesuvius volcano, where the MIS 5.5 marker was found at −29 m (Barra et al., 1991). Subsidence at this plain is likely controlled by the recent and ongoing volcanic activity of the Somma-Vesuvius volcanic complex (Scandone et al., 1991).

Thus, the elevation pattern of the marker indicates stability of the promontories and subsidence in the plains of this part of the region, attributable to the interplay of active onshore and onland normal faults bordering the plain (Fig. 10), and to volcanic collapse.

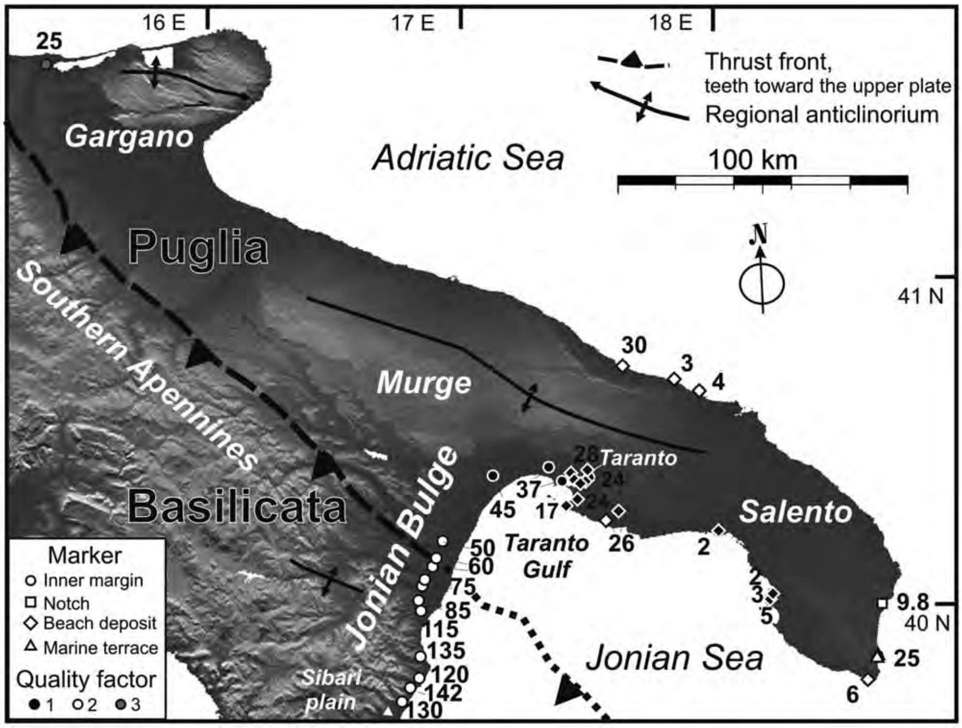


Fig. 12. Elevation of the MIS 5.5 markers, indicated by numbers in black in metres with respect to modern s.l., plotted on a DEM of Jonian Basilicata and Puglia. Markers type and quality factor as listed in Additional Table are indicated. Major folds in Puglia and in the Southern Apennines, as well as the thrust front of the belt are shown. The Jonian bulge shows a NE-ward slope, which constraints the elevation of the MIS 5.5 along the Jonian coast.

A different history of vertical displacement is found further to the south in the Sele plain, where the marker is uplifted for ~10 m. This plain is probably affected by the same tectonic activity as the southern Campania and Basilicata rocky coasts, where the marker is progressively uplifted to the south for a few metres relative to central and northern Campania (i.e. Policastro Gulf, Fig. 10). In addition, more recent uplift is testified by the present elevation of the 5c and 5a markers in the area, which lies some metres above the present sea-level (Iannace et al., 2001; Esposito et al., 2003).

5.5. Calabria

The MIS 5.5 sea-level highstand is documented in Calabria by a spectacularly wide marine terrace being part of a flight of terraces recording the long-term uplift of the region (Cosentino and Gliozzi, 1988; Westaway, 1993; Miyauchi et al., 1994). Locally, the terrace is associated with beach deposits which include rich *S. bubonius* assemblages, as in the case of Ravagnese and Bovetto (Gignoux, 1913; Bonfiglio, 1972). The elevation of the MIS 5.5 terrace increases from north to south and reaches its maximum values of 175 m in southern Calabria (Fig. 11).

On the Tyrrhenian side of the region, the terrace elevation increases by one order of magnitude from northern Calabria (Carobene and Dai Pra, 1990) to the Capo Vaticano promontory and the coasts of the Messina Straits (Dumas et al., 1982, 1987b; Barrier et al., 1988; Balescu et al., 1997; Miyauchi et al., 1994; Tortorici et al., 2003; Dumas and Raffy, 2004). The nature of the transition between the two elevation ranges is, however, poorly understood, since a ~100 km coastal stretch with unreported outcrops occurs between the two areas. On the Jonian side of the region, nothing is known about the marker in a nearly 100 km wide stretch north of the Crotone promontory and up to the Sibari plain (Fig. 11), where markers occur between 65 and 120–135 m (Carobene, 2003; Cucci and Cinti, 1998; Cucci, 2004). South of the Crotone promontory a number of sites show a north–south increase of elevation from ~80–100 m at the whole stretch of the Jonian coast (Gliozzi, 1988; Palmentola et al., 1990; Zecchin et al., 2004) to ~160 m at southernmost Calabria coasts (Hearty, 1986; Hearty et al., 1986; Dumas et al., 1987b, 1988; Dumas and Raffy, 1993; Miyauchi et al., 1994).

The uplift pattern in this region has been related to the interplay between regional and local (i.e. fault-related) components of vertical displacement, the former being associated with the subducted Jonian slab and the latter being encountered at the footwall of large-displacement normal faults (Cosentino and Gliozzi, 1988; Westaway, 1993; Miyauchi et al., 1994; Tortorici et al., 2003; Catalano et al., 2003). Recent work on the Holocene marker indicates a nearly 100% increase in uplift rates when compared to the late Pleistocene (Antonioli et al., 2006; Ferranti et al., in preparation).

5.6. *Sicily*

Outcrops of the MIS 5.5 sea-level highstand marker are abundant at the northern and eastern shores of the three-cornered island of Sicily, whereas they are almost missing on the southwestern shore (Fig. 11; for a detailed review see Antonioli et al., 2006).

The markers are at elevations between 2 and 175 m a.s.l., but an obvious asymmetry in elevation is observed, with sites in eastern Sicily commonly above 100 m, and sites in Sicily at a much lower altitude of 8–14 m. On the northern and eastern shore of the island, the elevation of the markers increases from west to south from quasi-eustatic to the maximum regional altitudes recorded in eastern Sicily. On the northern side, uplift commences at the newly discovered site of Cefalù (Antonioli et al., 2006) lying in the central part of the coast. On the eastern side, onset of regional uplift is observed in the northern portion of the Hyblean plateau (Fig. 11). Along the entire northeastern coast of Sicily, the highstand marker, which is represented by the inner margin of a marine terrace locally associated with *S. bubonius*-bearing deposits, has been uplifted to 140–175 m with maximum values centred around the Etna volcano (Fig. 11). As in Calabria, the spatial distribution of elevated markers documents regional-scale processes.

In western and southeastern Sicily, the marker lies generally only a few metres above the predicted eustatic elevation (Fig. 11). Local differences are explained by fault displacement particularly evident at the small promontories standing out from the main run of the coastline. Most of these faults are transpressional and in few cases cut through the MIS 5.5 terraces (Antonioli et al., 2006). Thus, local uplift and subsidence occurs along restraining and releasing bends, respectively, along the fault trace. The lack of MIS 5.5 markers on the southwestern shore of Sicily occurs in a region spatially coincident with the actively sliding Gela Nappa (Lickorish et al., 1999).

5.7. *Jonian basilicata*

Many MIS 5.5 markers were recognized along the coast of the Jonian Sea south of Taranto Gulf (Fig. 12), and are generally represented by marine terraces. However, the chronology of correlated deposits is weak and *S. bubonius* was only found at the Castellaneta-Ponte del Re site (Boenzi et al., 1985; Caldara, 1988). Attribution of the marine terrace stretching between the Sibari plain and Taranto Gulf (Fig. 12) is, thus, performed based on lateral correlation of dated sites (Dai Pra and Hearty, 1988; Cucci and Cinti, 1998; Amato, 2000). From this, the terrace is of MIS 5.5 age, and its uplift decreases from ~140 to ~40 m a.s.l. moving from south to north (Fig. 12).

A similar northerly decrease in elevation is observed in a flight of Middle–Late Pleistocene terraces overlying the MIS 5.5 terrace (Cucci and Cinti, 1998; Bordoni and Valensise, 1998; Amato, 2000). This morphological pattern represents a regional bulge with northeasterly tilt, here named the Jonian Bulge.

5.8. *Puglia*

The Puglia region represents the deformed foreland of the southern Apennines and is split in the three uplifted blocks of Gargano, Murge, and Salento, separated by plains and valleys of variable length (Fig. 12). Most MIS 5.5 markers appear on the Salento block to the south, whereas little is known about the marker distribution on Gargano and Murge further north.

Within Salento, the MIS 5.5 sites are clustered in the Taranto area to the west (Fig. 12), and belong to one wide marine terrace, whose inner margin can be observed between 37 and 24 m a.s.l. (Hearty and Dai Pra, 1992; Belluomini et al., 2002). At the Torre Castelluccia site, U/Th ages determined using *C. caespitose* yielded an age of about 138 ka (Dai Pra and Stearns, 1977; Dai Pra, 1982; Hearty and Dai Pra, 1992; Belluomini et al., 2002). Southeast along the Salento shore, the marker is found close to the eustatic altitude (Fig. 12). At Torre Castiglione, the inner margin of a marine terrace is situated at about 1.5 m a.s.l., and at Gallipoli deposits with *S. bubonius* appear close to modern sea-level (Dai Pra, 1982; Dai Pra and Hearty, 1988; Hearty and Dai Pra, 1992). A marker close to sea-level is also found at the southeastern tip of Salento, although the chronological constraint imposed by a dated flowstone growing on the alleged MIS 5.5 marine deposit (Mastronuzzi and Sansò, 2003) is relatively weak.

Remnants of the MIS 5.5 marine terrace along the Adriatic coast are rare and poorly constrained regarding timing and elevation. One indirect age constrain is available at the southern Murge (Torre Santa Sabina, site 227, Fig. 4) where a coastal deposit situated at about 3 m a.s.l. overlies a colluvial deposit bearing Late Paleolithic–Mousterian flints and, thus, could be of MIS 5.5 age (Mastronuzzi and Sansò, 2003).

Overall, the vertical tectonic pattern is characterized by mild uplift of the western side of Salento (Fig. 12). The elevation pattern in the Taranto area probably represents the northeast termination of the Jonian bulge. On the other hand, unravelling the vertical tectonic behaviour of the Adriatic coasts is hampered by the scarce chronological constraints. Activity of the Jonian bulge in post-MIS 5.5 times is consistent with the long-term history of the region, characterized by uplift of middle Pleistocene terraces (Amato, 2000), possibly related to the nucleation of folds and thrust faults in the crystalline basement of the region (Ferranti and Oldow, 2005a, b). Similar long-wavelength folds characterize Murge and Gargano, and a small lateral variability of the marker elevation might mirror this tectonic pattern (Fig. 12). Holocene uplift is reported on the northern Gargano shore (Mastronuzzi and Sansò, 2003), and thus testifies to recent and possibly modern uplift.

5.9. Central Adriatic

The central Adriatic coastline from Molise to Emilia-Romagna runs parallel to the foothills of the central Apennines thrust belt, which is still tectonically active beneath the coastal region and the Adriatic Sea (Lavecchia et al., 1994; Frepoli and Amato, 1997; Vannoli et al., 2004). Despite efforts to study MIS 5.5 deposits (Parea and Valloni, 1983; Molinaroli, 1984; Parea, 1986), the understanding of MIS 5.5 markers along the Abruzzi and Molise coasts (Fig. 4) is limited, and does not allow yet determination of ages and altitudes.

