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Coastal Environmental Change
During Sea-Level Highstands:
A Global Synthesis with implications
for management of future coastal change

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Quaternary coastal morphology and sea level changes

**Project 437**

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# Late Holocene sea-level changes in southern Apulia (Italy)

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## Geomorphological setting

The Apulia region represents the emerged part of the foreland domain of both Apenninic and Dinaric orogens; it is slightly deformed and it is affected by Apenninic and anti-Apenninic trending faults that determine different geodinamic units characterised by different uplift. Uplift of the Apulia region began during the Middle Pleistocene, when the thick continental lithosphere - the Apulian swell - reached the subduction hinge and offered resistance to flexure, thus causing the buckling of the foreland (Doglioni et al.,1994). Uplift rates along the southern Italian coast have been calculated by using OIS 5e shoreline and related deposits, in some places defined by the characteristic phauna with *Strombus bubonius* Lamarck, and assuming the eustatic sea level during OIS 5e to be about 6 m above the present position (Cosentino and Gliozzi, 1988; Hearty and Dai Pra, 1992; Westway, 1993; Bordoni and Valensise, 1998).

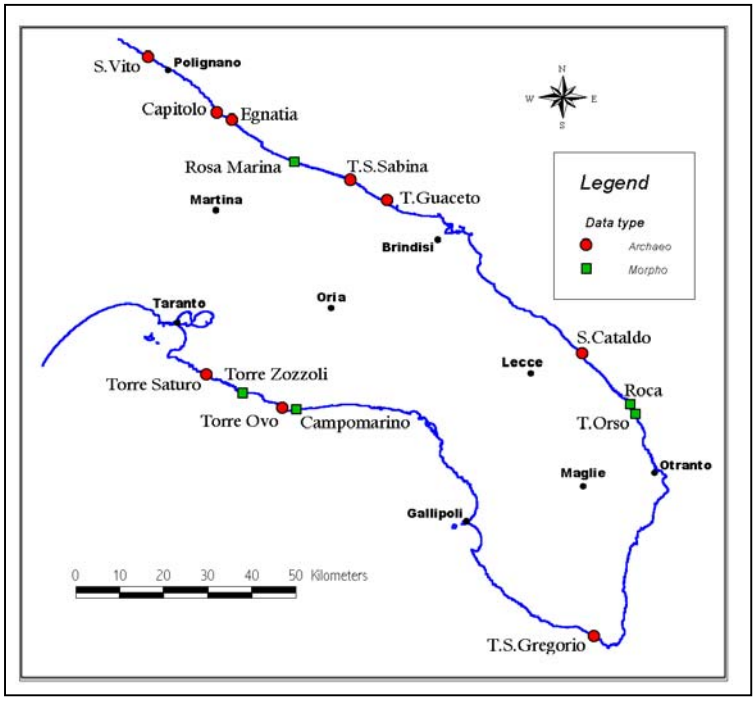


**Figure 1.** Localization of the archeological sites and geomorphological evidence.

Uplift rates decrease from north-west to south-east along the Ionian coast of Apulia; rates range, in fact, from 0.31 m/ka at the north-west of Taranto (Ponte del Re locality) to 0.03 m/ka at Gallipoli.

The landscape of the southeasternmost part of Apulia is characterised by low karstified plain surfaces dissecated by a poorly developed drainage network; the coastline is studded by a number of fresh water springs and coastal swamps and lakes.

Human activity and settlements localised along the coast since the Neolithic. The presence of coastal lagoon for hunting/fishery activities and coastal plain for agricultural activity determined the development of settlements during Bronze Age and preclassic Messapic times (Gravina, 1982).

During the second millennium b.C., the rise of numerous of settlements first and the Greek town-states then marked the southern Adriatic and Ionian coasts. During Roman times, the main towns of Apulia - *Tarentum*, *Brundisium, Hydruntum* and *Kallipolis* - were connected to Rome by a network of roads. Some of them as Via Traiana and Via Appia, ran along the coast and studded by a lot of villages, the *mantiones*. During the medieval age the coastal area was abandoned because of coastal swamps developement and malaria desease outspreading.

