

The submerged neolithic burials of the Grotta Verde at Capo Caccia (Sardinia, Italy). Implication for the Holocene sea-level rise

I reperti neolitici sommersi rinvenuti presso la Grotta Verde (Capo Caccia, Sardegna). Implicazioni sulla risalita del mare olocenica

ANTONIOLI F. (*), FERRANTI L. (**), LO SCHIAVO F. (***)

RIASSUNTO – Le ricerche sulle oscillazioni del livello marino nel corso dell'Olocene nell'area tirrenica, effettuate mediante osservazioni dirette lungo le fasce costiere emerse e sommerse, sono state favorite nel settore di Capo Caccia (Sardegna nord-occidentale) dal contributo dei dati archeologici provenienti dal sito sommerso della Grotta Verde dove ricerche e scavi archeologici effettuati dalla Soprintendenza Archeologica per le provincie di Sassari e Nuoro hanno rivelato l'esistenza di una necropoli neolitica attualmente sommersa dal mare.

La necropoli è ubicata in una piccola camera alla profondità di -8.5 m, raggiungibile da un "lago" terminale (in diretto contatto con il mare) posto nella porzione più bassa della Grotta Verde. All'interno delle sepolture, collocate in nicchie naturali o parzialmente ricavate nella roccia, sono stati recuperati reperti ceramici ed alcune ossa appartenenti a scheletri umani. L'ornamentazione di tipo "cardiale" presente sul vasellame ha consentito di accertare che la necropoli è stata frequentata a partire da una fase avanzata del Neolitico inferiore 5300-4700 cal. BC(1).

Le implicazioni paleoclimatiche legate al dato archeologico, in seguito ad una attenta valutazione geomorfologica, hanno fornito la possibilità di discriminare fra la componente eustatica e la subsidenza durante la risalita del mare nel corso dell'Olocene. Per ottenere informazioni sulla stabilità tettonica di Capo Caccia sono state effettuate numerose indagini sia di superficie che sottomarine. Forme e depositi marini, che per la loro continuità e rilevanza sono riferibili al periodo Eutirreniano, sono stati rinvenuti in 4 località ad un'altezza costante di 3.8 metri s.l.m., che risulta comparabile ad uno dei substadi dello stadio 5 della curva isotopica dell'ossigeno.

L'accertamento della stabilità tettonica nell'area di Capo Caccia a partire dall'Eutirreniano (125 ka) consente di fissare il livello marino di 7300-6700 anni fa ad una profondità inferiore a -10 m, corrispondente ad una finestra-pozzo nella parte più

bassa della camera sepolcrale. Questo dato è in ottimo accordo con le curve di oscillazione del livello marino, ed in particolare con quella calibrata sulla regione tirrenica.

PAROLE CHIAVE: necropoli Neolitica sommersa, geomorfologia costiera e subacquea, risalita olocenica del livello del mare, Sardegna.

ABSTRACT – In the Grotta Verde at Capo Caccia, located on the western flank of Sardinia (Italy), archeological underwater surveying by the Soprintendenza Archeologica per le provincie di Sassari e Nuoro revealed the existence of submerged Neolithic burials at -8.5 m depth, including pottery with "cardial" ornamentation (5.300-4700 cal. BC corresponding to 7300-6700 years BP). Submersion of such burials, previously related to a marked and very recent subsidence of Capo Caccia, was studied by means of coastal and scuba-diving surveys in order to collect data on the long-term geomorphological evolution and tectonic stability of the area. Marine forms and deposits referred to the Eutyrrhenian and chronologically corresponding to the stage 5e (125 ky) of the oxygen isotopic curve, were found in different localities at Capo Caccia to occur at an altitude of + 3.80 m a.s.l., broadly comparable to the Eutyrrhenian worldwide sea-level. By demonstrating a quite final tectonic stability of the Capo Caccia area at least from the Eutyrrhenian time, we were able to achieve 7300-6700 BP sea level at least -10 m lower than present one. This information is in good agreement with curves of Holocene sea-level rise in Tyrrhenian area and documents the "normal" tectonic behaviour of Capo Caccia.

KEY WORDS: submerged Neolithic burials, coastal and underwater geomorphology, Holocenic sea level rise, Sardinia.

