U/TH DATING OF A CLADOCORA CAESPITOSA FROM CAPO SAN MARCO MARINE QUATERNARY DEPOSITS (SARDINIA, ITALY)

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ABSTRACT: A whole specimen, not reworked and well preserved of Cladocora caespitosa has been found within the marine Quaternary deposits, outcropping along the eastern coast of the Capo San Marco Promontory. The U/Th dating of this sample has provided a minimum age of 70 ± 4 ka B.P. This dating allows to state that these marine deposits, containing the coral, are not Holocene in age.

Keywords: marine Quaternary deposits, Cladocora caespitosa, U/Th dating, Tyrrhenian, Sardinia.

1. INTRODUCTION

The Geological Survey of Italy, concerning the institutional activities related to the realization of the Geological Map of Italy at 1:50,000 scale (CARG Project), has done quick geological surveys to check and monitoring some sample areas of the 528 Oristano Geological Sheet (middle-western Sardinia), still in progress. In particular, marine and continental Quaternary deposits were taken into account. In the middle-western Sardinia, Sinis Peninsula and eastern coast of the Capo San Marco Promontory, these deposits occurred in peculiar outcroppings which have been studied in detail by several Authors (Maxia & Pecorini, 1968; Ulzega et al., 1982; Carboni & Lecca, 1985; Davaud et al., 1991; Kindler et al., 1997; Melis et al., 2001; Lecca & Carboni, 2007; Andreucci et al., 2009; Coltorti et al., 2010; Thiel et al., 2010).

The research has especially addressed marine Quaternary deposits, in relation with a scientific debate which has recently risen about the chronological attribution of these deposits (AIQUA, 2007; Bartolini et al., 2008; Catto, 2010). In the 528 Oristano Geological Sheet “the beach and beach ridge deposits” have been chronologically attributed to Holocene age, instead of the Upper Pleistocene age (Tyrrhenian) reported in literature and in the official Geological Map of Italy (Regione Autonoma della Sardegna, 1989).

During the field activity many fossils have been collected including a specimen of Cladocora caespitosa which has been dated with the U-series method.

The aim of this note is to give a additional element to dating the Quaternary deposits outcropping in this area of the Sardinia Region, and to provide a useful contribution to the scientific debate in progress.

2. GEOLOGICAL SETTING

The Capo San Marco Promontory, which from a...
The geomorphological point of view extends a few kilometers offshore, represents the end of the Sinis Peninsula (Fig. 1). The western coast consists of an high and steep Miocene-Pliocene cliff, while the eastern coast, gently dipping seaward, is mainly made of marine and continental Quaternary deposits. In this area, in fact, the pre-Quaternary bedrock crops out only in a few sites along of the coast where the Quaternary deposits were dismantled by the intense wave action.

The basal portion of the substrate is represented by the Capo San Marco Formation (Cherchi et al., 1978), divided into two facies: the lower one consists of "dark grey clays" and the upper one is made of "marly - calcareous deposits". The outcropping thickness is about 50 m, the age is Upper Tortonian – Lower Messinian.

The Nuraghe Baboe Formation (Spano, 1989) overlies the marly - calcareous deposits of the Capo San Marco Formation, with a transgressive unconformity surface. This unit consists of a marine succession made of breccias, conglomerates, sandstones, calcareous sandstones, silty-marly clays, calcarenites and marly clays.

<table>
<thead>
<tr>
<th>Sample</th>
<th>ppm U</th>
<th>$^{230}<em>{\text{Th}}$/ $^{232}</em>{\text{Th}}$</th>
<th>$^{238}<em>{\text{U}}$/ $^{230}</em>{\text{U}}$</th>
<th>($^{234}<em>{\text{U}}$/ $^{238}</em>{\text{U}}$)</th>
<th>$^{230}<em>{\text{Th}}$/ $^{234}</em>{\text{U}}$</th>
<th>Age (ka)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capo San Marco</td>
<td>3.098 ± 0.088</td>
<td>81.398 ± 2.306</td>
<td>1.124 ± 0.024</td>
<td>1.151 ± 0.029</td>
<td>0.478 ± 0.018</td>
<td>70 ± 4</td>
</tr>
</tbody>
</table>

Table 1 - Uranium content, uranium and thorium activity ratios and age of the coral.
U/Th dating of a Cladocora caespitosa from Capo San Marco ...

...mudstone. The thickness is about 35 m, the age is Lower Pliocene.

The Golfo di Oristano basalt Formation (Costa Randata facies), unconformably overlying on the previous formations, represents the top and the southern cliff of the promontory. These basalts, dated 3.12 Ma (Bec-caluva et al., 1985), are made of several superimposed flows and their maximum thickness is about 30 m; the occurrence of columnar structures suggests a slow cooling of the lavas.

3. OBSERVATIONS ON QUATERNARY DEPOSITS

The Quaternary deposits widely crop out in the area of the 528 Oristano Geological Sheet. The best and more complete stratigraphic sections occur near the San Giovanni di Sinis area, within which some Authors recognize different facies (Maxia & Pecorini, 1968; Ulzega et al., 1982; Carboni & Lecca, 1985; Davaud et al., 1991; Kin-dier et al., 1997; Melis et al., 2001; Lecca & Carboni, 2007; Andreucci et al., 2009; Collotti et al., 2010). Quaternary deposits have been also recognized along the fossil beach ridge that closes the Cabras lagoon. These deposits are formed by Thyrrenian bioclastic calcarenites (Forti & Orrù, 1995).