## Geomorphological, geochronological and archaeological data

In the Mediterranean basin, the reconstruction of past sea-levels can be made using some geomorphological (beachrock, notches, wave cut platforms) and archaeological (submerged structures as harbour groins, quarries, sewers, tombs and so on) indicators.

## Beach/dune deposits

Three generations of Holocene dune belt have been found along the coast of southern Apulia (Mastronuzzi & Sansò, 2002). Numerous radiocarbon age determinations performed on pulmonate gastropods point out that they developped during three distinct morphogenetic phases occurred about 6-7 ka, 3-2 ka and during the middle age.

The oldest one is about parallel to the present coastline or form small dune fields at major inlets. Along the Adriatic coast (Rosa Marina locality), the aeolianite grades downward into a beach deposit characterised by bioturbation; the contact is placed at about 1 m above m.s.l.. $^{14}$C age determination performed on some specimens of *Helix* sp. collected at the base of the aeolianite yielded the conventional age of 6084±52 years BP (6934 +/- 70 cal years BP). Luminescence age determination suggest an age of 5400 years BP. Along the Ionian coast a more complete sequence has been recognised. To the North of Campomarino harbour, at Scorcialupi locality, infact, a beachrock crop out along a strip stretching up to 65 +/- 10 cm above the limit of living brown algae. The beachrock is formed of medium-sized sand particles well cemented and moderately-sorted; they are a packstone composed essentially by fragments of molluscs, red algae, echinoids, briozoan, benthic foraminifers, intraclasts; detrital grains are also present. Isopachous carbonatic cement forms fringes of uniform crystals grew radially to grain surfaces, while interparticle voids are filled of micrite rarely peloidal, in which are dispersed small silty-sized skeletal fragments.

These diagenetic features indicate early cementation of beachrock in intertidal environment under marine-phreatic condition; on the other hand the silty matrix indicate an emergence and a second phase of diagenesis in vadose environment.

The beachrock grade upward into emerged beach sediments, marked by discontinuous level of small pebbels, first and then into an aeolianite with remains of pulmonate gastropods (*Helix* sp.). $^{14}$C AMS analysis performed on a *Helix* sp. shell collected at the dune layers just above the beach deposits yielded the conventional age of 6600 years BP (7546 +/- 21 cal years BP).

## Wave cut platforms

A wave cut platform cut through weak calcareous sandstones of Pliocene age marks the coast between Torre dell'Orso and Torre Sant'Andrea, to the north of Otranto. The platform is placed up to 2.5 m above present sea-level, up to 40 m wide and backed by a cliff up to 8 m high. In the small ria of Torre Santo Stefano a notch is modelled in continuity to the platform inner margin (Mastronuzzi *et al*., 1994). Radiocarbon age determinations have been performed on shells and on vermetids encrousting boulders scattered on the platform surface and belonging to storms deposits. They suggest that the shaping of the wave-cut platform should occurred before 1.5 ka BP. In the Taranto area (San Pietro island) a wave cut platforms shaped on 5a biocalcarenites is at about 0.60 cm a.m.s.l.. Roman pottery (*sigillata africana*) enclosed in brown algae which encrust the outer margin of the platform has been found (Dini et al., 2000).

