

## Dating deepest Mediterranean submerged speleothem (Capo Palinuro, Italy): biological and Holocene sea-level considerations

### *Datazione del più profondo speleotema sommerso campionato nel Mediterraneo (Capo Palinuro): considerazioni biologiche sul livello del mare olocenico*

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ABSTRACT – A stalagmite, sampled at 48 m water depth (Capo Palinuro, Italy) is up to now, the deepest speleothem collected, studied and dated of the Mediterranean Sea. A puntiform target (a date mussel shell) from the speleothem has been  $^{14}\text{C}$  dated. The particular ecology of the boring bivalves, such as *Lithophaga lithophaga*, allows their use as puntiform marker of the submersion of the sample site. The  $^{14}\text{C}$  date ( $10,253 \pm 72$  years BP) is in full agreement with previous analyses carried out on similar samples from shallower sites, allowing a more precise reconstruction of the sea level changes during the last 10,000 years. Evidences of a variable rate of sea level ascending during the Holocene address to the biological implications of very rapid phases of sea level changes vs. period of stasis or very low change rate.

KEY WORD: sea-level rise, Holocene, submerged speleothems.

RIASSUNTO – In una grotta sommersa di Capo Palinuro (complesso della Scaletta-Punta Iacco) è stata campionata una stalagmite, a 48 m di profondità. Si tratta attualmente dello speleotema raccolto alla maggiore profondità nel Mediterraneo. È stata datata una conchiglia fossile del mollusco bivalente fosforio *Lithophaga lithophaga* prelevata dallo speleotema, ritenuta un buon marcatore dei primissimi stadi di immersione dello stesso. Il dato ( $10,253 \pm 72$  anni BP) è ampiamente coerente ed in accordo stratigrafico con precedenti datazioni effettuate su analoghi campioni provenienti da quote più superficiali della stessa grotta. Le evidenze di variazioni nel tasso di ascesa del mare nell'Olocene, comportano notevoli implicazioni biologiche legate alle fasi di rapido cambiamento del livello marino con periodi di stasi o di cambiamento molto lenti. La radiodatazione viene discussa e comparata con numerosi altri riferimenti cronologici provenienti sia dal Mediterraneo che da altre zone.

PAROLE CHIAVE: livello del mare, Olocene, speleotemi sommersi.

#### 1. – INTRODUCTION

The Capo Palinuro promontory, formed by Mesozoic limestones, though of limited extension, is characterized by a large presence of karstic cavities, mostly located below the sea-level. The present intense karstic phenomenon in the area has been extensively studied by GUIDA *et alii*, (1981), MUSCIO & SELLO (1993), ALVISI *et alii* (1994) and ANTONIOLI & FERRANTI (1994). In this framework the hypothesis on the speleogenesis of two distinct sets of submerged caves is here summarized. The most shallow water caves (0-20 m water depth) developed with a basal level a little lower than the present one, when the cape yet had acquired the present configuration (Middle Pleistocene). The deeper water caves (20-50 m water depth) according to their dimension and morphology, should have required water masses definitely incompatible with the present hydrogeological pattern of the promontory. The origin of the caves of this group should be referred to a preceding time (the end of the Lower Pleistocene). At that time a hydrogeological palaeo-connection with the carbonatic Bulgheria massif (now interrupted by the Lambro and Mingardo rivers) did exist, with such a disposal of water as to allow the development of the observed phreatic karstism of the deeper caves.