The Quaternary deposits crop out without interruption all over the eastern coast of the Capo San Marco Promontory, from the southernmost end up to 1 km to the north of Tharros archeological site.

These deposits are often fractured, disrupted and prone to fall and topple landslides due to the intense marine erosive processes acting along the coasts of the promontory.

At the tip of the promontory the basalts are overlapped by aeolian deposits, made of well cemented...
quartz-sandstone, characterized by high angle cross stratification with foresets landward dipping.

The aeolian deposits continue below sea level and are characterized by a recently formed tidal notch.

These deposits are modelled by a flat marine erosional surface, gently sloping seaward, located at about 4 m above sea level, delimited upslope by a notch of about 50 cm of height.

This surface is capped by 1 m-thick marine deposit. The lower portion consists on huge prevailing basalt blocks, well rounded, with a diameter up to 50 cm, in a well cemented, gravelly-sandy matrix, with abundant fossils. The upper part consists of a well cemented level of coarse to medium fossiliferous sandstone. The fossils are mostly bivalves (Anomia ephippium, Arca noe, Fissurella italica, Glycimeris sp., Cardium sp., ostreids) and gastropods (Murex taurinensis, Trochocochlea turbinata, Pupura haemastoma, Patella ferruginea).

The age of the aeolian deposits, assigned using OSL dating on a sample collected just above the notch, is 174 ± 13 ka, thus referable to the Middle Pleistocene (Thiel et al., 2010).

At La Caletta Site (Fig. 2) a marine deposit crops out at present-day sea level. This deposit is composed by huge meter-sized, well rounded basaltic boulders, in a gravelly-sandy supporting matrix, rich in fossils (Ostrea sp., Arca noe, Glycimeris sp., Patella ferruginea, etc.). This sedimentary body, dipping 10° seaward, rise upward for a few meters along the slope. It is completely capped by Upper Pleistocene aeolian quartz-sandstones which deep below sea level. In this site the geometrical relationships between these deposits can be observed in a three-dimensional view.

During the field survey it was noteworthy the finding of one whole specimen of Cladocora caespitosa at about 2.5 m above sea level. This fossil has been collected from marine Quaternary deposits unconformably lying on the bedrock with an articulated erosional surface. The specimen not reworked and well preserved has been considered suitable for an isotopic dating according to the U/Th method.

4. U/TH DATING

Corals are considered excellent samples to be dated with U-series disequilibria methods because in most cases they consist of pure calcium carbonate, free from a detrital component that makes problematic the dating of dirty carbonates.

The 230Th/234U method is the most widely used dating technique applied to corals and is based on the extreme fractionation of the parent isotopes 238U and 234U from their long-lived daughter 230Th in the hydrosphere. Uranium, markedly more soluble than Th in the surface and near-surface environments, is readily mobilised as the highly soluble uranyl ion (UO2²⁺) and its complexes, whereas Th is easily hydrolyzed and precipitated or adsorbed on detrital particles. Uranium is co-precipitated with CaCO₃ on exsolution of CO₂.
while Th is generally negligible. In the absence of detrital Th, 230Th only forms in situ by radioactive decay of co-precipitated U. In a closed system the extent to which the 230Th/234U activity ratio has returned towards unity is a function of time, taking into account also the state of disequilibrium between 234U and 238U (Kaufman & Broecker, 1965). Moreover, it is important to verify the original aragonitic nature of the coral and check the eventual presence of calcite. The occurrence of relevant calcite indicate that weathering processes have affected the coral after its burial, with consequent opening of the chemical system. In this case, semi-quantitative X-ray diffractometry analysis has evidenced the aragonitic nature of the coral with the presence of moderate calcite amount (Fig. 6) that can be estimated around approximately 10%.

About 3 g of coral were ultrasonically washed in deionized water and dissolved in nitric acid. Few milliliters of hydrogen peroxide were added and heated at 100 °C in order to destroy organic matter. Isotopic complexes of uranium and thorium were extracted according to the procedure described in Edwards et al. (1986) and alpha-counted using high resolution ion implanted Ortec silicon surface barrier detectors. The age, 70 ± 4 ka, was calculated by means of Isotop/Ex (version 3.0), a plotting and regression program designed by Ludwig (2003) for radiogenic-isotope data. U-series data are reported in Table I. Errors are quoted as 1σ.

The U/Th dating on a sample of Cladocora caespitosa has provided an age of 70 ± 4 ka B.P. The specimen of Cladocora caespitosa, not reworked and well preserved, was sampled at about 2.5 m above sea level within the marine Quaternary deposits, overlying the Miocene-Pliocene bedrock, along the eastern coast of the Capo San Marco Promontory.

This finding agrees with the results reported in Dorale et al. (2010) and Tuccimei et al. (2010), inferred from phreatic overgrowths on speleothems in coastal caves of Mallorca (Balearic Islands - Spain). These authors assert that the western Mediterranean relative sea level stood at about 1m above present sea level during marine Isotope Stage 5a, between ~ 82 and 80 ka ago. Furthermore, the data of Mallorca coastal caves, show good coherence with those observed from Tuccimei et al. (2012) in the Capo Caccia area (north-western Sardinia), located not far from Capo S. Marco.

The U/Th dating of Cladocora caespitosa allows to state that the marine deposits outcropping along the eastern coast of the Capo San Marco Promontory are not Holocene in age, as reported in the documents and maps up to now realized for the 528 Cristiano Geological Sheet, still in progress.

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