## Archaeological data

Numerous archaeological structures have been found below present sea-level along the southern Apulia coast. Along the Adriatic coast, in Torre Guaceto site, Northern of Brindisi, pile's holes of huts of a village ascribed to Bronze

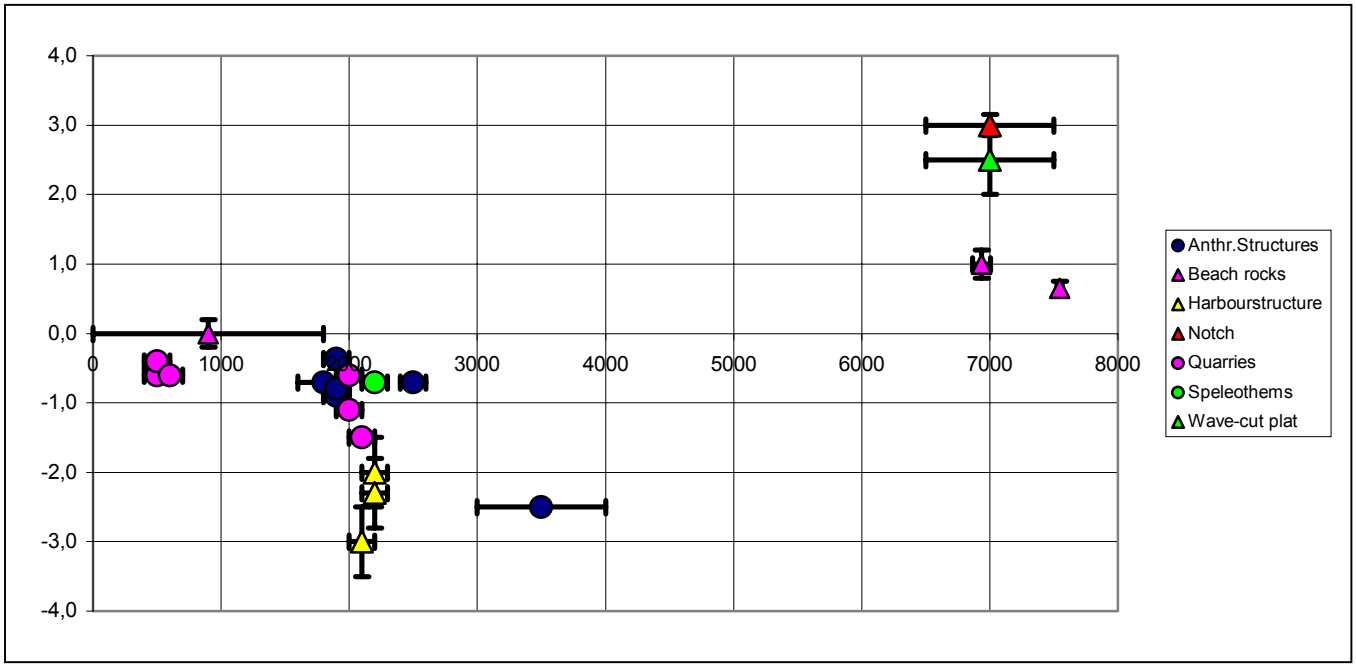


**Figure 2.** Age-depth diagram made with data from archaeological sites, $^{14}$C age determinations and geomorphological evidences of relative sea-levels indicators.

age (about XV century b.C.) have been found between 0.5 and 2.5 m below sea-level.Egnatia, near Monopoli on Adriatic coast, is a very important site for sea level reconstruction. Here, in the perimeter of the Messapic town, quarries show the base at about 0.5 ÷ 1.5 m below present sea-level. Some of them are cut by pseudosarcophagus graves aged between V and IV century b.C. which are totally below present sea level with the bottom at -0.2 ÷ -0.7 m. Submerged graves of pre-Roman and Roman age have been found also at San Vito near Polignano and in Torre Santa Sabina. Along the Ionian coast, at Torre San Gregorio near Capo Santa Maria di Leuca, and in Torre Saturo near Taranto, harbour structures of Hellenistic age (II century b.C.) are present. They are made by heap of stones up to 80 m long and 40 m wide; the top of structures, elevated up to 4 m from sea bottom, are at about 2 ÷ 2.3 m below present sea-level. The last indicator of sea level rise since Hellenistic age is represented by the Grotta della Poesia Piccola, near Otranto. Here submerged speleothems (about 0.7 m deep) cover inscriptions aged at II century b.C. At Egnatia, harbour structures in *opus caementicium* of Roman age (I century b.C.) have the top at 3 m below present sea-level.