Further north, along the Marche and southern Emilia coastline, MIS 5.5 marine terraces are found between 7 and 16 m a.s.l. (Fig. 8; sites 237–239 in Fig. 4), with differential uplift related to segmented growth of anticlinal folds (Vannoli et al., 2004). The slow coastal uplift resulting from the marker's altitude confirms the model of the long-term and present-day tectonic regime of the area, which is compressional along the front of the Apennines (Fig. 5a and b).

5.10. Northern Adriatic

North from the slightly uplifted terraces of the Marche region, the MIS 5.5 marker is strongly down-dropped at the northern Adriatic coast. The marker is recovered in boreholes between −85 and −117 m b.s.l. in the northern Emilia-Romagna region (Fig. 8). The marker is here represented by a wedge-shaped littoral sand body, which can be traced by borehole correlation up to 30 km inland from the modern shoreline (Amorosi et al., 1999a, b, 2004). Attribution of the deposit to the last interglacial is based on pollen series correlation (e.g. Tzedakis et al., 1997), which provides an MIS 6 age for the alluvial plain deposits underlying the beach sands (Amorosi et al., 1999a, b, 2004). The lateral continuity of the littoral sediment suggests that it developed during the main 5.5 highstand, cautiously supported by new ESR age data on shells (Table 2).

Consequently, significant tectonic subsidence occurred since around 125 ka. Quantification of the subsidence rates, however, is not straightforward, since large uncertainties exist for both the age and the paleo-shoreline position of the sampled deposits. Given all the above uncertainties, a subsidence of 0.8–1.0 mm/a is reasonable.

The boreholes are located in the southern margin of the Po plain, which represents the foredeep basin for the active northern Apennines thrust belt (Fig. 5a and 8). Thus, the subsidence pattern of the MIS 5.5 marker in northern Emilia-Romagna indicates flexure probably associated with the compression occurring on the northern Apennines front, which underlies this location. These sites are located in the hanging-wall of the thrust front (Ferrara arc, Fig. 8) but, unlike sites further south, they experience strong subsidence instead of mild uplift (Fig. 8).

Two sites located further north in Veneto and Friuli (Fig. 8; sites 239 and 240, Fig. 4), although having a very high uncertainty regarding age and shoreline position, display less subsidence relative to the Emilia-Romagna sites. These two northern sites are closer to the northern side of the Po Plain, and thus might indicate flexure related to the Southern Alpine and Dinaric contraction (Fig. 5a, b and 8).

6. Discussion

6.1. Tectonic models for displacement of the MIS 5.5 marker

The different altitudes at which markers of the MIS 5.5 highstand have been placed by tectonic movements have been used to propose models of regional deformation in Italy. By compiling the altitude of 31 outcrops

Table 2
Analytical data for the new ESR ages for Pò Plain cores

Site	Lab. no.	H_2O (Sed.) (%)	U-cont. (Sed) (ppm)	Th-cont. (Sed) (ppm)	K-cont. (Sed.) (%)	U.cont (foss.) (ppm)	De (Gy)	Do (μGy/a)	ESR age (ka)
205-S10	K-4383	30	2.8±0.2	6.9±0.6	1.58±0.1	0.5±0.2	163.09±18.91	1318±148	124±20
240-S8	K-4384	30	1.06±0.1	6.5±0.5	1.31±0.1	0.5±0.2	126.64±7.92	993±127	129±18
222-S2	K-4385	30	3.5±0.2	8.5±0.6	1.3±0.1	0.5±0.2	209.51	1364±168	154±26

The surface of the mollusk shells was cleaned with acid. The ages have been calculated using the early uptake model (computer programme DATA VII from Rainer Grün, Canberra, Australia). De is the equivalent dose (“accumulated dose”), Do is the “annual dose” (the dose of radiation a samples receives during a year).

showing marine deposits with *S. bubonius*, Cosentino and Gliozzi (1988) identified the uplift pattern of the Calabria region (Southern Italy). Uplift rate estimates by Cosentino and Gliozzi (1988) were, however, of limited accuracy due to the large correction (+25 m) applied to account for the unknown palaeo-bathymetry of the Strombus-bearing deposits. Cosentino and Gliozzi (1988) proposed that uplift of Calabria resulted from deep forces originating within or above the slab subducted beneath the southern Tyrrhenian Sea and margin (Fig. 5a). Based on a detailed field investigation of the last interglacial and older terraces in Southern Italy, Westaway (1993) and Miyauchi et al. (1994) concluded that the Calabrian sector has experienced regional uplift since ~0.7–1 Ma.

The recent compilation from Bordoni and Valensise (1998) incorporated a larger number of data (105) of the MIS 5.5 from southern as well as central Italy. Based on the altitudes of the MIS 5.5 markers, the authors identified three different crustal sectors. The central Italy sector shows a moderate (~20 m amplitude) bulge tapering off along the coast, which they attribute to the injection of magma in the >20 ka old volcanic centres of Lazio. A larger amplitude (~150 m) bulge spanning from the hinterland, over the frontal thrust belt to the foreland was first recognized in the southern Italy sector. The sector with the largest uplift (up to 170 m) is located between Sicily and Calabria, and shows spikes related to local extensional subsidence in a general uplift context (Bordoni and Valensise, 1998).

Our compilation of the MIS 5.5 data identifies coastal sectors where vertical tectonic displacements are consistent with existing models, and refine current estimates of displacement rates. For the remaining sector of the Italian coastline (northern Italy and Sardinia), our analysis provides the first comprehensive overview of the vertical displacement pattern, which gives new insights into the current deformation processes.

Fig. 13 shows the average uplift rates occurring along the entire Italian coastline since the MIS 5.5. We recognize that the uplift rates are average estimates since ~125 ka, and do not show the temporal variability that might have occurred at the earthquake cycle scale. Moreover, tectonic stability, as well as vertical tectonic displacement must be checked against independent evidence, which is best provided by the altitude of younger (i.e. Holocene) markers. However, determination of Holocene displacement is difficult for most sites in Italy because of observational limitations imposed by the small displacement accrued. Thus, the pattern provided by the MIS 5.5 markers remains for most of the Italian coastline an unsurpassed proxy for recent vertical tectonic motion.

Sardinia is tectonically stable with a very slight subsidence of all but the central part of the eastern side, where localized uplift prevails (Fig. 13). This reveals a continental margin approaching a mature and thermally cooled stadium. However, weak tectonic deformation is indicated by displacement of the marker. Small differential subsidence of the southern sites is consistent with GPS velocities studies (Oldow and Ferranti, 2005), which indicate modern, aseismic strike-slip deformation across the Campidano graben (Fig. 7).

A similar situation might occur in NW Sardinia, where local fault-induced subsidence might explain the westward down-step of the highstand marker, consistent with tectonic reconstructions (Casula et al., 2001). On the eastern side of the island, the local dome outlined by the MIS 5.5 marker might be related to residual volcanic injection at shallow depth in an area which experienced intense but localized Pliocene–Quaternary volcanism (Assorgia et al., 1997; Casula et al., 2001).

The paucity of data regarding the Liguria coastlines makes the interpretation of the regional vertical tectonics problematic. The little information available indicates a mild uplift with the eastern coast moving at higher rates than the western coast (~0.02 and ~0.2 mm/a, respectively, Fig. 13). This appears consistent with the long-term geological record, which documents a different vertical behaviour from east to west, with exhumation of the Ligurian Alps (western Liguria) at ~0.1 mm/a in the last 5 Ma (Foeken et al., 2003), and Quaternary surface uplift of the Ligurian Apennines (eastern Liguria) at ~1 mm/a (Bernini and Papani, 2002). This area has experienced extensional tectonics throughout the Neogene, and extension is still active today as documented by seismicity (Fig. 5a and b). It is therefore deduced that the uplift rates in the last 1 million years are similar to those in the last 100 ka, but further investigations are needed to fully support this interpretation.

On the eastern coast of Northern Italy vertical displacements occur in an area of contractional tectonics. This displacement changes along the coast from weak uplift to strong subsidence (Fig. 13). The low uplift rates (less than 0.1 mm/a) of the MIS 5.5 marker in the Marche region are related to low-amplitude folds growing underneath the coast (Vannoli et al., 2004). This situation occurs behind the active frontal thrust and in the hanging-wall of an inner thrust which borders the mountainous topography of the northern Apennines (Fig. 8). Further to the north, the subsidence of the northern Adriatic coast (Fig. 13) at a rate of ~1 mm/a occurs behind the buried frontal thrust, which is supposed to be active (Benedetti et al., 2000; Burrato et al., 2003) and in the footwall of the thrust which forms the chain escarpment (Fig. 8) and is characterized by contractional earthquakes (Fig. 5b). This subsidence decreases towards the fronts of the Southern Alps and Dinarids (Figs. 5b and 13). The subsidence pattern is consistent with the model of a flexure situated in front of the seismically active main thrust of the northern

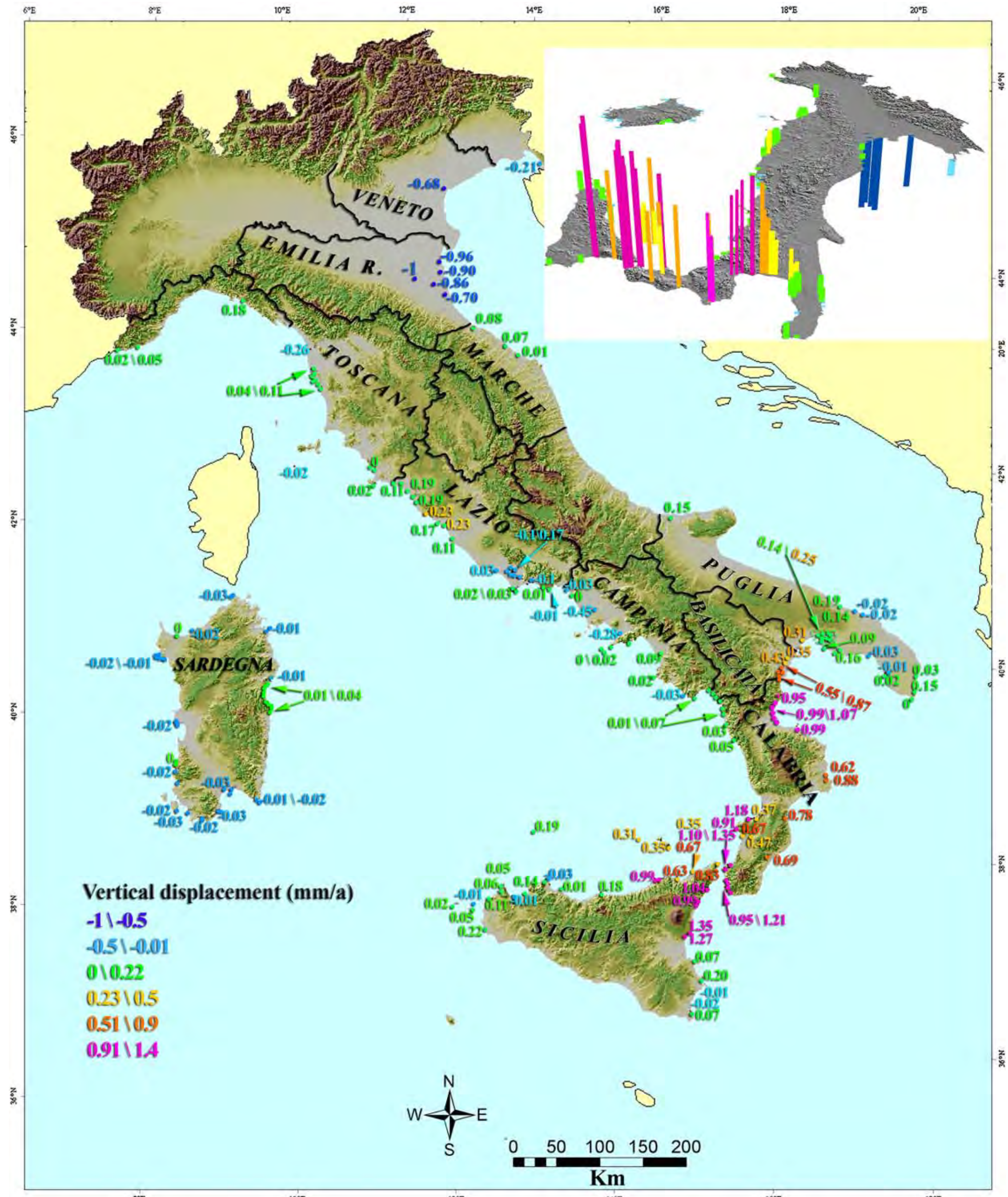


Fig. 13. Uplift rate in mm\a plotted on a DEM of Italy (see Additional Table for site values). For the colour classes see the legend. Inset shows a schematic three-dimensional representation of the same data set.