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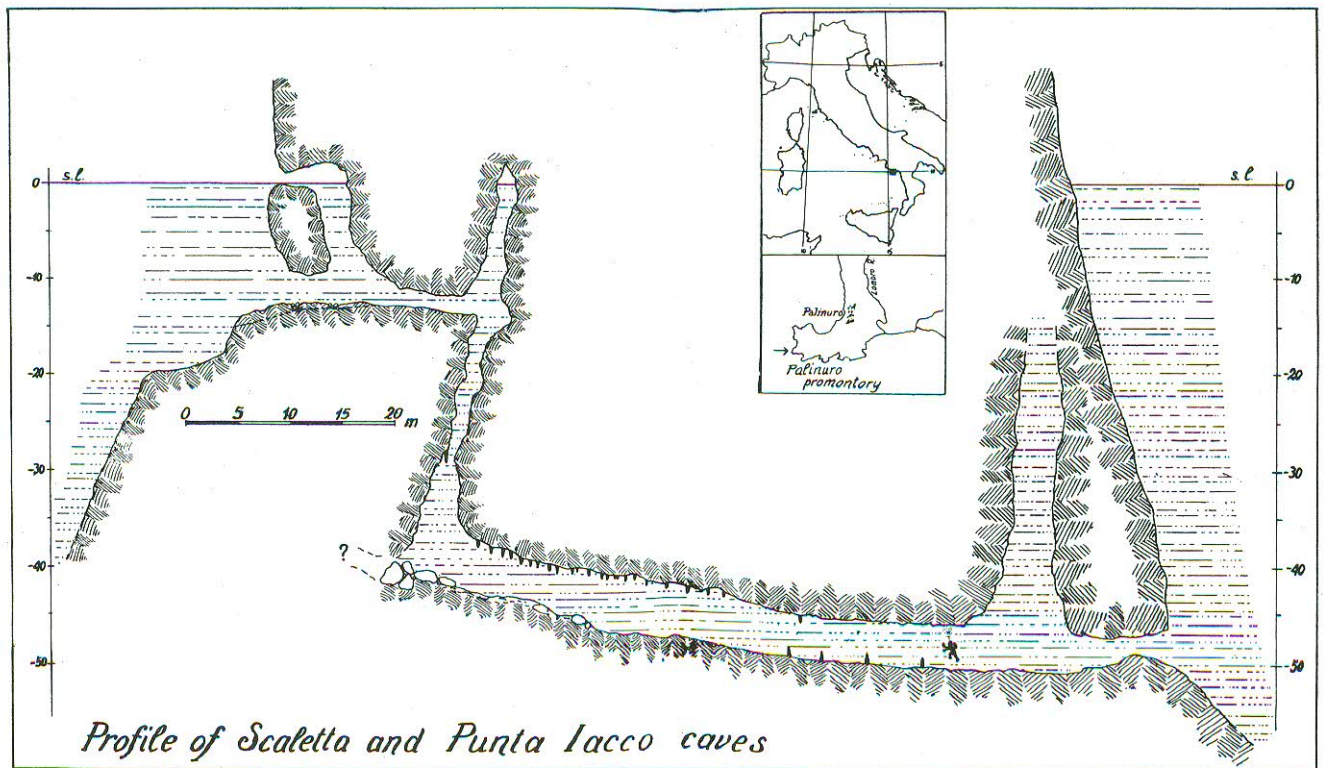


Fig. 1 – The Scaletta and Punta Iacco cave complex (Palinuro, Italy): location map and profile.  
 Il complesso delle grotte Scaletta e Punta Iacco (Palinuro, Italia): carta della localizzazione e profilo.

## 2. – THE COLLECTING SITE

The caves “Scaletta” and “Punta Iacco” (fig 1), described in the present volume but still not completely explored, show similar direction and according to their morphology and depth, it was presumable the existence of a single submerged complex. During a survey aimed also to the location of deep speleothemes, the connection between the two cavities has been verified. The caves showed similar morphology and speleogenesis. They consist of a base level at 42-52 m water depth, with a subhorizontal phreatic tube. The whole gallery (ca. 75 m long) is comprised between 42 and 51 m water depth. The base level is at an average of 50 m with a variable section (an average width of 3 m and an height of 3-9 m). The ground floor is encrusted by a reincised alabastrine cover and with a final deposition of stalagmites of remarkable sizes (up to 50 cm diameter). We hypothesize an initial formation with a very low base level (accounting to the high potential energy of the fresh water layer stratum, capable to create the large tubes). In a second time the stratum decreased the flow, becoming a water drop that, rather than abrading, started the deposition. This phase started with the alabastrine cover of the ground

floor, followed by the building of the speleothemes. When in a successive time, the erosive processes became newly dominant, a channell was incised on the alabastrine cover. The tube communicates with the higher base levels of the northern side (opening at 12 m water depth with an abraded gallery) by sub-vertical shaft. The lower base level also opens at sea presently on the southern side. This exit bears strong evidences of sea stationing (uncemented beach conglomerate, notch, holes of date-mussels). Presently, the very opening is completely abraded by the sea energy action. The presence of the beach conglomerate, the notch and of the date-mussel holes confirms a long time stasis of the sea level at ca. 45-48 m of present water depth.

