



## A Higher Sea Level During the Holocene in Sardinia? – New Findings Based on <sup>14</sup>C and OSL Dating

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*Italien  
Sardinien  
Holozän  
Meeresspiegelschwankung  
Radiokarbondatierung  
Lumineszenzdatierung*

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### War der Meeresspiegel bei Sardinien im Holozän höher? Neuergebnisse aus <sup>14</sup>C- und Lumineszenz-Datierungen

#### Zusammenfassung

Neue geologische Karten von Sardinien gaben Anlass, das Alter und die Bedeutung zahlreicher quartärer Ablagerungen zu überdenken. Um strittige Fragen zu klären, wurden an ausgewählten, in der Vergangenheit häufig untersuchten Aufschlüssen Proben sowohl für Radiokarbon- als auch für OSL-Datierungen entnommen. Die Ergebnisse lassen darauf schließen, dass Sardinien nicht, wie zumeist angenommen, tektonisch stabil war und der Meeresspiegel im Holozän zeitweilig höher lag als der heutige.

#### Abstract

New geological maps of Sardinia presented new evidence and perspectives which gave rise to a large debate on the age and significance of some Quaternary deposits. To solve the open questions, samples for radiocarbon and OSL dating were taken at various key sites along the coast of Sardinia. The results suggest that Sardinia is not tectonically stable as generally supposed and that the Holocene sea level was temporarily higher than the present-day level.

### 1. Introduction

The Mediterranean island of Sardinia is located between the Tyrrhenian and Balearic Sea, both being extensional and opening embryonic ocean basins far from the actively rising Apennine chain. It has been considered a stable area with an estimated mean sea level for the Mediterranean during the Last Interglacial at ca. 5 m asl (LAMBECK et al., 2004). Late Miocene marine deposits rest at ca. 700 m asl to the north of the Campidano basin suggesting a long term uprising. Moreover, in the same area and almost at the

same elevation Middle Pliocene Basaltic flows create a mesa landscape. These basalts are also found at depths of over 300 m below the sea level in boreholes of the Campidano area (POMESANO CHERCHI, 1971) revealing more complicated tectonic movements in a long term perspective. On a shorter time scale, the MIS 5e notches (Tyrrhenian stage), that are well known along the Orosei Gulf, vary in elevation between 8 and 12 m while at Calamosca (Cagliari Gulf), which is the type locality of the Tyrrhenian

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transgression, the Tyrrhenian stage is found at a maximum elevation of 3.8 m. At Calasetta, on the northern shore of the S. Antioco Island, the MIS 5e can be observed at sea level (CAROBENE & PASINI, 1987; COLTORTI et al., 2007). In recent years, an intense debate has started regarding the sea level changes along the coast of Sardinia, and more generally in the Mediterranean, during the Holocene (ANTONIOLI, 2007; COLTORTI et al., 2007). In fact, based on a review of the existing data around the Italian coasts, ANTONIOLI (2007), following the results reported in LAMBECK et al. (2004), and ANTONIOLI et al. (2007) stated that the present day level is the highest during the last 10 ka. On the contrary, following field evidence resulting from some of the new geological mapping of Sardinia (APAT, 2005; APAT, in press), COLTORTI et al. (2007) stated that many beach deposits previously attributed to the Tyrrhenian stage are in fact Holocene in age.

To support the field observations and clear any doubts, a series of samples were collected in the type localities of Is Arenas (Cagliari Gulf), Scala'e Croccas (Orsei Gulf), Santa Reparata (northernmost tip of Sardinia) and Capo S. Marco (Oristano Gulf) for  $^{14}\text{C}$  and OSL dating in order to have a review of all the most intriguing deposits along the Sardinian coasts.

## 2. Geological Setting

The Is Arenas site is a beach ridge to the rear of the Poetto beach and to the north of the S. Elia Cape, the latter splitting the Cagliari Gulf in two. The previous correlation of these slightly cemented sandy gravelly beaches to the MIS 5e marine high stand was mostly based on

- 1) their elevation of ca. 5–6 m asl,
- 2) the claim that few *Strombus bubonius* were found in this area and
- 3) the result of Isoleucine Epimerisation datings (ULZEGA et al., 1982; ULZEGA & HEARTY, 1986; HEARTY et al., 1986; BELLUOMINI et al., 1986; KINDLER et al., 1997).