(*) Department of Environment, ENEA Casaccia. Via Anguillarese 301, I-00060 Rome,

(**) Dipartimento di Scienze della Terra, Università "Federico II" di Napoli

(***) Soprintendenza Archeologica per le provincie di Sassari e Nuoro

(1) Si riporta questa terminologia utilizzata in ambito archeologico. Tradotta nel linguaggio usualmente utilizzato nell'ambito della geologia del Quaternario si deve intendere: 7300-6700 BP calibrato.

1. - INTRODUCTION

In the frame of a research project on the Quaternary geology of Capo Caccia, located on the western flank of Sardinia, Italy (fig. 1), we carried out a survey along both the coastal and the underwater belt. Underwater research, by means of direct investigations of submerged morphostructures and deposits, allowed to enlarge our field area and to gain further insights into events eventually not recorded on land. Our research, dealing with late Pleistocene-Holocene sea level oscillations and paleoenvironmental variations in this sector of Sardinia, has been greatly aided by the availability of archeological data from the Grotta Verde, which provided sound constraints on the timing and amplitude of quoted sea-level oscillations.

Capo Caccia, located about 12 km west of Alghero, is a N-S elongated promontory bounded by steep cliffs (fig. 1). The rugged physiography, subject to fast-modeling morphogenetic processes, has allowed preservation of morphologic and stratigraphic records of past sea-levels only in conservative settings like caves and small inlets, where we concentrated our research.

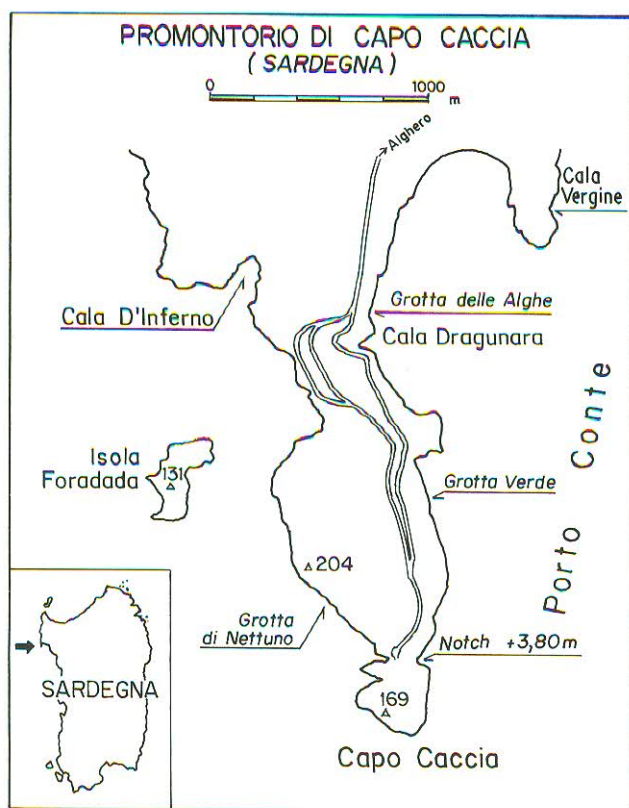


Fig. 1 - Map of Capo Caccia, showing the location of sites quoted in the text. Inlet shows location of Capo Caccia in Sardinia island.
Carta topografica di Capo Caccia con l'ubicazione dei siti studiati

2. - GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The geological setting of Capo Caccia is characterized by the abundance of carbonate rocks mostly of Cretaceous age, deposited in wide platform domains placed on the north-western side of Tethys along the European continental margin (CHERCHI, 1985). A weak deformation reached the sedimentary successions of Capo Caccia during alpine tectonogenesis (TREMOLIERS *et alii*, 1984), when Sardinia was the foreland to the western Alpine belt. Later extensional deformation occurred during the opening of western Mediterranean basins in the Paleogene-early Neogene, and minor block-faulting occurred until recently.

Carbonate rocks are mostly affected by high angle normal faults which downthrow towards the western continental margin. Normal faults and associated fractures pivoted the late Neogene-Quaternary morphogenesis, which modeled the present configuration of the promontory and individuated karst systems along structural discontinuities.

Stratigraphic successions at Capo Caccia show a southward-younging trend. More in detail, a Vaalngian-Campanian sequence (CHERCHI *et alii*, 1987) outcrop south of the saddle formed by Cala Dragunara and Cala d'Inferno (fig. 1), which has formed on a WNW-ESE trending fault and separates the promontory proper from the mainland. The successions dip toward S, and the Grotta Verde is formed within younger beds (Coniacian-Santonian in age). Prevailing lithofacies are represented by bioclastic limestones with scattered rudistid mounds.