## 3. – MATERIAL AND METHODS

In the cave complex “Scaletta-Punta Iacco” two stalagmites have been searched for, located at 47 and 48 meters water depth respectively, and sampled (fig 2). Sampling was performed by SCUBA diving on July, 7th and 10th 1994, during the accomplishment of the preliminary survey of the cave complex. Elevations were measured by a digital



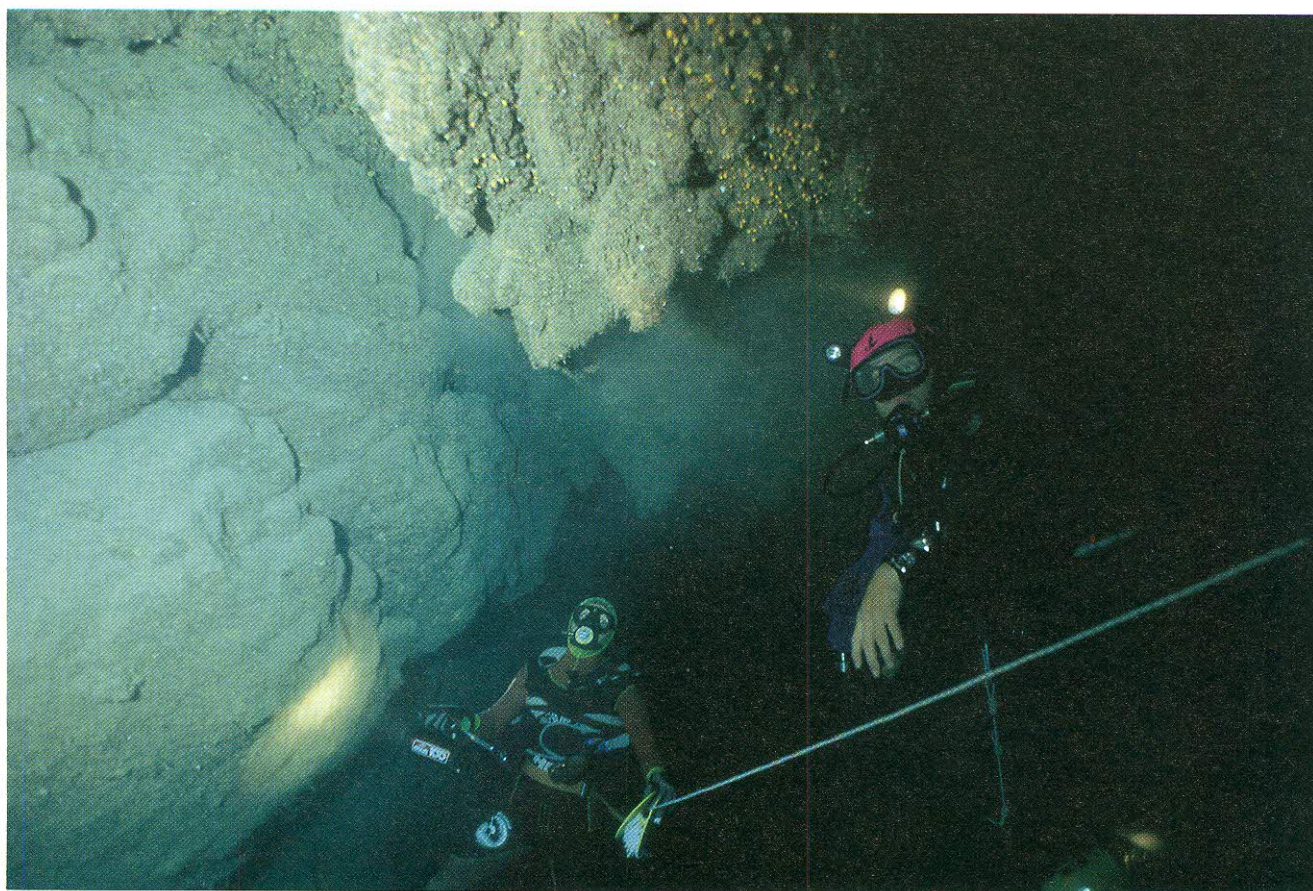


Fig. 2 – Sampling submerged speleothems in the Scaletta and Punta Iacco cave complex.  
 Operazioni di campionamento degli speleotemi nel complesso della Scaletta- Punta Iacco.

depth gauge ( $\pm 0.1$  m), corrected for water density. The speleothemes have been selected among others present in the cave according to their position, size, and the presumable size of the encrusting organogenic layers. Formerly, two stalactites had been sampled in the same cave complex (Scaletta portion) at 21 and 41 m respectively. Data from that samples have been used for comparison.

The benthic community (present and fossil) producing the organogenic encrusting layers on the speleothemes, has been studied, in order to identify the dominant organisms, and the structure of the community itself. A continuous sample of the encrusting layers on the 48 m speleothem has been  $^{14}\text{C}$  dated: that is the activity has been summed of the carbonatic skeletons of all layers from the interior one to the exterior one. A mathematical model developed to this aim (ALESSIO *et alii*, 1992), allowed to estimate the deposition starting point, assuming a constant rate of deposition of the organogenic material by the community, and nearly no effect of erosion (either mechanical or biological).

The presence of date mussel (*Lithophaga lithophaga*) shells has been detected, after cutting longitudinally the speleothemes (figs 3 and 4). The ecology of the date mussel (see below) allows the use of its fossil submerged rests as good markers of land submersion during eustatic sea level change. A date shell was sampled in the 48 m speleothem, in a hole entirely comprised in the continental core, and sealed by the successive encrusting layers. The carbonatic shell has been  $^{14}\text{C}$  AMS dated in 1994, from the *National Ocean Sciences, Woods Hole Oceanographic Institution* USA.