Apennines chain and involving the frontal thrust, whereas the foreland in the Southern Alps and Dinarids experiences lesser flexure (Mariotti and Doglioni, 2000). To the south along the Apennines front, whereas motion of the buried frontal thrust on the flexed foreland occurs further offshore, the coast experiences weak uplift related to active displacement at the foothills of the mountain belt.

At the opposite, Tyrrhenian coast displacement of the MIS 5.5 marker occurs in a region which experienced Pliocene–Quaternary extension along NW–SE and NE–SW trending faults (Mariani and Prato, 1992; Hippolyte et al., 1994), and southward migrating volcanic activity (Beccaluva et al., 1989). The coast between Tuscany and northern Calabria is typically viewed as tectonically stable at the regional scale (Patacca et al., 1990), but on a small scale the area reveals remarkable alternation of stable and weakly deformed sectors (Fig. 13). Today, NE–SW and NW–SE extension coexists in the southern Tyrrhenian coastal sector as suggested by offshore well breakouts (Amato and Montone, 1997) and offset of the sea-floor (Mariani and Prato, 1992). In this area, regional Quaternary uplift ended probably during the late Pleistocene (e.g. Brancaccio et al., 1991; Cinque et al., 1993) and, thus, the MIS 5.5 marker was in situ before final tectonic submergence into the Tyrrhenian Sea (Ferranti and Oldow, 2005b).

Minor uplift of promontories and, locally, coastal plains in the eastern Tyrrhenian coast is attributed either to flexural unload at the footwall of normal faults (e.g. southern border of Versilia plain at ~0.1 mm/a, Figs. 9 and 13), or to volcano-tectonic deformation (central sector of Lazio at ~0.25 mm/a; Figs. 9 and 13). Subsidence of the plains results from hanging-wall displacements at the bordering faults (e.g. Versilia and Pontina-Fondi plains subsidence at ~0.3 and 0.1 mm/a, respectively, Figs. 8, 9 and 13) or severe volcano-tectonic collapse possibly triggered by fissural eruptions (e.g. Volturno-Sarno plain subsidence at ~0.5, Figs. 10 and 13).

Today, these processes probably stopped at the northern-central Tyrrhenian Sea coasts. In the Versilia plain (Fig. 8) the Holocene marker is not displaced (Nisi et al., 2003), and the modern tidal notch at the promontories in Tuscany and Lazio indicates a stable relative sea-level during the Holocene (Antonioli et al., 1999b, c). In Lazio, significant volcanic activity ended by ~20 ka (Barberi et al., 1994). Likewise the Holocene marker is not displaced in the subsiding Campania plains, and, thus, stability has been attained.

Along the southern Tyrrhenian Sea, however, displacement of the MIS 5.5 marker continues today. The transition from stable tectonic conditions or local subsidence to regional uplift probably occurs in central Campania, indicated by the small uplift of the Sele plain at ~0.1 mm/a (Figs. 10 and 13). The slow uplift rates of southern Campania and Basilicata point to a uplift pattern observed further south in Calabria (Figs. 11 and 13).

Since the middle Pleistocene Calabria and eastern Sicily have been subject to relatively high uplift rates. Continuous uplift is documented by flights of marine terraces (Dumas et al., 1982, 1987b; Westaway, 1993; Miyauchi et al., 1994). Uplift rates documented by the MIS 5.5 marker increase towards the Messina Strait between Sicily and Calabria and towards central eastern Sicily (Fig. 13). The maximum uplift rate is identified in the Messina Straits and at the east Sicily coast where it might be centred at the Etna volcano (Fig. 11), where a volcano-tectonic component (Monaco et al., 2002) adds to the regional deformation. Recent investigation of the Holocene shorelines in the area indicate that uplift rates increased from the late Pleistocene to the late Holocene of ~65–125% (Antonioli et al., in press), possibly as a result of Holocene clustering of fault displacement superposed on a steady regional uplift (Ferranti et al., in preparation).

The geometry and dimension of the uplift pattern in southern Calabria and northeast Sicily points to a mechanism situated deep in the crust. Uplift of Calabria is viewed as an isostatic response to slab break-off (Westaway, 1993; Wortel and Spakman, 2000), or due to a dynamic support from the asthenosphere wedge beneath the Calabria–NE-Sicily forearc, which is decoupled from the subducting plate (Gvirtzman and Nur, 2001; D'Agostino and Selvaggi, 2004). However, the area uplifted (Fig. 14) is larger than the area covering the subducted slab as revealed by tomography and deep earthquakes (Fig. 5a), as it includes the Jonian coasts of Basilicata. This latter coastline crosses the front of the southern Apennines thrust belt and the foredeep basin. The pattern that the MIS 5.5 terrace describes is of bulging and tilting of the coast to the northeast. The basin and frontal belt subsided throughout the Pliocene–early Pleistocene, but experienced uplift since the middle Pleistocene (Cinque et al., 1993; Westaway, 1993; Amato, 2000) together with the Murge-Salento block (Ferranti and Oldow, 2005a, b) in Puglia (Fig. 12). This pattern continued after the last interglacial with an uplift rate of ~1 mm/a. Bulging and tilting of the MIS 5.5 terrace occurred across the thrust front of the southern Apennines, whose activity ceased in the early Pleistocene (Patacca and Scandone, 2001). Thus, displacement of the MIS 5.5 markers in the Jonian bulge is not indicative of motion of the frontal thrust, but is consistent with contraction stepped at deeper crustal levels and involving the whole eastern part of southern Italy, as documented by GPS velocities and earthquakes offshore Puglia (Fig. 5b; Ferranti and Oldow, 2005a, b). In Puglia, the altitude distribution of the MIS 5.5 marker documents moderate elevation (~25–37 m a.s.l.) of relatively small coastal sectors, which alternate with sectors where the marker is close to the eustatic datum. The consistently low elevation attained by the displaced markers might indicate a prevailing regional control on vertical displacement, particularly for the Taranto area which lies at the northeastern tip of the Jonian bulge. Deep-seated, large-wavelength folds affect the Puglia structural block during the Quaternary (Bertotti et al., 2001) and might be reflected by the low-amplitude bulges indicated by peaks in the marker's altitude on the Adriatic coast of Puglia.

The displacement of MIS 5.5 markers in Sicily, west and south of the regional bulge, reveal active tectonic processes. In western Sicily and Ustica Island, small uplift rates (~0.1–0.2 mm/a) of the marker point to on-land encroachment of the active contractional belt detected by seismicity and GPS velocities (Fig. 5b; Oldow and Ferranti, 2005). The occurrence of limited areas affected by subsidence probably results from local components of strike-slip deformation, documented in several sites along the Tyrrhenian coast of northern

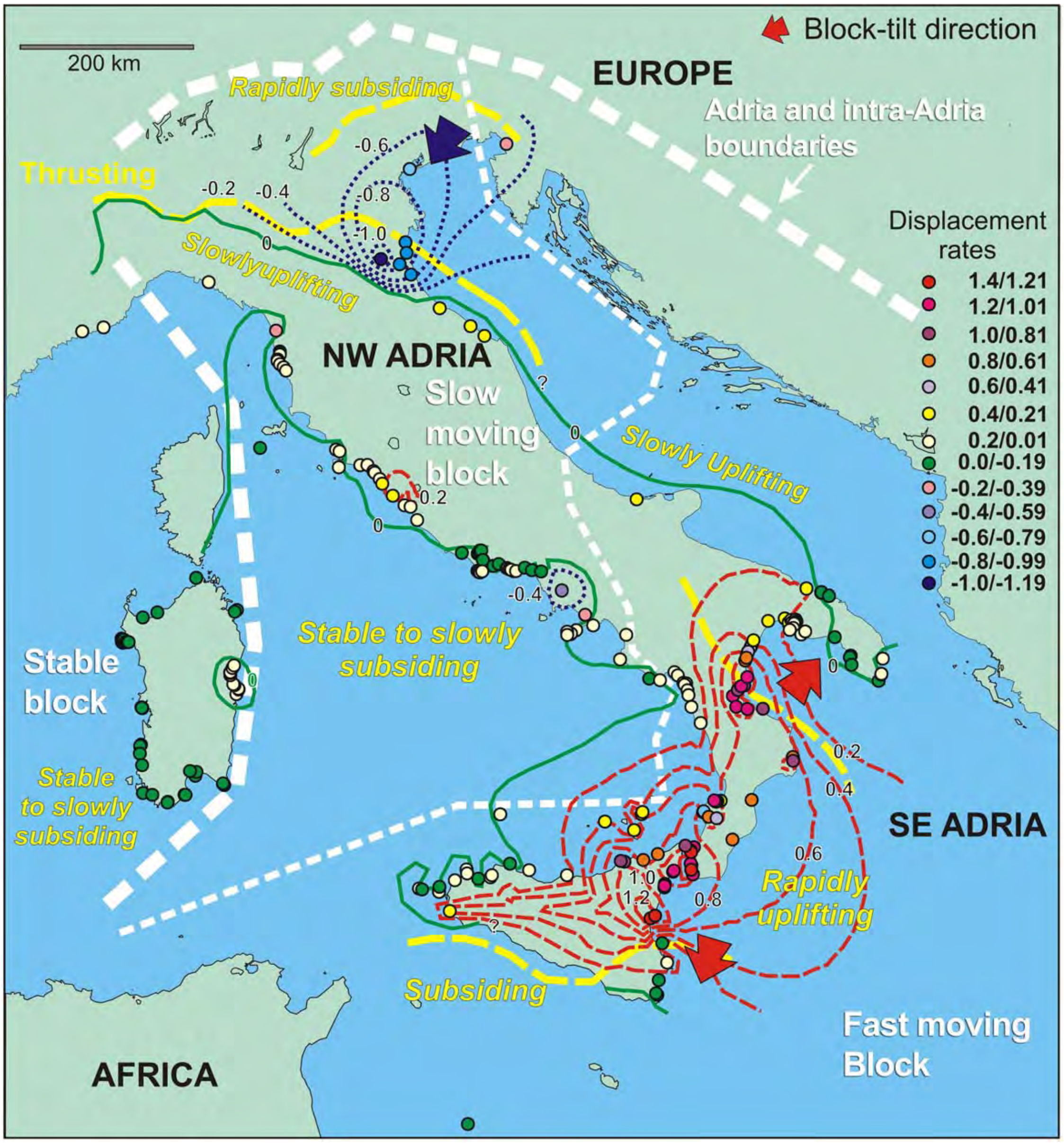


Fig. 14. Summary of the vertical tectonic behaviour of peninsular and insular Italy deduced from the elevation of the MIS 5.5 marker, and of the spatial relation of the vertical motion domains (yellow italic notations) with the domains of fast versus slow geologic to contemporary horizontal displacement (white bold notations) both within and at the boundaries of the Adriatic block (thin and thick dashed white lines, respectively, drawn from Fig. 5b. The average vertical displacement rate is contoured at a 0.2 mm/a interval (positive: dashed red line; stable: solid green line; negative: dotted blue line); dots with different colour fill identify sites uplift rate ranges. Also portrayed is the relation of the tilt pattern of the MIS 5.5 marker (large arrows: blue for subsidence and red for uplift) with recent thrust activity (yellow lines).