The Cretaceous sequence is affected by NW-SE trending normal faults which displace toward SW, and by N-S normal faults which displace toward E into the Porto Conte bay.

The promontory is characterized by a steeper profile on the western side, which faces the open Mediterranean Sea, with sheer cliffs at places 300 m high that continues underwater down to depths of 50 m b.s.l.; easterly, the slope is less steep toward Porto Conte bay and the sea-bottom along the coastline does not reach great depths.

Quaternary marine and transitional deposits at Capo Caccia have been studied by MALATESTA (1953; 1954) and by PECORINI (1963), who described the paleontological contents of Tyrrhenian beaches in particular in the Grotta di Nettuno (fig. 1); according to cited Authors, in the surroundings of the town of Alghero (east of Capo Caccia) Tyrrhenian deposits with *Strombus bubonius* lay between + 2 and + 5 m a. s. l., locally more, and are cove-

red by several generations of eolianites. ANTONIOLI *et alii* (1994) outlined the geomorphological evolution of the Grotta delle Alghe, located less than 1 km north of the Grotta Verde; the Authors point out the existence of a notch at + 3.8 m a.s.l. related to the Eutyrrhenian, and of lithic industry and meal remains (*Patella* sp. and *Trochus* sp. shells mainly) of likely mesolithic age.

3. – SPELEOLOGICAL ASPECTS OF THE GROTTA VERDE

Inside the carbonate successions several caves, presently located both below and above sea level, were formed during the late Neogene-Quaternary. Among those, the Grotta Verde represents one of the most relevant due its remarkable dimensions (fig. 2). It is located on the bayward side of the promontory, facing the Porto Conte bay, named *Portus Nimpharum* by the Romans (fig. 1).

The entrance is at + 88 m a.s.l., and leads to an impressive half-emerged vaulted room about 30 m high. Huge columns decorate the *foyer* of the cave and are covered by green mosses and lichens, to which the cave owes its name (verde=green). The lens-shaped room deepens westward, becoming than a narrow descending meander that leads, among other lateral branches, to a terminal room occupied by a lake. The submerged part of the cave below the lake is formed by a subvertical hole dipping into a small room at -8.5 m depth. From there, a narrow tunnel leads to a window at -10 m depth, which faces a larger room with bottom at -40 m. From there, other galleries branches and develop toward still partly unexplored systems and possibly to the open sea. Along the walls of the main room, a decimetric-thick black band is continuously observed at a depth of -10 m b.s.l. (FODDAI *et alii*, 1975). It is mostly formed by Fe and Mn-oxides as revealed by analysis performed on a similar crust covering a speleothem, which has been sampled in the nearby Grotta Dragunara (2).

The upper part of the Grotta Verde has formed along an antithetic NW-SE normal faults dipping 60° toward NE, and similar fracture systems have been pivoting the speleogenesis also in the lower part of the cave. Deeper part formed probably during a first stage, when the lateral extension of the promontory was likely larger than presently. An-

cient larger Capo Caccia could have provided a more significant water supply than what can be done today, leading to the development of the large cave system and huge speleothem concretions. Also the present localization of the cave, hanging over a sheer cliff, document that the promontory has been modified in space and dimensions after the early formation of the cave. Thus, early speleogenetic phases date back before last significant episodes of block-faulting, and can be attributed to the early Quaternary if not earlier.

Subsequently, during the upwards development of the karst system, the entrance room enlarged and the cave came to the light due to a combination of progressive rockfall and dissolution along the fault.

4. – THE SUBMERGED NEOLITHIC BURIALS

In the small room at -8.5 m depth (fig. 2), archeological underwater surveying and excavations carried out by the Soprintendenza Archeologica per



Fig. 2 – Speleothems near the entrance of Grotta Verde. Enormi speleotemi concrezionano l'ingresso della Grotta Verde.

(2) Analysis has been kindly provided by E. Franco - Dipartimento di Scienze della Terra of Napoli.

le provincie di Sassari e Nuoro, revealed the existence of submerged burials (TANDA, 1980; PALLARES, 1981; LAMBERTI *et alii*, 1986; LO SCHIAVO, 1987); inside the graves, set along the sidewall partly in natural niches and partly cut by the inhabitants within the rockbed, ceramic material and few human bones were recovered. The pottery was intentionally left in the burials, as documented by the finding of several intact samples. Other pots were found in the large submerged room at -4 and -22 m depth.