They were made in place by coffer-dam tecnique with the top at sea-level; unfortunately, the presence of a thin layer of pebble as foundation at the base produced in some case a slide of structures and then the impossibility to evaluate the sea level rise. Near these structures, a cistern watertight by means of *coccio pesto* shows its bottom up to 60 cm below present sea-level. In Egnatia, in San Vito and in the *mantiones* of *Karbina* (present Torre Santa Sabina near Brindisi) sewer channels of Roman age have the outlets at present 0.6 ÷ 0.9 m below present sea-level. Not dated, still enigmatic, anthropic structures have been found in San Cataldo locality, near Lecce along the Adriatic coast and in Torre Ovo, near Gallipoli, along the Ionian coast. They could represent remains of Greek-Roman constructions at present between 1.5 ÷ 3 m below present sea level. Lastly, medieval quarries whose bottom is up to 1 m below present sea-level are present near Torre Santa Sabina (Brindisi), Torre San Vito (Polignano) and Il Capitolo (Monopoli), along the Adriatic coast.

## Discussion

The geomorphological, archaeological and radiometric data collected on the studied coast do not allow the estimation of the precise sea level changes during the second half of the Holocene, mainly because of the lack of good indicators of past sea levels.

| N° | Sample | Locality | Remain | $\delta^{13}C_{PDB}$ (‰) | $\delta^{18}o$ (‰) | Uncalibrated Age (years BP) | Calibrated Age ) | Lab. | Reference |
|---|---|---|---|---|---|---|---|---|---|
| **Coastal dune belt** | | | | | | | | | |
| 1 | SSB3 | Dune deposit - TorreSanta Sabina | Pomatia sp. | -8,27 | -0,84 | 565±80 | 615 ± 31 | A | Dini et al, 2000 |
| 2 | - | Torre Castiglione | Helix sp. | - | - | 865 ± 90 | 745 ± 51 | - | Cotecchia et al., 1969 |
| 3 | - | Torre Castiglione | Helix sp. | - | - | 1995 ± 95 | 1961 ± 102 | - | Cotecchia et al., 1969 |
| 4 | Torre Canne 1 | Soil –Torre Canne | Helix sp. | - | - | 2110±90 | 2071 ± 86 | - | Magri & Zezza, 1970 |
| 5 | - | Punta Prosciutto | Helix sp. | - | - | 2160 ± 100 | 2113 ± 72 | - | Dai Pra & Hearty, 1989 |
| 6 | P17 | Dune belt - Fosso Pantore | Helix sp. | -7,09 | -2,15 | 2910±50 | 3019 ± 62 | A | Dini et al, 2000 |
| 7 | P8 (GX-26736) | Soil - Lido Morelli | Pomatia sp. | -5,5 | - | 4330±40 AMS | 4860 ± 20 | B | Present paper |
| 8 | SSB2 | Dune belt -Torre Santa Sabina | Helix sp. | -5,95 | -1,31 | 5290±120 | 6062 ± 130 | A | Dini et al, 2000 |
| 9 | - | Torre Zozzoli | Helix sp. | - | - | 5360 ± 115 | 6038 ± 44 | - | Cotecchia et al., 1969 |
| 10 | RM1 | Dune belt – Rosa Marina | Helix sp. | -6,53 | -0,89 | 5796±70 | 6595 ± 71 | A | Present paper |
| 11 | RMD (GX-18124) | Dune belt – Rosa Marina | Helix sp. | -7,4 | - | 6084±52 AMS | 6934 ± 70 | B | Dini et al, 2000 |
| 12 | TSL6 | Dune belt – Torre San Leonardo | Helix sp. | -7,48 | -1,41 | 6185±90 | 7187 ± 23 | A | Dini et al, 2000 |
| 13 | LB 1 | Torre San Vito | Helix sp. | -7,68 | - | 6386 ± 70 | 7294 ± 41 | A | Dini et al., 2000 |
| 14 | CAMPO 1 Gx 29910 | Dune belt – Campomarino | Helix sp | -6.8 | - | 6600 +/- 40 AMS | 7546 ± 21 | B | Present paper |
| 15 | - | Posto Li Sorci | Helix sp. | - | - | 6780 ± 125 | 7651 ± 92 | - | Cotecchia et al., 1969 |
| **Deposit on Wave cut platform** | | | | | | | | | |
| 16 | Orso 1 | Torre Santo Stefano | Travertino | - | - | 1358 ± 80 | 1280 ± 55 | A | Dini et al., 2000 |
| 17 | TS 2 | Otranto Torre Sant'andrea | Marine shell | -0.4 | - | 1920 ± 50 AMS | 1343 ± 75 | B | Present paper |
| 18 | TSS 7 | Torre Santo Stefano | Vermetids | - | - | 2060 ± 50 | 1484 ± 90 | A | Dini et al., 2000 |