Sicily (Nigro and Sulli, 1995; Nigro and Renda, 1999; Giunta et al., 2000). In southeastern Sicily, a decreasing uplift south of the Etna volcano might indicate shortening of the crust at the Hyblean front, which is consistent with Quaternary geology (Torelli et al., 1998; Lickorish et al., 1999) and borehole break-outs (Ragg et al., 1999). The lack of the MIS 5.5 marker along the entire southwestern coast of Sicily might result from erosional processes, or indicate prolonged subsidence related to ongoing southwestern sliding of the Gela nappe at the offshore location of the thrust front.

6.2. Implications of tectonic behaviour of the coastlines for the active geodynamics of the Italian peninsula, Sardinia and Sicily

At a regional scale, the displacements testified by the MIS 5.5 marker define the vertical component of deformation, and give deep insights into the tectonic behaviour of crustal blocks. The island of Sardinia is stable to locally slowly subsiding, and forms a block almost coherent with mainland Europe (Fig. 5). Thus, Sardinia provides the best eustatic reference (6 ± 3 m) for the central Mediterranean.

The Ligurian Sea coasts display different local uplifts between the western (Alpine) and eastern (Apenninic) sectors, mirroring its geologic history of vertical displacement and testifying a still active separation between the Alpine and Apenninic compartments. The northern Adriatic coasts trend from weak uplift to strong subsidence towards the north, and this probably reflects the transition from imbrication in the shallow thrust wedge to deep crustal flexure towards the northern Apennines orogen (Figs. 5 and 13). Foreland flexure beneath the northern Apennines is consistent with the model of slab roll-back of the Adriatic lithosphere explaining the rapid advancement of the thrust belt (Royden et al., 1987; Doglioni, 1991). The central and northern coasts of the eastern Tyrrhenian Sea are generally stable (promontories) or slowly subsiding (plains), and localized volcano-tectonic effects are observed as mild uplift and moderate subsidence within Lazio and Campania, respectively.

Overall, the central and northern Tyrrhenian and Adriatic coasts pass from stability or weak uplift to subsidence. The coasts run across the north-western part of the Adriatic block, which is caught between the African and European plates and is characterized by slower geodetic motion and less seismic release than its southeastern counterpart (Fig. 14; Oldow et al., 2002; Oldow and Ferranti, 2005). Thus, a relation ensues between stability to subsidence and moderate deformation rates.

On the other hand, regional uplift characterizes the southeastern Tyrrhenian, southern Adriatic and Jonian coasts, which span the southeastern sector of the Adriatic block (Fig. 14), where GPS velocities are faster and seismicity is higher (Oldow et al., 2002; Oldow and Ferranti, 2005). The uplift is weak in Puglia and in western and southern Sicily, but increases towards the canter of the block peaking between Sicily and Calabria, and far to the northeast in the central Jonian coasts (Fig. 14). The bulge might have a common origin and span over a wider lithospheric area than the subducted Ionian slab underneath the southern Tyrrhenian Sea (Fig. 5a), which is traditionally claimed as the source for Calabria's uplift (Cosentino and Gliozzi, 1988; Westaway, 1993; Gvirtzman and Nur, 2001). Although the western side of the bulge resides in an area of extensional tectonics, a component of crustal or even lithospheric shortening related to Adria–Europe interaction might contribute to the uplift in the eastern sector.

7. Conclusions

The coasts of Italy display well-developed and well-preserved indicators of the MIS 5.5 sea-level highstand, which provide excellent information about altitude and time. The distribution of the indicators reflects primary paleoclimatic and paleogeographic conditions and subsequent tectonic processes, manifested in a combination of regional and local displacements. Compilation of altitudes of 246 MIS 5.5 shoreline outcrops along the coastline of Italy, supported by uncertainty estimation of both age and elevation, provides an insightful picture of the recent and active tectonic processes in the central Mediterranean. The vertical displacement experienced by the highstand marker is complicated at the local scale, but in the regional frame appears consistent with stability to slow subsidence in Sardinia and the central-northern Tyrrhenian sea, slow to rapid uplift moving north along the Adriatic coast, and rapid uplift of the southern Tyrrhenian and Jonian coast. Viewed at this scale, the along-shore variability in the marker elevation highlights different tectonic processes in laterally adjoining compartments. Displacement of the marker is thus a response to both surface and deep crustal processes, and, in the absence of more recent indicators, the MIS 5.5 highstand marker stands as an unsurpassed proxy for the vertical component of active tectonic displacement in the Central Mediterranean.

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Appendix A. Supplementary materials

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.quaint.2005.07.009

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Site no.	Locality	Administrative region	East longitude	North latitude	Marker	Uncertainty (m)	Shoreline elevation (m a.s.l.)	Vertical displacement rate (mm/a)	Vertical displacement rate variance (s2)	Faunal assemblage	Tecnique of chronological attribution	Age (Ka)	Reference(s)	quality factor
1	Cala Mosca	SARDEGNA	9.149	39.184	Inner margin	3.0	6.00	0.00	0.00115	*Strombus b.*	Paleontology, U-Th, Aminostratigraphy	< 138±8	Issel 1914; Ulzega & Ozer, 1980; Ulzega & Hearty, 1986; Heraty, 1986	1
2	Is Arenas	SARDEGNA	9.164	39.225	beach deposits	3.0	4.00	-0.02	0.00115	*Strombus b.*	Aminostratigraphy		Ulzega & Ozer, 1980	1
3	Capo Carbonara	SARDEGNA	9.518	39.100	Inner margin	3.0	5.10	-0.01	0.00115	*Patella ferruginea , Arca noae*	Paleontology - Morphostratigraphical correlation		Palmerini, 1967; Orrù & Pasquini, 1991	3
4	Cala Is Cascias	SARDEGNA	9.535	39.087	Inner margin	3.0	4.00	-0.02	0.00115	*Patella ferruginea , Arca noae*	Paleontology - Morphostratigraphical correlation		Palmerini, 1967; Orrù & Pasquini, 1991	3
5	Porto su Forru	SARDEGNA	9.520	39.104	Inner margin	3.0	3.50	-0.02	0.00115	*Patella ferruginea , Arca noae*	Paleontology - Morphostratigraphical correlation		Palmerini, 1967; Orrù & Pasquini, 1991	2
6	Pedra Longa	SARDEGNA	9.706	40.031	tidal notch	0.1	7.70	0.01	0.00058		Morphostratigraphical correlation		Antonioli & Ferranti, 1992	1
7	Capo Monte Santu	SARDEGNA	9.737	40.079	tidal notch	0.1	7.60	0.01	0.00058		Morphostratigraphical correlation		Antonioli & Ferranti, 1992	1
8	Porto Quao	SARDEGNA	9.734	40.088	tidal notch	0.1	7.80	0.01	0.00058		Morphostratigraphical correlation		Antonioli & Ferranti, 1992	1
9	Punta Caroddi	SARDEGNA	9.680	40.124	tidal notch	0.1	8.00	0.02	0.00058		Morphostratigraphical correlation		Antonioli & Ferranti, 1992	1
10	Punta Caroddi 2	SARDEGNA	9.666	40.135	tidal notch	0.1	8.10	0.02	0.00058		Morphostratigraphical correlation		Antonioli & Ferranti, 1992	1
11	Cala Luna	SARDEGNA	9.627	40.228	tidal notch	0.1	9.20	0.03	0.00058		Morphostratigraphical correlation, Paleontology		Antonioli & Ferranti, 1992	1
12	Bue Marino	SARDEGNA	9.625	40.251	tidal notch	0.1	9.53	0.03	0.00058		Morphostratigraphical correlation		Carobene & Pasini, 1982	1

13	Cala Fuili	SARDEGNA	9.626	40.257	tidal notch	0.1	9.70	0.03	0.00058		Morphostratigraphical correlation	Carobene & Pasini, 1982	1
14	Cala Fuili 2	SARDEGNA	9.627	40.259	tidal notch	0.1	9.65	0.03	0.00058		Morphostratigraphical correlation	Carobene & Pasini, 1982	1
15	Bidiriscottai	SARDEGNA	9.656	40.303	tidal notch	0.1	10.49	0.04	0.00058		Morphostratigraphical correlation	Carobene & Pasini, 1982	1
16	Cuccuru e Sor	SARDEGNA	9.677	40.329	Inner margin	3.0	5.00	-0.01	0.00115	*Mytilus galloprovincialis*	Paleontology	Comaschi Caria, 1955	1
17	Isola di Tavolara	SARDEGNA	9.723	40.906	tidal notch	0.1	6.50	0.00	0.00058		Morphostratigraphical correlation	Orrù & Pasquini, 1991	1
18	Isola di Tavolara Punta La Mandria	SARDEGNA	9.693	40.889	Inner margin	3.0	1.80	-0.03	0.00115	*Glycimeris; C Patella ferruginea*	Aminostratigraphy	Belluomoni et al. 1986	1
19	Santa Reparata 1	SARDEGNA	9.167	41.239	Inner margin	3.0	2.00	-0.03	0.00115	*banal fauna*	Aminostratigraphy	Ulzega & Hearty, 1986; Kindler et al.,1996	2
20	Santa Reparata 2	SARDEGNA	9.166	41.237	Inner margin	3.0	2.50	-0.03	0.00115	*banal fauna*	Aminostratigraphy	Ulzega & Hearty, 1986; Kindler et al.,1996	2
21	Punta Tramontana	SARDEGNA	8.634	40.883	Inner margin	3.0	3.25	-0.02	0.00115	*banal fauna*	Aminostratigraphy	Belluomoni et al. 1986	1
22	Balai	SARDEGNA	8.434	40.830	Inner margin	3.0	6.50	0.00	0.00115		Paleontology	Ulzega & Ozer, 1980	3
23	Cala della Barca	SARDEGNA	8.149	40.608	tidal notch	0.1	3.75	-0.02	0.00058		Morphostratigraphical correlation	Antonioli et al. 1998	1
24	Cala della Puntetta	SARDEGNA	8.147	40.603	tidal notch	0.1	3.65	-0.02	0.00058		Morphostratigraphical correlation	Antonioli et al. 1998	1
25	Torre Pegna	SARDEGNA	8.148	40.599	tidal notch	0.1	3.70	-0.02	0.00058		Morphostratigraphical correlation	Antonioli et al. 1998	1