The "cardial" ornamentation on the pottery allowed to refer the burials to the later phase of Ancient Neolithic (LAMBERTI *et alii*, 1985) of Western Mediterranean, dated in Sardinia at 7300-6700 years BP (LO SCHIAVO 1987, TAYKOT, 1994).

Such findings document that this sector of the cave experienced the stable occupation of the Ancient Neolithic peoples, when the sea-level was *at least* -10 m below the present one, to allow the use of the Necropolis. The inhabitants used the fetch water through the window from the large room; a freshwater layer overlaying the sea-water probably existed at that time in the large room, as it occurs presently in the terminal lake. Occasionally, pots fell down in the room, where they have been recovered

by first explorers on small terraces along the steep walls (TANDA, 1980). Surely, the sea-level was some metres lower than the Necropolis in the tunnel at -8.5 m depth, since ropes were used to fetch water (likely the fresh lens above sea-water).

In order to constrain the archeological attribution by absolute dating, we performed ^{14}C analysis on the bones. Unfortunately the bad state of preservation of bone due to the long underwater standing made dating so far unsuccessful. Some bones were fragmented or even dissolved during the underwater excavation.

5. - GEOMORPHOLOGICAL EVOLUTION OF CAPO CACCIA AREA

The geomorphological implications of the archeological data are of fundamental importance to constrain the late geodynamic evolution of the area. Moreover, the constraints on sea-level exerted by archeological evidences can be evaluated in a more regional frame. Data from the coastal (both emerged and underwater) belt of the Tyrrhenian Sea are synthetized in a sea-level curves of ALESSIO *et alii*