APAT (2005) and COLTORTI et al. (2007) claim a Holocene age because

- 1) the beach ridge lies inside a downcutting valley affecting the Late Pleistocene and Early Holocene alluvial terraces,
- 2) they dam the present day alluvial deposits and
- 3) evidence of a deep weathering profile is missing.

The deposits at Scala 'e Croccas are beach ridges located more than 1 km inland from the present day coastline. It is made of sandy and gravelly material reaching an elevation of ca. 4–5 m asl. The correlation to MIS 5e is again associated to the previous map of this area. However, more recent works for the new geological map showed that these sediments belong to a series of beach ridges that rest seaward from an inactive sea cliff that marks the Holocene transgressional inner edge, cutting alluvial fan deposits that, in the south at Cala Gonone, cover the Tyrrhenian notches.

The Santa Reparata outcrop is located to the east of the isthmus connecting Capo Testa with the rest of Sardinia in its northernmost tip. This site was at first investigated by ULZEGA et al. (1982) and later ULZEGA & HEARTY (1986). In the opinion of these authors the coarse beach sands and gravels, which are very rich in molluscs but without *Strombus bubonius*, rest below aeolian deposits attributed to the Last Glaciation. On the contrary, a detailed stratigraphic investigation revealed that these deposits generated notches and seal fractures affecting the aeolianites and are therefore younger in age. Many datings are available for the aeolianites in the area indicating a Late Pleistocene age (APAT, in press), but again, like in many other sections of Sardinia, the  $^{14}\text{C}$  dating of marine shells gave unreliable ages due to

possible re-crystallisation. However, along the cliff these deposits evidently create a marine notch that affects slightly cemented and loose aeolian deposits whose sedimentation was interrupted by an organic soil.

The Capo S. Marco (Tharros Peninsula) deposits are located on the southwestern side of the promontory, close to the lighthouse. The sequence is composed of coarse gravels and boulders containing marine shell resting unconformably over cemented aeolianites and are locally creating a notch in these deposits at ca. 6–7 m asl. The inner edge of a marine terrace laterally connected with these deposits also rests at this elevation. Impressively, this sequence can be followed almost continuously to the eastern side of the promontory where the notch is located at ca 1.5 m asl, indicating important tectonic movements.

## 3. Samples and Methods

Recent excavations at Is Arenas exposed organic mud at ca. 9 m below the surface, which was used for radiocarbon dating. The layer contains lagoonal shells (*Ceritium*, *Cardium*, etc.). Three samples were taken for OSL dating in the overlying sandy layers as well as in a nearby abandoned quarry.

Four samples of loose, middle to coarse grained sands were collected for OSL at the beach ridges of Scala 'e Croccas and one sample of cemented aeolianite at Capo S. Marco. Special treatment with hydrochloride acid was needed to dissolve the carbonate cementation of the aeolianite.

At Santa Reparata, one sample for OSL was collected from aeolian deposits and the organic soil interrupting the aeolian sedimentation was taken for radiocarbon dating.

Coarse grained quartz (100–200  $\mu\text{m}$ ) was used for the OSL measurements, and the De values of the samples were obtained by a SAR protocol. The dose rate was calculated using high-resolution gamma-ray spectrometry. The OSL ages were obtained by dividing the De values with the dose rate.

## 4. Results and Discussion

The results of the Is Arenas section indicate that the beach ridges evolved in historical times. The reason for that could be the rapid slope erosion following deforestation and later long shore drifting of sediments coming from the Riu Corongiu, a major stream creating a large fan delta to the north of the Poetto beach.

The deposits of Capo S. Marco can be attributed to the Holocene, thus indicating not only a higher sea level than the present-day one but also ongoing noteworthy tectonic movements in this part of Sardinia.

Furthermore, the Capo S. Marco and Santa Reparata deposits are associated with a clear marine notch whose mean elevation reflects the mean sea level (CAROBENE & PASINI, 1987). At least an elevation of ca 1–1.5 m asl is documented in both sites and in the latter, it reaches a mean elevation of ca 6–7 m asl on the western side of the promontory confirming not only that the present day mean sea level is not the highest reached during the Holocene but also that Sardinia is tectonically not stable, just like the rest of Italy and the Mediterranean. Thus, it is rather difficult to establish the mean sea level during the MIS 5e and the Holocene because of the variable local response to neotectonic movements that affected also the "stable" areas such as Sardinia.

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