26	Punta Malrepos	SARDEGNA	8.152	40.581	tidal notch	0.1	3.45	-0.02	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
27	Cala d'Inferno	SARDEGNA	8.156	40.580	tidal notch	0.1	3.05	-0.02	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
28	Grotta dei Palombi	SARDEGNA	8.153	40.571	tidal notch	0.1	3.60	-0.02	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
29	Grotta Pizzi e Ricami	SARDEGNA	8.166	40.564	tidal notch	0.1	3.90	-0.02	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
30	Semaforo	SARDEGNA	8.167	40.567	tidal notch	0.1	3.45	-0.02	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
31	Grotta Verde	SARDEGNA	8.166	40.571	tidal notch	0.1	3.45	-0.02	0.00058	Morphostratigraphical correlation, Paleontology	Antonioli et al. 1998	1
32	La Dragonara	SARDEGNA	8.164	40.575	tidal notch	0.1	3.80	-0.02	0.00058	Morphostratigraphical correlation, Paleontology	Antonioli et al. 1998	1
33	Tramariglio	SARDEGNA	8.173	40.584	tidal notch	0.1	3.80	-0.02	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
34	Porto Tramariglio	SARDEGNA	8.177	40.595	tidal notch	0.1	4.00	-0.02	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
35	Punta del Frara	SARDEGNA	8.178	40.596	tidal notch	0.1	4.20	-0.01	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
36	Capo Bocato	SARDEGNA	8.199	40.574	tidal notch	0.1	4.60	-0.01	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
37	Capo Bocato 2	SARDEGNA	8.203	40.572	tidal notch	0.1	4.40	-0.01	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1
38	Punta Giglio	SARDEGNA	8.207	40.570	tidal notch	0.1	4.40	-0.01	0.00058	Morphostratigraphical correlation	Antonioli et al. 1998	1

39	Punta Giglio 2	SARDEGNA	8.209	40.572	tidal notch	0.1	5.00	-0.01	0.00058		Morphostratigraphical correlation	Antonioli et al. 1998	1
40	Punta Giglio 3	SARDEGNA	8.210	40.573	tidal notch	0.1	5.00	-0.01	0.00058		Morphostratigraphical correlation	Antonioli et al. 1998	1
41	Punta de Rumani	SARDEGNA	8.217	40.571	tidal notch	0.1	5.20	-0.01	0.00058		Morphostratigraphical correlation	Antonioli et al. 1998	1
42	Porto Agra	SARDEGNA	8.235	40.570	tidal notch	0.1	5.40	0.00	0.00058		Morphostratigraphical correlation	Antonioli et al. 1998	1
43	Punta Galera	SARDEGNA	8.244	40.572	tidal notch	0.1	5.30	-0.01	0.00058		Morphostratigraphical correlation	Antonioli et al. 1998	1
44	Funtana Meiga	SARDEGNA	8.424	39.895	Inner margin	3.0	3.00	-0.02	0.00115	*Clacodora coespitosa*	Aminostratigraphy	Carboni & Lecca, 1985; Ulzega & Hearty, 1986; Davaud et al, 1991; Kindler et al., 1996	2
45	Cave - Tombe romane	SARDEGNA	8.432	39.889	Inner margin	3.0	3.50	-0.02	0.00115	*Glycymeris, Cladocora coespitosa*	Aminostratigraphy	Carboni & Lecca, 1985; Ulzega & Hearty, 1986; Davaud et al, 1991; Kindler et al. 1997	1
46	San Giovanni di Sinis	SARDEGNA	8.435	39.886	Inner margin	3.0	3.50	-0.02	0.00115	*Glycimeris; Cladorora coespitosa*	Aminostratigraphy	Carboni & Lecca, 1985; Forti & Orrù, 1995	2
47	Punta Acqua Durci	SARDEGNA	8.421	39.505	Inner margin	3.0	5.50	0.00	0.00115	*Glycymeris; Conus testudinarius*	Aminostratigraphy	Palmerini & Ulzega, 1969; Orrù.1982; Ulzega & Hearty, 1986	2
48	Sacquadroxiu	SARDEGNA	8.410	39.493	Inner margin	3.0	6.00	0.00	0.00115	*Glycymeris; Arca; Patella*	Paleontology	Orrù, 1982	3
49	Buggerru	SARDEGNA	8.407	39.414	tidal notch	0.1	4.00	-0.02	0.00058		Paleontology	Cesaraccio et al.1986	3
50	Fontanamare	SARDEGNA	8.438	39.293	Inner margin	3.0	2.50	-0.03	0.00115	*Glycymeris; Patella ferruginea*	Paleontology	Orrù & Ulzega, 1986	3
51	Maladroxia	SARDEGNA	8.451	39.003	Ttidal notch	0.1	3.80	-0.02	0.00058	*Conus testudinarius; Cardium tuberculatum*	Paleontology	Ulzega & Ozer 1980	3

52	Cala Su Turcu	SARDEGNA	8.577	38.985	Inner margin	3.0	2.50	-0.03	0.00115	*Strumbus b.*	Aminostratigraphy		Ulzega & Ozer 1980	1
53	Piscinnì	SARDEGNA	8.782	38.912	beach deposits	3.0	3.00	-0.02	0.00115	*Clycymerys*	Paleontology		Ulzega & Ozer 1980; Kindler et al. 1997; Grazzini et al.1998; Pintus, 2001	2
54	Torre di Piscinnì	SARDEGNA	8.779	38.905	Inner margin	3.0	4.00	-0.02	0.00115	*banal fauna*	Paleontology , Morphostratigraphical correlation		Grazzini et al.1998; Pintus, 2001	2
55	Fradis Minoris	SARDEGNA	9.005	38.986	beach deposits	3.0	2.50	-0.03	0.00115	*Strombus b.*	Aminostratigraphy	< 125	Ulzega & Hearty, 1986	1
56	Fradis Minoris 2	SARDEGNA	9.007	38.987	beach deposits	3.0	2.00	-0.03	0.00115	*Strombus b.*	Aminostratigraphy		Ulzega & Hearty, 1986; Kindler et al. 1997	2
57	Nora	SARDEGNA	9.018	38.986	beach deposits	3.0	3.00	-0.02	0.00115	*Strombus b.*	Aminostratigraphy		Ulzega & Hearty, 1986; Ulzega & Ozer 1980	2
58	Sa Illetta	SARDEGNA	9.078	39.233	beach deposits	3.0	2.50	-0.03	0.00115	*Cladocora coespitosa*	U/Th Aminostratigraphy	< 149±10	Ulzega & Hearty, 1986; Peirano et al. 2004	1
59	Balzi Rossi (Barma Grande)	LIGURIA	7.541	43.790	tidal notch	0.1	12.00	0.05	0.00058	*Strombus b.,* fauna senegalensis	Paleontology, U-Th	170±35	Stearns and Thurber, 1967; De Lumley, 1969	1
60	Balzi Rossi (Grotta del Principe)	LIGURIA	7.541	43.790	tidal notch	0.1	12.00	0.05	0.00058	*Strombus b.,* fauna senegalensis	Paleontology, U-Th	160±35	Barral and Simon, 1965; Stearns and Thurber, 1967; De Lumley, 1969;	1
61	Balzi Rossi (ex Casinò)	LIGURIA	7.541	43.790	Inner margin	3.0	8.00	0.02	0.00115	*Strombus b.* , fauna senegalensis	Paleontology		Vicino, 1976	1
62	Bussana (Madonna dell'Arma)	LIGURIA	7.845	43.835	beach deposits	3.0	8.00	0.02	0.00115	*Strombus b.* , fauna senegalensis	Paleontology, U-Th	95±5; 60±5	Isetti et al., 1962; Stearns and Thurber, 1967; De Lumley, 1969	1
63	Lavagna (Villa Monteverde)	LIGURIA	9.354	44.310	Inner margin	3.0	28.00	0.18	0.00120		OSL	139±11	Federici and Pappalardo, 2001; Federici and Pappalardo, this volume;	2
64	Versilia Plain (ENEA core)	TOSCANA	10.317	43.800	lagoon deposits	2.0	-69.00	-0.26	0.00141	*Cerastoderma*	U-Th	129±15; 133±15	Nisi et al., 2003	3

65	C.le Vallino	TOSCANA	10.367	43.583	inner margin	3.0	14.00	0.06	0.00116		Morphostratigraphical correlation		Nisi et al., 2003	2
66	Pian di Rota	TOSCANA	10.367	43.567	inner margin	3.0	15.00	0.07	0.00116		Morphostratigraphical correlation		Nisi et al., 2003	2
67	Bagnetti	TOSCANA	10.367	43.550	inner margin	3.0	20.00	0.11	0.00117		Morphostratigraphical correlation		Nisi et al., 2003	2
68	Antignano	TOSCANA	10.333	43.500	inner margin	3.0	20.00	0.11	0.00117		Morphostratigraphical correlation		Nisi et al., 2003	2
69	Punta Casotto	TOSCANA	10.333	43.483	inner margin	3.0	15.00	0.07	0.00116		Morphostratigraphical correlation		Nisi et al., 2003	2
70	Quercianella	TOSCANA	10.367	43.450	inner margin	3.0	17.00	0.09	0.00116		Morphostratigraphical correlation		Nisi et al., 2003	2
71	Buca dei Corvi	TOSCANA	10.417	43.417	beach deposits	4.0	11.00	0.04	0.00160	Senegalese fauna	TL	>108	Blanc, 1953; Hearty et al., 1986 a ; Hearty and Dai Pra, 1987; Mauz, 1999	2
72	Rosignano S.	TOSCANA	10.450	43.383	inner margin	3.0	15.00	0.07	0.00116		Morphostratigraphical correlation		Nisi et al., 2003	2
73	Pianosa	TOSCANA	10.067	42.583	tidal notch	0.1	3.00	-0.02	0.00058	*Strombus b.*	Paleontology		Colantoni & Borsetti, 1973; Haerty & Dai Pra, 1987	1
74	Talamonaccio	TOSCANA	11.133	42.550	tidal notch	0.1	5.30	-0.01	0.00058		Morphostratigraphical correlation		Haerty & Dai Pra, 1987	1
75	Campo Regio	TOSCANA	11.183	42.533	lagoon deposits	2.0	6.00	0.00	0.00083	*Cerastoderma*	Aminostratigraphy		Haerty & Dai Pra, 1987	1
76	Argentario Promontory	TOSCANA	11.167	42.367	beach deposits	2.0	4.00	-0.02	0.00083	Senegalese fauna	Paleontology		Segre, 1959	2
77	San Angelino-Selva Nera	TOSCANA	11.467	42.383	lagoonal deposits	2.0	12.00	0.05	0.00084	*Cerastoderma*	Aminostratigraphy		Haerty & Dai Pra, 1987	1

78	Lasco del Pozzo	TOSCANA	11.467	42.383	lagoonal deposits	2.0	7.00	0.01	0.00083	*Cerastoderma*	Aminostratigraphy		Haerty & Dai Pra, 1987	1
79	Aurelia Km 115	LAZIO	11.567	42.383	lagoonal deposits	2.0	20.00	0.11	0.00085	*Cerastoderma*	Aminostratigraphy		Haerty & Dai Pra, 1987	1
80	Mandrione	LAZIO	11.650	42.317	lagoonal deposits	2.0	28.00	0.18	0.00088	*Strombus b.*	Paleontology		Bonadonna, 1967; Palieri & Sposato, 1988	1
81	Aurelia Km 103/122	LAZIO	11.667	42.300	beach deposits	5.0	30.00	0.19	0.00223	*Glycymeris Cerastoderma*	U-Th , ESR, Aminostratigraphy	82-115,	Haerty & Dai Pra, 1986; Radtke, 1986	1
82	Tarquinia Railway Station	LAZIO	11.733	42.233	beach deposits	5.0	27.00	0.17	0.00222	Senegalese fauna	Paleontology		Palieri & Sposato, 1988	1
83	Colle Olivastro	LAZIO	11.767	42.183	beach deposits	5.0	30.00	0.19	0.00223	*Strombus b.*	Paleontology		Haerty & Dai Pra, 1987	1
84	Monna Felice	LAZIO	11.907	42.055	beach deposits	5.0	35.00	0.23	0.00226	*Strombus b.*	Paleontology		Dai Pra, 1978; Haerty & Dai Pra, 1987	1
85	Cerveteri	LAZIO	12.067	41.950	lagoonal deposits	2.0	27.00	0.17	0.00088	*Strombus b., Cerastoderma*	Paleontology, Aminostratigraphy		Haerty & Dai Pra, 1987	1
86	Casale di Statua	LAZIO	12.150	41.933	lagoonal deposits	2.0	35.00	0.23	0.00092	*Strombus b., Cerastoderma*	Paleontology, Aminostratigraphy		Blanc, 1936; Haerty & Dai Pra, 1987	1
87	Roma	LAZIO	12.234	41.793	inner margin	3.0	20.00	0.11	0.00117		Morphostratigraphical correlation		Giordano et al., 2003	2
88	Borgo Sabotino	LAZIO	12.833	41.433	lagoonal deposits	2.0	10.00	0.03	0.00083	*Strombus b., Cerastoderma*	Paleontology, Aminostratigraphy		Blanc, 1935; Haerty & Dai Pra, 1986	1
89	Pontinia I	LAZIO	13.050	41.417	lagoonal deposits	2.0	5.30	-0.01	0.00083	*Cerastoderma*	Aminostratigraphy		Antonioli et al. 1999b	1
90	Pontinia II	LAZIO	13.067	41.417	lagoonal deposits	2.0	4.40	-0.01	0.00083	*Cerastoderma*	Aminostratigraphy		Antonioli et al. 1999b	1