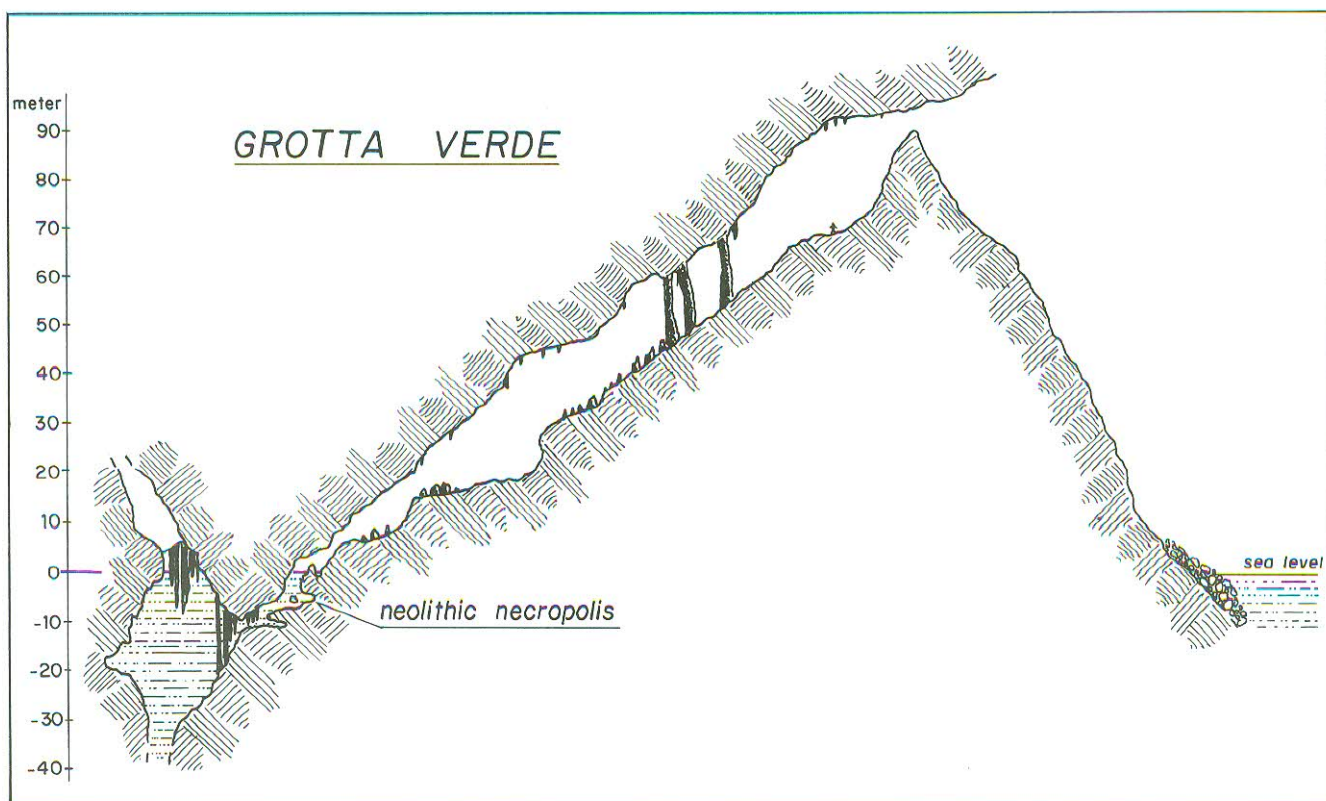


Fig. 3 - Topographic section across the Grotta Verde.
Sezione topografica della Grotta Verde.



Fig. 4 – The continuous black band on the speleothemes into the Grotta di Nettuno at 3.8 m a.s.l.
 La banda scura di ossidi di ferro e manganese sugli speleotemi all'interno della grotta di Nettuno a +3,8 m s.l.m.

(1992), and ANTONIOLI & FERRANTI (1994) who show oscillations that occurred in this basin since 40.000 y BP and during the Holocene, respectively. In order to insert correctly in this frame the archaeological data from the Grotta Verde, we carried on investigations on the late Pleistocene-Holocene geomorphological evolution and on the tectonic stability of Capo Caccia by means of coastal and scuba-diving underwater surveys.

A sea-level indicator has been found recurrently at an elevation of + 3.8 m a.s.l. In the well-known Grotta di Nettuno (Neptune cave), located on the western side of the promontory, the + 3.8 level is marked into the cave by a continuous black band (on limestones and speleothemes), similar to and sharing an analogous significance with the one found in at -10 m in the Grotta Verde.

An interesting section with marine deposits is observed within some coastal caves at Cala Vergine (fig. 3), on the eastern side of Capo Caccia. The marine deposit, overlaying ancient rockfall debris (Cr), outcrops in the northernmost cave (fig. 3a). Two different facies are observed: a) lithified marine conglomerate with extremely rounded clasts encrusted by bryozoans and seaweeds (Cm). The de-

posits fill ancient pot-holes and is few metres thick. Mollusk fragments and very few specimens of *Conus testudinarius* are present; b) Cladocora-bearing biocalcarene, which extensively mantle the cave walls (Ca). Said deposits are affected by *Lithophaga* holes up to + 3.8 m a.s.l. where they interrupt in correspondence of a notch.

The upper part of the cala Vergine sequence is observed in the southern cave (fig. 3b). Notch and marine deposits of the northern cave are stratigraphically followed by continental deposits, represented by about 3 m of well-cemented reddish sands with small-size mammal bones and pulmonate gastropods (S) intercalated by cave-calcite layers (Al). The sands evolve to stratified and lithified talus breccia (Br), in turn passing to cross-laminated eolianites (Eol). Red loose sands (Tr) hosting prehistoric meal remnants (mostly *Patella* and *Trochus*) terminate the succession, which attains a maximum thickness of about 6 m.

In the Grotta delle Alge (ANTONIOLI *et alii*, 1994), a notch at + 3.8 m a.s.l. has been observed; the relative transgression has been followed by alternating pulses of continental deposition and re-incision with similar evolutive trends to Cala Vergine.