**Table 1.** $^{14}C$ age (± 1s ) of Holocene dune belt occuring along the southern Apulia coast and of deposits lying the wave cut platform of Otranto. **A** - Laboratorio di Geochimica Isotopica, Università degli Studi, Trieste (Italia); **B** - Geochron Laboratoires Krueger Enterprises Inc. (Cambridge, Massachusets, U.S.A.).

On the contrary, a better definition of the post glacial maximum sea-level rise has been possible thank to the occurrence of Campomarino beach rocks and Rosamarina beach sediments. They mark the maximum position reached locally by the Holocene transgression at the end of the rapid postglacial eustatic sea level rise.

Along the Ionian coast, the Campomarino beach rock is at least up to 65 +/- 10 cm above present limit of living algae corresponding to biological sea level (Laborel and Laborel- Deguen, 1994).

Mean tidal range here is about 40 cm; it allows us to estimate calculate a high sea-level stand not less than 25 +/- 10 cm above present sea level whereas the first occurrence of *Helix* sp. in the following beach/dune deposit fixes it at about 7.5 ka cal BP. Along the Adriatic side, Rosa Marina beach deposit suggests similar indications. Here bioturbation are present up to 80 +/- 10 cm above limit of living algae. Due to the small tidal range, it is possible to identify a high sea-level stand of about 50 cm occurred about 7 ka cal BP as indicated by the age of Helix sp in the first dune levels. The indications coming from the presence of the wave cut platform of Torre Santo Stefano and of San Pietro island are less valuable, since no direct age determinations have been obtained. However, geomorphological and chronological data suggest that these particular landforms could be evidence of recent tectonic activity in southern Apulia (Selleri et al., 2003). More recent positions of sea level can be inferred by archaelogical. In particular, the harbour structures of the ancient Egnatia point out a position of sea level at -3 m about 2100 years BP even if this data could be slight affected by the occurrence of possible phenomena of collapse due to a layer of pebbles at the base of the structures. Similar positions of sea level at the same age are also indicated by Torre S. Gregorio and Torre Saturo harbour structures. Furthermore, Torre Guaceto pile's holes of huts referred to the Bronze age suggest lower position of sea level after the Middle Holocene high stand.

## Conclusion

The geomorphological, radiometric and archaeological data collated along the coast of southern Apulia allow us to define in broad lines the sea level changes during Mid - Late Holocene times.

Infact, notwithstanding the inaccuracy of the geological and chronological record, and the incompleteness of historical reports, the following scheme of events can be outlined:

a) after the last glacial low stand, sea-level rose quickly until about 7000 years BP reaching the maximum position at about 0,5 m above the present one; this high stand promoted a first, important phase of beach-dune belt formation;
b) sea level dropped up to about 2,5 m below present position at about 3500 years BP; a new phases of dune belts formation, of regional importance suggest that this phase was accompanied by the presence of wide and well nourished beaches;
c) from Bronze Age sea-level rose up to the present position with a minimum rate of 0.7 mm/year.

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