91	Pontinia III	LAZIO	13.067	41.433	lagoonal deposits	2.0	2.30	-0.03	0.00083	*Cerastoderma*	Aminostratigraphy		Antonioli et al. 1999b	1
92	Pontinia IV	LAZIO	13.083	41.433	lagoonal deposits	2.0	0.80	-0.04	0.00083	*Cerastoderma*	Aminostratigraphy		Antonioli et al. 1999b	1
93	Pontinia V	LAZIO	13.083	41.450	lagoonal deposits	2.0	-0.50	-0.05	0.00084	*Cerastoderma*	Aminostratigraphy		Antonioli et al. 1999b	1
94	Pontinia VI	LAZIO	13.100	41.450	beach deposits	5.0	-15.50	-0.17	0.00088	*Cerastoderma*	U-Th, Aminostratigraphy	118±24	Barbieri et al., 1999	1
95	Borgo Vodice I	LAZIO	13.117	41.350	lagoonal deposits	2.0	1.00	-0.04	0.00083	*Cerastoderma*	Aminostratigraphy		Antonioli et al. 1999b	1
96	Borgo Vodice II	LAZIO	13.117	41.350	lagoonal deposits	2.0	-0.60	-0.05	0.00058	*Cerastoderma*	Aminostratigraphy		Antonioli et al. 1999b	1
97	Borgo Vodice III	LAZIO	13.117	41.350	lagoonal deposits	2.0	-1.80	-0.06	0.00084	*Cerastoderma*	Aminostratigraphy		Antonioli et al. 1999b	1
98	Breuil Cave	LAZIO	13.036	41.241	tidal notch	0.1	8.30	0.02	0.00058		Morphostratigraphical correlation		Bietti et al., 1990	1
99	La batteria, Circeo	LAZIO	13.042	41.235	top of lithophaga holes	2.0	8.00	0.02	0.00083		Morphostratigraphical correlation		Dai Pra & Ozer, 1985	2
100	Fossellone Cave	LAZIO	13.050	41.228	tidal notch	0.1	9.00	0.02	0.00058		Morphostratigraphical correlation		Blanc, 1936; Durante, 1975	1
101	Capre Cave, Circeo	LAZIO	13.060	41.224	tidal notch	0.1	9.60	0.03	0.00058		Morphostratigraphical correlation		Blanc & Segre, 1953; Durante & Settepassi, 1974; Ozer et al., 1987	1
102	Torre del Fico, Circeo	LAZIO	13.072	41.222	tidal notch	0.1	9.20	0.03	0.00058		Morphostratigraphical correlation		Dai Pra & Ozer, 1985	1
103	Guattari Cave, Circeo	LAZIO	13.100	41.233	tidal notch	0.1	9.20	0.03	0.00058		Morphostratigraphical correlation		Blanc & Segre, 1953; Durante & Settepassi, 1974; Ozer et al., 1987; Segre, 1991	1

104	Pisco Montano, Terracina	LAZIO	13.259	41.284	tidal notch	0.1	7.30	0.01	0.00058		Morphostratigraphical correlation		Antonioli et al. 1988	1
105	Fondi Plain	LAZIO	13.333	41.300	lagoonal deposits	2.0	-6.00	-0.10	0.00085	*Cerastoderma*	Aminostratigraphy		Antonioli et al. 1988	1
106	Sperlonga Promontory	LAZIO	13.440	41.254	tidal notch	0.1	7.30	0.01	0.00058		Morphostratigraphical correlation		Antonioli, 1991	1
107	Tiberio Cave	LAZIO	13.450	41.250	beach deposits	3.0	6.90	0.01	0.00115	*Glycymeris*	Aminostratigraphy		Antonioli et al. 1988; Antonioli, 1991	1
108	Torre Capovento	LAZIO	13.476	41.239	top of lithophaga holes	2.0	7.40	0.01	0.00083		Morphostratigraphical correlation		Ozer et al., 1987	2
109	S. Agostino	LAZIO	13.500	41.233	tidal notch	0.1	7.00	0.01	0.00058		Morphostratigraphical correlation		Antonioli, 1991	1
110	Areunauta	LAZIO	13.533	41.217	tidal notch	0.1	7.50	0.01	0.00058		Morphostratigraphical correlation		Antonioli, 1991	1
111	Gaeta I	LAZIO	13.567	41.217	tidal notch	0.1	5.30	-0.01	0.00058	*Glycymeris*	Aminostratigraphy		Antonioli, 1991	1
112	Minturno Promontory	LAZIO	13.687	41.248	tidal notch	0.1	9.40	0.03	0.00058		Morphostratigraphical correlation		Antonioli, 1991; Delicato, 1999	1
113	Garigliano coastal plain	CAMPANIA	13.783	41.217	lagoonal deposits	2.0	2.00	-0.03	0.00083	*Cerastoderma*	Aminostratigraphy		Delicato, 1999	1
114	Garigliano coastal plain	CAMPANIA	13.910	41.199	beach deposits	3.0	6.00	0.00	0.00115	*Glycimeris g., Venus sp., Laevicardium crassum, Spondylus gaederopus, Natica sp .*	Aminostratigraphy		Brancaccio et al., 1990	1
115	Volturno plain core	CAMPANIA	14.176	40.992	beach deposits	3.0	-50.00	-0.45	0.00147	*Cladocora coespitosa*	U-Th	126±10	Romano et al., 1994	2
116	Sarno plain core	CAMPANIA	14.476	40.728	foreshore deposits	5.0	-29.00	-0.28	0.00230		Morphostratigraphical correlation		Barra et al., 1991	3

117	Cala di Ieranto Sorrento Peninsula	CAMPANIA	14.340	40.574	tidal notch	0.1	6.80	0.01	0.00058	*Cladocora coespitosa*	U-Th	133±6	Brancaccio et al., 1978	1
118	Conca dei Marini Sorrento Peninsula	CAMPANIA	14.575	40.613	tidal notch	0.1	8.00	0.02	0.00058	*Cladocora coespitosa*	U-Th	128±5	Brancaccio et al., 1978	1
119	Tragara, Capri	CAMPANIA	14.260	40.536	tidal notch	0.1	8.10	0.02	0.00058		Morphostratigraphical correlation		Ferranti & Antonioli, unpublished	1
120	Vascio 'o Funno, Capri	CAMPANIA	14.267	40.543	tidal notch	0.1	7.50	0.01	0.00058		Morphostratigraphical correlation		Cinque., 1986; Ferranti & Antonioli, unpublished	2
121	Grotta Binocolo, Capri	CAMPANIA	14.215	40.565	tidal notch	0.1	5.40	0.00	0.00058		Morphostratigraphical correlation		Ferranti & Antonioli, unpublished	1
122	Cala Articolo, Capri	CAMPANIA	14.216	40.531	tidal notch	0.1	6.50	0.00	0.00058		Morphostratigraphical correlation		Ferranti & Antonioli, unpublished	1
123	Sele River coast	CAMPANIA	15.014	40.493	backshore deposits	5.0	17.00	0.09	0.00219	*Glycymeris Glycymeris, Glycymeris insubricus, Cardium edule*	Aminostratigraphy		Brancaccio et al., 1986	2
124	Punta Licosa - Cilento	CAMPANIA	14.909	40.243	marine terrace	9.0	9.00	0.02	0.00576		Morphostratigraphical correlation		Iannace et al., 2001	3
125	Palinuro Cape, Cilento	CAMPANIA	15.283	40.024	tidal notch	0.1	2.20	-0.03	0.00058	*Strombus b., Glycimeris gl.*	Paleontology; morphostratigraphical correlation		Antonioli et al., 1996	1
126	Porto Infreschi, Cilento	CAMPANIA	15.426	40.000	marine terrace	15.0	10.00	0.03	0.01498				Esposito et al., 2003	3
127	Sapri	CAMPANIA	15.629	40.071	beach deposits	3.0	15.00	0.07	0.00116		Morphostratigraphical correlation		Brancaccio et al.1990	2
128	Acquafredda	BASILICATA	15.671	40.036	inner margin	3.0	6.90	0.01	0.00115		Aminostratigraphy		Carobene & Dai Pra, 1991	2
129	Marina di Maratea	BASILICATA	15.738	39.955	inner margin	3.0	9.30	0.03	0.00115		Aminostratigraphy		Carobene & Dai Pra, 1991	2

130	Maratea (Punta Ludia)	BASILICATA	15.774	39.947	marine terrace	9.0	9.50	0.03	0.00576		Morphostratigraphical correlation		Carobene & Dai Pra, 1991	2
131	Praia a Mare (Porticello di Castrocucco)	CALABRIA	15.750	39.933	tidal notch	0.1	9.50	0.03	0.00058		Morphostratigraphical correlation		Carobene & Dai Pra, 1991	1
132	Praia a Mare (Dino Island)	CALABRIA	15.785	39.874	tidal notch	0.1	7.00	0.01	0.00058		Morphostratigraphical correlation		Carobene & Dai Pra, 1990	2
133	Scalea (Torre Talao)	CALABRIA	15.792	39.823	marine terrace	8.0	8.00	0.02	0.00467		Morphostratigraphical correlation		Carobene & Dai Pra, 1990	2
134	Cirella-Diamante	CALABRIA	15.820	39.700	tidal notch	0.1	10.00	0.03	0.00058		Morphostratigraphical correlation		Carobene & Dai Pra, 1990	1
135	Cetraro (Punta la Testa)	CALABRIA	15.926	39.526	tidal notch	0.1	12.00	0.05	0.00058		Morphostratigraphical correlation		Carobene & Dai Pra, 1990	2
136	Vibo Valentia Marina	CALABRIA	16.112	38.708	inner margin	20.0	50.00	0.35	0.02637	*Strombus b,, Cladocora coespitosa*	U\Th, Paleontology	121±7	Pata, 1947; Dai Prà et al. 1993	3
137	Vibo Valentia Marina	CALABRIA	16.112	38.708	inner margin	20.0	52.00	0.37	0.02639	*Strombus b,, Cladocora coespitosa, Glycymeris*	U\Th, Paleontology	130±8	Dumas et al., 1991	3
138	Briatico (Sacco)	CALABRIA	16.069	38.705	inner margin	20.0	153.00	1.18	0.02839		TL	134±13	Balescu et al, 1993	3
139	Briatico (Paradisoni)	CALABRIA	16.049	38.701	inner margin	20.0	140.00	1.07	0.02801		TL	128±13	Balescu et al, 1993	3
140	Briatico	CALABRIA	16.028	38.716	inner margin	20.0	216.00	1.68	0.03069		TL , Morphostratigraphical correlation		Balescu et al, 1993; Tortorici et al., 2003	3
141	Capo Vaticano	CALABRIA	15.868	38.603	inner margin	20.0	120.00	0.91	0.02751		Morphostratigraphical correlation		Miyauchi et al., 1994	2
142	Capo Vaticano	CALABRIA	15.878	38.613	inner margin	20.0	285.00	2.23	0.03415	*Patella ferruginea, Clanculus granoliratus, Columbella Rustica, Myoforceps aristata, Cardita senegalensis*	Paleontology, Morphostratigraphical correlation		Barrier et al., 1988, Tortorici et al., 2003	3