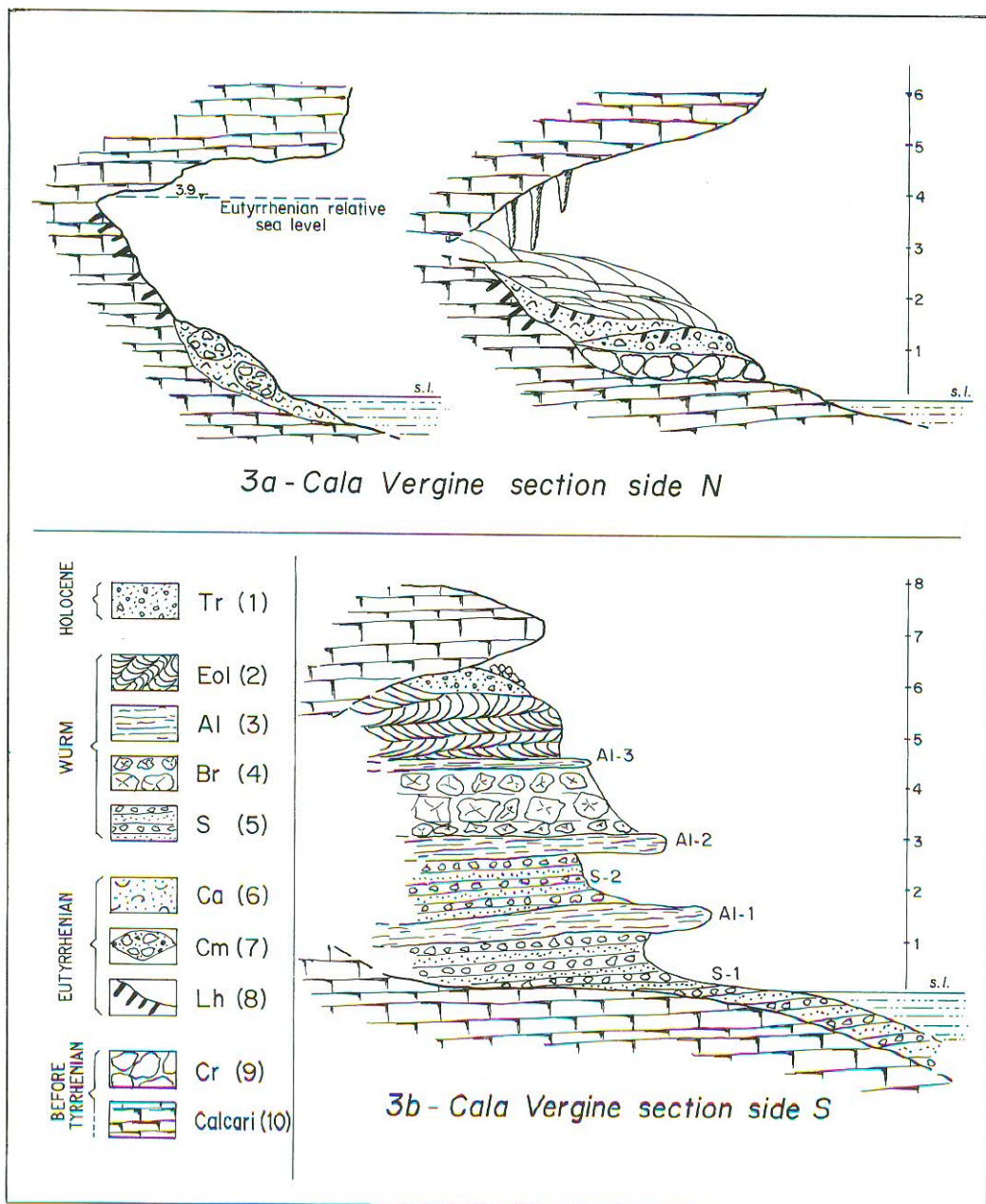


Fig. 5 - Coastal section at Cala Vergine showing the morpho-stratigraphical relationships between late Pleistocene deposits.
 Sezioni morfo-stratigrafiche presso Cala Vergine

LEGEND - LEGENDA

- | | |
|--|--|
| 1) Reddish sands with <i>Patella</i> and <i>Trochus</i> , hosting ancient human tools | 6) Organogenic calcarenite with <i>Cladocora</i> and <i>Conus textudinarius</i> |
| 1) <i>Terre rosse sciolte</i> con <i>Patella</i> , <i>Trochus</i> , <i>industria litica</i> | 6) <i>Calcareniti organogene</i> a <i>Cladocora</i> e <i>Conus textudinarius</i> |
| 2) Eolianite | 7) Well cemented beach conglomerate |
| 2) <i>Sabbie eoliche cementate</i> | 7) <i>Puddinghe ad elementi cementati</i> |
| 3) Calcite encrust and layers | 8) Lithophaga holes |
| 3) <i>Banchi alabastrini</i> e <i>concrezioni stalagmitiche</i> | 8) <i>Fori di organismi litofagi</i> |
| 4) Stratoid breccia | 9) Consolidated rockfalls |
| 4) <i>Brecce stratoidi</i> | 9) <i>Massi di crollo cementati</i> |
| 5) Pulmunates and small mammals bearing red sands | |
| 5) <i>Sabbie rosse poco cementate</i> con fossili di gasteropodi terrestri e piccoli mammiferi | |



Fig. 6 – Reddish sands containing small-size mammal bones and pulmonate gastropods (S).
Sabbie rosse contenenti ossa di piccoli mammiferi e polmonati.

The + 3.8 notch and marine deposits observed in various sites at Capo Caccia were formed during interglacial conditions, as documented by the height above present sea-level and by associated deposits. The continental sediments that follow the marine deposits and suture the notch can be fairly attributed to the Würm on the ground of lithofacies and fossil contents (MALATESTA 1954), and evidences of subsequent transgression are never observed. Therefore the + 3.8 sea-level is related to the last interglacial (Eutyrrhenian), and is broadly comparable to the eustatic sea-level height attained during the substage 5e (125 ky BP) of the oxygen-isotope curve (WILLIAMS *et alii*, 1988).

It is also suggested that the black band found in the deep submerged room at -10 m depth marks a short standstill of the sea-level (3), and formed during a water-table stand that lasted enough to allow mineral segregation in a partly oxidative

environment. A similar mineral band has been observed in a stalactite sampled in the Grotta Grande dell'Argentola, Tuscany (mainland Italy), at roughly the same depth (-9.5 m b.s.l.); the black band separates two marine biogenic deposits covering the continental concretion, and it has been attributed to an episodic sea-level stand during two distinct episodes of rise above the present -9.5 m b.s.l. which have been dated at 6770 ± 190 yr BP and 6470 ± 110 yr. BP (ALESSIO *et alii*, 1992).

6. – IMPLICATIONS OF THE GROTTA VERDE BURIALS FOR THE LATE GEODYNAMICS OF CAPO CACCIA

The attribution of the + 3.8 m a.s.l. notch and relative marine deposits to the Eutyrrhenian (substage 5e of the oxygen-isotope curve), and its occurrence at an altitude broadly comparable to the worldwide altitude of the 5e sea-level rise, document that Capo Caccia gained a quite definitive tectonic stability at or soon after Eutyrrhenian times

(3) Probably this happened just before the later phase of Ancient Neolithic.

(125 ky BP). Previous excavation reports at Grotta Verde (PALLARES, 1981) invoked a general subsidence of the promontory which occurred after Neolithic times in order to justify the present submerision of the burials. Evidences for this unrealistic fast process have not yet been found in the coastal Tyrrhenian area, except for particular settings affected by volcano or sismotectonics movement in recent times (COSENTINO & GLIOZZI, 1988). On the contrary, Capo Caccia and the Sardinia in general have been representing a very stable sector since long, and they were neither affected by Alpine tectonics nor subsequent orogenetic uplift. Our research documents that the present submerision of the burials is best concealed with the Holocene eustatic sea-level rise that reached the Neolithic necropolis after 7300 years BP.

By demonstrating a quite definite tectonic stability of Capo Caccia (at least from Eutyrrhenian times, about 125 ky BP), we were able to achieve a 7.3–6.7 ky BP paleosea-level at least –10 m below the present one. This information is in good agreement with an existing curves of late Pleistocene-Holocene sea-level oscillations in the Tyrrhenian area (ALESSIO *et alii*, 1992; ANTONIOLI & FERRANTI, 1994), which show a 7.3–6.7 ky BP sea-level ranging between –14 and –9.5 m below present one. Providing that the rate of sea level rise was in this period about 1 meter for century (ANTONIOLI & FERRANTI, 1994), the estimated age should be quite accurate.

Radiocarbon analysis of a –1 m submerged stalagmite sampled in the Grotta Verde, give an age of 4623 years BP (ALESSIO *et alii*, this Volume). This datum confirme the very recent variation of eustatic sea level.

Such result suggests the profound influence of interactive archeological and geomorphological investigations in order to reconstruct effective sea-level curves.