143	Gioia Tauro Basin (C.da Iannì)	CALABRIA	15.940	38.550	inner margin	20.0	90.00	0.67	0.02690	*Strombus b.*	Paleontology		Bonfiglio et al, 1988, Miyauchi et al., 1994	2
144	Gioia Tauro	CALABRIA	16.040	38.530	beach deposits	4.0	65.00	0.47	0.00196	*Strombus b.*	Paleontology		Cosentino & Gliozzi, 1988	2
145	Scilla	CALABRIA	15.715	38.248	inner margin	20.0	125.00	0.95	0.02763		Morphostratigraphical correlation		Miyauchi et al., 1994	2
146	Villa San Giovanni	CALABRIA	15.669	38.218	inner margin	20.0	143.00	1.10	0.02810		Morphostratigraphical correlation		Miyauchi et al., 1994	2
147	Villa San Giovanni	CALABRIA	15.671	38.208	inner margin	20.0	170.00	1.31	0.02893		Morphostratigraphical correlation		Valensise & Pantosti, 1992; Dumas & Raffy, 2004	3
148	Villa San Giovanni	CALABRIA	15.673	38.200	inner margin	20.0	175.00	1.35	0.02910		TL , Morphostratigraphical correlation		Balescu et al, 1993; Catalano et al., 2003	3
149	Capo Zafferano	SICILIA	13.537	38.115	tidal notch	0.1	7.00	0.01	0.00058	*Strombus b., Arca s.p.*	Aminostratigraphy		Antonioli et al., 1994	1
150	Capo Gallo	SICILIA	13.289	38.190	beach deposits	2.0	2.00	-0.03	0.00083	*Strombus b.*	Paleontology		Gignoux, 1913	1
151	Castellamare -Terrasini	SICILIA	13.025	38.058	beach deposits	3.0	18.00	0.10	0.00117		TL	101±43	Mauz et al., 1997	2
152	Castellamare -Terrasini	SICILIA	13.045	38.080	beach deposits	3.0	12.00	0.05	0.00116		TL	131±43	Mauz et al., 1997	2
153	Castellamare	SICILIA	12.865	38.050	beach deposits	2.0	5.00	-0.01	0.00083		TL	140±24	Mauz et al., 1997	2
154	San Vito lo Capo	SICILIA	12.716	38.151	tidal notch	0.1	8.00	0.02	0.00058	*Strombus b.*	Paleontology		Antonioli et al., 1999c; Antonioli et al., 2002;	1
155	San Vito lo Capo	SICILIA	12.720	38.110	inner margin	3.0	14.00	0.06	0.00116	*Strombus b.*	Paleontology		Antonioli et al., 1999c; Antonioli et al., 2002;	1

156	Cofano-Trapani	SICILIA	12.557	38.043	inner margin	3.0	20.00	0.11	0.00117	*Strombus b.*	Paleontology		Antonioli et al., this volume	1
157	Marettimo	SICILIA	12.084	37.971	tidal notch	0.1	8.20	0.02	0.00058	senegalese fauna	Paleontology		Malatesta, 1957; Abate et al., 1996; Antonioli et al., 1999c	1
158	Favignana	SICILIA	12.345	37.929	tidal notch	0.1	12.50	0.05	0.00058	*Strombus b.*	Paleontology		Malatesta, 1957; Abate et al., 1992	1
159	Levanzo	SICILIA	12.352	37.981	tidal notch	0.1	5.00	-0.01	0.00058	*Strombus b.*	Paleontology		Malatesta, 1957	1
160	Marsala, Torre Scibiliana	SICILIA	12.477	37.726	inner margin	3.0	34.00	0.22	0.00123	*Strombus b.*	Paleontology		Ruggieri et al., 1976; Ruggieri & Unti, 1988; D'Angelo & Vernuccio, 1996	2
161	Pachino	SICILIA	15.110	36.748	beach deposits	3.0	15.00	0.07	0.00116	*Strombus b.*	Paleontology		Malatesta, 1985	2
162	S. Lorenzo	SICILIA	15.095	36.765	beach deposits	2.0	4.00	-0.02	0.00083		Morphostratigraphical correlation		Antonioli et al., this volume	3
163	Avola	SICILIA	15.139	36.899	beach deposits	2.0	5.00	-0.01	0.00083		Morphostratigraphical correlation		Antonioli et al., this volume	3
164	Contrada Fusco	SICILIA	15.262	37.074	inner margin	3.0	85.00	0.63	0.00179		ESR on mammal teeth, Morphostratigraphical correlation		Rhodes, 1996; Bianca et al., 1999	3
165	Augusta Mt. Tauro	SICILIA	15.216	37.279	inner margin	3.0	16.00	0.08	0.00116	*Strombus b.*	*Strombus b.*		Di Grande & Scamarda, 1973; Di Grande & Neri, 1988; Antonioli et al., this volume	1
166	Catania (Leucatia)	SICILIA	15.085	37.543	inner margin	20.0	165.00	1.27	0.02876		K-Ar on lava flows		Monaco et al., 2002	2
167	Aci Trezza	SICILIA	15.147	37.568	beach deposits	5.0	175.00	1.35	0.00510		K-Ar on lava flows		Monaco et al., 2002	2
168	Taormina	SICILIA	15.291	37.854	beach deposits	5.0	115.00	0.87	0.00339	*Patella ferruginea*	ESR	76.4±7, 103.3±12.5 124.5±15	Antonioli et al., this volume	2

169	Taormina	SICILIA	15.295	37.870	tidal notch	0.1	130.00	0.99	0.00215		Morphostratigraphical correlation		Bonfiglio, 1991	3
170	Taormina	SICILIA	15.300	37.890	inner margin	20.0	185.00	1.43	0.02946		Morphostratigraphical correlation		Catalano & De Guidi, 2003	3
171	Capo d Alì	SICILIA	15.419	38.011	inner margin	20.0	140.00	1.07	0.02801		Morphostratigraphical correlation		Antonioli et al., this volume	2
172	Capo d Alì	SICILIA	15.429	38.021	inner margin	20.0	210.00	1.63	0.03044		Morphostratigraphical correlation		Catalano & De Guidi, 2003	3
173	Capo Peloro\Ganzirri	SICILIA	15.604	38.270	inner margin	20.0	110.00	0.83	0.02728	*Strombus b.*	Paleontology		Bonfiglio & Violanti, 1983; Hearty & Bonfiglio, 1987	1
174	Milazzo	SICILIA	15.235	38.203	marine terrace	20.0	90.00	0.67	0.02690	*Glycymeris*	Aminostratigraphy		Haerty 1986	3
175	Tyndari	SICILIA	15.041	38.153	top of lithofaga holes	2.0	85.00	0.63	0.00147		Morphostratigraphical correlation		Gliozzi & Malatesta, 1982	3
176	Naso	SICILIA	14.793	38.148	inner margin	20.0	130.00	0.99	0.02775		Morphostratigraphical correlation		Catalano & Di Stefano, 1997; Antonioli et al., this volume	2
177	Acquedolci	SICILIA	14.744	38.157	inner margin	20.0	130.00	0.99	0.02775		Morphostratigraphical correlation		Bonfiglio, 1991	3
178	Cefalù	SICILIA	14.029	38.042	beach deposits	4.0	29.00	0.18	0.00165		Aminostratigraphy		Antonioli et al., this volume	2
179	Lipari	SICILIA	14.945	38.467	inner margin	20.0	45.00	0.31	0.02633		Morphostratigraphical correlation		Lucchi et al., 2004	3
180	Lipari	SICILIA	14.945	38.467	beach deposits	4.0	30.00	0.19	0.00166		U-Th	50-87±20	Radtke, 1986; Lucchi et al., 2002	2
181	Salina	SICILIA	14.945	38.467	inner margin	3.0	50.00	0.35	0.00135		Morphostratigraphical correlation		Lucchi et al., 2004 a, b	2

182	Filicudi	SICILIA	14.569	38.574	inner margin	3.0	45.00	0.31	0.00131		Morphostratigraphical correlation		Lucchi et al., 2004 a, b	2
183	Filicudi	SICILIA	14.569	38.574	beach deposits	2.0	5.00	-0.01	0.00083		ESR	78-141	Radtke, 1986	3
184	Panarea	SICILIA	15.058	38.628	inner margin	3.0	115.00	0.87	0.00237		Morphostratigraphical correlation		Lucchi et al., 2004 a, b	2
185	Panarea	SICILIA	15.071	38.649	beach deposits	5.0	50.00	0.35	0.00237		Aminostratigraphy		Hearty, 1986	2
186	Ustica	SICILIA	13.192	38.708	inner margin, beach deposits	3.0	30.00	0.19	0.00121	*Cladocora coespitosa*	U-Th	132±5 - 121±7	Ruggieri amd Buccheri 1968; de Vita et al., 1998, Hearty 1986	1
187	Lampedusa	SICILIA	12.608	35.506	tidal notch, beach deposits	0.1	8.00	0.02	0.00058	*Strombus b.*	Paleontology		Segre, 1960, Buccheri et al., 1999	1
188	Ravagnese	CALABRIA	15.657	38.081	inner margin	20.0	129.00	0.98	0.02773	*Strombus b., Glycimeris gl.*	Paleontology, TL, aminostratigraphy	116±13	Bonfiglio, 1972; Dai Pra et al., 1974; Balescu et al., 1997; Hearty, 1986; Hearty et al., 1986 a o b	2
189	Bovetto	CALABRIA	15.664	38.065	inner margin	20.0	140.00	1.07	0.02801	*Strombus b., Glycimeris gl.*	Paleontology, TL , aminostratigraphy	116±12	Bonfiglio, 1972; Balescu et al., 1997; Hearty, 1986; Hearty et al., 1986; Miyauch et al., 1994; Gignoux, 1913	2
190	Pellaro (Nocella)	CALABRIA	15.658	38.018	inner margin	20.0	175.00	1.35	0.02910	*Strombus b., Glycimeris gl.*	Paleontology, aminostratigraphy		Dumas et al., 1987b; 1988	2
191	Lazzaro	CALABRIA	15.677	37.968	inner margin	20.0	146.00	1.12	0.02818	*Glycimeris*	Aminostratigraphy		Dumas & Raffy, 1993	2
192	Locri	CALABRIA	16.227	38.297	inner margin	20.0	92.00	0.69	0.02693		Morphostratigraphical correlation		Dumas et al., 1995	2
193	Soverato	CALABRIA	16.520	38.690	inner margin	20.0	104.00	0.78	0.02716		Morphostratigraphical correlation		Dumas & Raffy, 1996	2
194	Crotone	CALABRIA	17.111	39.096	inner margin	20.0	83.00	0.62	0.02678	*Strombus b. ,Cardita calyculata senegalensis; Hyotissa hyotis*	Paleontology, TL	142±20, 149±64	Palmentola et al., 1990; Mauz & Hassler, 2000	2