REFERENCES

- ALESSIO L., ALLEGRI M., ANTONIOLI F., BELLUOMINI G., FERRANTI L., IMPROTA S., MANFRA L. & PROPOSITO A. (1992) - *Risultati preliminari relativi alla datazione di speleotemi sommersi nelle fasce costiere del Tirreno centrale*. Il Giornale di Geologia, **54/2**: 165-193.
- ANTONIOLI F. & FERRANTI L. (1994) - *Holocene sea level data from the coasts and shelf of italian Tyrrhenian sea. An historical review*. Volume dei riassunti 77° Congresso della Società geologica Italiana, Bari 26-28 Settembre 1994.
- ANTONIOLI F., FERRANTI L. & MUCCEDDA M. (1994) - *Osservazioni geomorfologiche e paleoclimatiche nella grotta delle Alghe (Capo Caccia, Sardegna)*. Memorie dell'Ist. Italiano di Speleologia, **6**: 137-142.
- CHERCHI A. (1985) - Introduction to the geology of Sardinia. In: Cherchi A. (Ed.), 19th European Micropaleontological colloquium. Micropaleontological researches in Sardinia, Guidebook, 1-23.
- CHERCHI A., SCHROEDER R., D'ARGENIO B., CARANNANTE G., SIMONE L., MURRU M., OGGIANO S., SANNA G. & TEMUSSI I. (1987) - *Excursion dans le Crétacé de la Sardaigne Nord-Occidentale*. In: CHERCHI A. (Ed.), *Excursion en Sardaigne, Groupe Française du Crétacé, Livret-guide*, 61-71.
- COSENTINO D. & GLIOZZI E. (1992) - *Considerazioni sulle velocità di sollevamento di depositi Eutyrrheniani dell'Italia meridionale e della Sicilia*. Mem. Soc. Geol. It. **41**: 653-665.
- FODDAI R., ZARINI F. & SACCO C. (1975) - *Esplorazione del laghetto terminale della Grotta Verde*. Speleologia Sarda, **15**: 3-10.
- LAMBERTI L., LO SCHIAVO F., PALLARES F. & RICCARDI E. (1986) - *Lo scavo del laghetto interno della grotta Verde di Alghero (Campagna 1979)*. Rivista di studi Liguri, 545-552.
- LO SCHIAVO F. (1986) - *Ricerche subacquee nella Grotta Verde di Alghero*. Archeologia Subacquea 3, suppl. al n. 37-38 Boll. Arte., 63-67.
- LO SCHIAVO F. (1987) - *Grotta Verde 1979: un contributo sul neolitico antico della Sardegna*. Atti XXVI Riun. Scient. IIPP, Firenze 1985, 845-858.
- MALATESTA A. (1954) - *Risultati del rilevamento del Foglio 192, Alghero, I, Note di stratigrafia quaternaria*. Boll. Serv. Geol. It., **75**: 371-395.
- MALATESTA A. (1954) - *Risultati del rilevamento del Foglio 192, Alghero, II, Fossili delle spiagge tirreniane*. Boll. Serv. Geol. It., **76**: 9-32.
- PALLARES F. (1981) - *Grotta Verde (Alghero)*. Istituto Internazionale di Studi Liguri, Forma Maris Antiqui XI-XII (1975-1981), 235-245.
- PECORINI G. (1963) - *Contributo alla stratigrafia post-miocenica della Nurra di Alghero*. Rend. Sem. Scient. Univ. Cagliari, **33**: (12) 1-11.
- TANDA G. (1980) - *Il Neolitico antico e medio della Grotta Verde, Alghero*. Atti XXII Riun. Scient. Ist. Ital. Preist. Protostoria, 45-94.
- TREMOLIERS P., CHERCHI A. & SCHROEDER R. (1984) - *Phenomenes de chevauchement d'age Pyrenien dans le Mesozoique in Nord-Ouest de la Sardaigne*. C.R. Acad. Sc. Paris, **292** (4): 2791-2800.
- TYKOT R.H. (1994) - *Radiocarbon Dating Absolute Chronology in Sardinia and in Corsica*, Radiocarbon Dating and Italian Prehistory, Accordia Specialist Studies on Italy 3, Archaeo. Monograph BSR **8**: 115-145.
- WILLIAMS D.F., THUNELL R.C., TAPPA E. & RAFFI I. (1988) - *Chronology of the Pleistocene oxygen isotope record: 0-1.88 M.y. BP* Palaeogeogr. Palaeoclim. Palaeoecol., **64**: 221-240, Amsterdam.