195	Crotone	CALABRIA	17.111	39.056	inner margin	20.0	100.00	0.83	0.02708	*Strombus b.*	U-Th, Paleontology, aminostratigraphy	123	Gliozzi, 1988; Cosentino and Gliozzi, 1988; Zecchin et al., 2004	2
196	Fiume Trionto right bank	CALABRIA	16.793	39.574	inner margin	20.0	130.00	0.99	0.02775		Morphostratigraphical correlation		Cucci, 2004	3
197	Rossano	CALABRIA	16.636	39.583	marine terrace	20.0	140.00	1.07	0.02801		Morphostratigraphical correlation		Cucci, 2004	3
198	Spezzano	CALABRIA	16.396	39.681	inner margin	20.0	135.00	1.03	0.02788		Morphostratigraphical correlation		Cucci, 2004	3
199	Francavilla	CALABRIA	16.396	39.808	inner margin	20.0	145.00	1.11	0.02815		Morphostratigraphical correlation		Cucci, 2004	3
200	Trebisacce	CALABRIA	16.520	39.687	inner margin, beach deposits	20.0	130.00	0.99	0.02775		Aminostratigraphy		Cucci, 2004	2
201	Avena River, right bank	CALABRIA	16.550	39.897	inner margin	20.0	142.00	1.09	0.02807		Morphostratigraphical correlation		Cucci and Cinti, 1998	3
202	Avena River, left bank	CALABRIA	16.589	39.977	inner margin	20.0	120.00	0.91	0.02751		Morphostratigraphical correlation		Cucci and Cinti, 1998	3
203	Capo Spulico	BASILICATA	16.618	39.987	inner margin	20.0	135.00	1.03	0.02788		Morphostratigraphical correlation		Cucci and Cinti, 1998	3
204	Piano San Nicola (Nova Siri)	BASILICATA	16.591	40.133	inner margin	20.0	115.00	0.87	0.02739		Morphostratigraphical correlation		Cucci and Cinti, 1998	3
205	Sinni River, right bank	BASILICATA	16.609	40.161	inner margin	20.0	85.00	0.63	0.02682		Morphostratigraphical correlation		Dai Pra & Hearty, 1988	2
206	Sinni River, left bank	BASILICATA	16.628	40.204	inner margin	20.0	75.00	0.55	0.02666		Morphostratigraphical correlation		Cotecchia & Magri, 1967; Dai Pra & Hearty, 1988	2
207	Agri river, right bank	BASILICATA	16.641	40.223	inner margin	20.0	75.00	0.55	0.02666		Morphostratigraphical correlation		Dai Pra & Hearty, 1988	2

208	Agri river, left bank	BASILICATA	16.676	40.260	inner margin	20.0	60.00	0.43	0.02647		Morphostratigraphical correlation		Dai Pra & Hearty, 1988	2
209	Cavone river, right bank	BASILICATA	16.694	40.285	inner margin	20.0	60.00	0.43	0.02647		Morphostratigraphical correlation		Dai Pra & Hearty, 1988	2
210	Cavone river, left bank	BASILICATA	16.725	40.335	inner margin	20.0	50.00	0.35	0.02637		Morphostratigraphical correlation		Dai Pra & Hearty, 1988	2
211	Castellaneta - Ponte del re	PUGLIA	16.947	40.520	inner margin	20.0	45.00	0.31	0.02633	*Strombus b.*	Paleontology, Aminostratigraphy		Boenzi et al., 1985; Caldara,1988; Dai Pra & Hearty, 88; Hearty & Dai Pra 92	1
212	Taranto - Ponte Romano	PUGLIA	17.172	40.530	inner margin	20.0	37.00	0.25	0.02627	*Cladocora coespitosa*	U-Th	107.7±1.5	Mastronuzzi and Sansò 2002	1
213	Mass. Ruggiero	PUGLIA	17.220	40.484	inner margin	20.0	37.00	0.25	0.02627	*Strombus b.*	Paleontology, OSL	93±8	Mastronuzzi, 2001; Mastronuzzi & Sansò, 2002	1
214	Mass. Santa Teresiola	PUGLIA	17.257	40.508	beach deposits	5.0	28.00	0.18	0.00223	*Strombus b., Cladocora coespitosa*	Paleontology, U-Th	125±6, 205±20, 162+23/-18, 89.8 ±4.8, 93+8.8/-8.1	Dai Pra & Stearns,1977; Hearty & Dai Pra 1992; Mastonuzzi e Sansò, 2002	1
215	Punta Penne	PUGLIA	17.270	40.484	beach deposits	5.0	28.00	0.18	0.00223	*Strombus b.*	Paleontology		Dai Pra & Stearns,1977; Caldara & Laviano, 1980; Hearty & Dai Pra,1985, 1992	1
216	Mass. San Pietro	PUGLIA	17.317	40.508	beach deposits	5.0	28.00	0.18	0.00223	*Strombus b., Cladocora coespitosa*	Paleontology		Dai Pra and Stearns, 1977; Caldara and Laviano, 1980; Dai Pra and Hearty, 1988; Hearty and Dai Pra 1985; 1992; Belluomini et al., 2002;	1
217	Casa d'Ajala	PUGLIA	17.328	40.488	inner margin, beach deposits	3.0	24.00	0.14	0.00119	*Strombus b.*	Paleontology		Gigout, 1960; Dai Pra & Stearns, 1977; Mastronuzzi & Sansò, 2003	1
218	Il Fronte	PUGLIA	17.314	40.477	beach deposits	3.0	24.00	0.14	0.00119	*Strombus b.*	Paleontology, U-Th, Aminostratigraphy	125, 126, 123;	Gignoux, 1913; Gigout, 1960; Dai Pra & Stearns, 1977; Hearty & Dai Pra, 1985, 1992	1
219	Mass.Tuglia - Mass.Pantaleo	PUGLIA	17.292	40.468	beach deposits	3.0	24.00	0.14	0.00119	*Strombus b., fauna senegalensis*	Paleontology		Dai Pra & Stearns, 77; Mastronuzzi, 2001, Mastron. & Sansò 2002	1
220	Mass. Abate Resta	PUGLIA	17.274	40.425	beach deposits	3.0	24.00	0.14	0.00119	*Strombus b.*	Paleontology		Mastronuzzi & Sansò, 2002	1

221	San Giorgio Masseria Baronia	PUGLIA	17.697	40.758	inner margin	3.0	24.00	0.14	0.00119	*banal fauna*	Morphostratigraphical correlation		Mastronuzzi, 2001; Mastronuzzi & Sansò, 2002	2
222	Taranto - Torre San Vito- Torre Castelluccia	PUGLIA	17.227	40.408	beach deposits	3.0	17.00	0.09	0.00116	*Cladocora coespitosa*	U-Th, Aminostratigraphy	138±14; 139,6±4.5	Dai Pra & Stearns. 1977, Dai Pra & Hearty, 1988; Hearty & Dai Pra,1985, 1992; Belluomini et al. 2002; Cita e Castradori, 1994	1
223	Torre Castelluccia	PUGLIA	17.375	40.349	beach deposits	3.0	26.00	0.16	0.00119	*Glycimeris*	Aminostratigraphy		Dai Pra & Stearns. 1977, Hearty & Dai Pra, 1992; Cita e Castradori, 1994	2
224	Lizzano - Canale dei lupi	PUGLIA	17.432	40.377	beach deposits	3.0	26.00	0.16	0.00119	*Strombus b.*	Paleontology		Cotecchia et al. 1971, Hearty & Dai Pra 1992	1
225	Torre Castiglione	PUGLIA	17.820	40.288	beach deposits	3.0	2.00	-0.03	0.00115	*Strombus b.*	Paleontology, U-Th	156±20	Dai Pra & Stearns, 1977; Dai Pra, 1982; Hearty & Dai Pra, 1992	1
226	Torre Sabea	PUGLIA	18.009	40.081	beach deposits	3.0	2.00	-0.03	0.00115	*Strombus b.*	Paleontology		Cotecchia et al., 1969; Hearty & Dai Pra, 1985, Hearty & Dai Pra, 1992	1
227	Gallipoli	PUGLIA	17.996	40.065	beach deposits	3.0	5.00	-0.01	0.00115	*Strombus b.*	Aminostratigraphy		Cotecchia et al., 1969; Hearty & Dai Pra, 1985, Hearty & Dai Pra, 1992	1
228	Canale della Volpe	PUGLIA	17.996	40.065	beach deposits	3.0	3.00	-0.02	0.00115	*Strombus b.*	Aminostratigraphy		Hearty & Dai Pra, 1992	1
229	Grotta del Diavolo/Capo Santa Maria di Leuca	PUGLIA	18.347	39.792	beach deposit - speleothems	2.0	6.00	0.00	0.00083		Morphostratigraphical correlation		Mastronuzzi and Sansò, 2003	2
230	Marina di Novaglie	PUGLIA	18.391	39.855	marine terrace	15.0	25.00	0.15	0.01501		Morphostratigraphical correlation		Parroni, F. & Silenzi, S., 1997	2
231	Marina di Novaglie	PUGLIA	18.394	39.862	marine terrace	15.0	25.00	0.15	0.01501		Morphostratigraphical correlation		Parroni, F. & Silenzi, S., 1997	2
232	Grotta Romanelli	PUGLIA	18.434	40.017	tidal notch	0.1	9.80	0.03	0.00058		Morphostratigraphical correlation		Cosentino & Gliozzi (1988); Di Stefano et al. (1988); Bordoni & Valensise (1998)	2
233	Torre Santa Sabina	PUGLIA	17.704	40.760	beach deposit	2.0	3.00	-0.02	0.00083		Palethnology		Mastronuzzi and Sansò 2003	2

234	T.Mattarelle-T.Guaceto	PUGLIA	17.799	40.717	beach deposit	2.0	4.00	-0.02	0.00083		Palethnology		Di Geronimo (1970); Mastronuzzi & Sansò (1998); Bordoni & Valensise (1998)	2
235	Villanova-Monopoli	PUGLIA	17.504	40.815	beach deposit	3.0	30.00	0.19	0.00121		Palethnology		Di Geronimo, 1970); Iannone & Pieri 1979; Bordoni & Valensise, 1998	2
236	Fortore floodplain	PUGLIA	15.287	41.881	inner margin	3.0	25.00	0.15	0.00119		Morphostratigraphical correlation		Mastronuzzi at al. (1989); Bordoni & Valensise (1998)	3
237	Metauro River	MARCHE	13.295	43.672	inner margin	3.0	7.00	0.01	0.00115		Morphostratigraphical correlation		Vannoli et al., 2004	2
238	Arzilla River	MARCHE	13.104	43.780	inner margin	3.0	15.00	0.07	0.00116		Morphostratigraphical correlation		Vannoli et al., 2004	2
239	Conca River	EMILIA-ROMAGNA	12.675	43.982	inner margin	3.0	16.00	0.08	0.00116		Morphostratigraphical correlation		Vannoli et al., 2004	2
240	core 205 S10	EMILIA-ROMAGNA	12.222	44.681	beach deposit	10.0	-112.50	-0.96	0.00841		Morphostratigraphical correlation, ESR	124±20	Amorosi et al., 2004	2
241	core223 S17	EMILIA-ROMAGNA	12.229	44.569	beach deposit	10.0	-105.00	-0.90	0.00824		Palinologic curve, ESR		Amorosi et al., 1999	2
242	core 222 S2	EMILIA-ROMAGNA	11.856	44.515	beach deposit	10.0	-85.50	-1.00	0.00783		Palinologic curve, ESR		unpublished data (A. Amorosi)	2
243	core 223 S12	EMILIA-ROMAGNA	12.124	44.455	beach deposit	10.0	-100.00	-0.86	0.00813		Palinologic curve, ESR	154±26	Amorosi et al., 2004	2
244	core 240 S8	EMILIA-ROMAGNA	12.283	44.343	beach deposit	10.0	-117.00	-0.70	0.00853		Palinologic curve, ESR	129±18	Amorosi et al., 2004	2
245	Venezia	VENETO	12.326	45.439	lagoonal deposits	2.0	-79.00	-0.68	0.00157		Palinologic curve,		Kent et al., 2002	2
246	Trieste	FRIULI	13.770	45.648	Inner margin	20.0	-20.00	-0.21	0.02625		Morphostratigraphical correlation		Albrecht and Mosetti 1987	3

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