## 4. - RESULTS

### 4.1. - THE BENTHIC COMMUNITY

The Recent benthic community settled on the speleothem consists exclusively of animals, due to the absolute lack of light. In such an aphotic environment, the sessile community is composed by Porifera, Cnidaria, Annelida, Mollusca, Brachiopoda,





Fig. 3 – Longitudinal section of -48 stalagmite sampled in the Scaletta and Punta Iacco cave complex (note the hole of date mussels).  
 Sezione longitudinale della stalagmite dei -48 m campionata nel complesso della Scaletta- Punta Iacco (notare il foro del bivalve fossorio).

da and Bryozoa. The structure of the communities settled on submerged speleothemes is controlled by a complex of factors. Due to the trophic habits of the involved organisms (all are filter feeders *sensu lato*), the dominating factor is the hydrodynamism (OLIVIERO, 1992). In the sampled speleothemes (47 and 48 m water depth) the living community was dominated by Bryozoa Gymnolemata. The following species was identified: *Calpensia nobilis*, *Scrupocellaria scrupea*, *Escharina* sp., *Trypostega venusta*. The last species was the major component of the living community. Nearly all the animals encountered in the living community leave, and left, rests of their skeletons on the speleothem, resulting in a series of encrusting layers of organogenic material (mainly  $\text{CaCO}_3$ , plus a minor fraction of other more degradable materials). Evidences of the structure of the fossil communities have been searched for in the inner layers of encrusting organogenic materials till to the continental carbonatic core of the speleothem. Bryozoan rests continue to be the major component, but an increasing presence of polychaete tubes was noti-

ced in the proximal (older) layers. Obviously, caution must be used in such cases, since differential degradation of rests of other organism cannot be excluded, as well as bioerosion phenomena could have altered the pattern. Anyway, caves (and especially their inner portions) are commonly considered stable environments, and there is little ground to think that communities very different from the living ones, have been supported by the speleothem during its submerged life. An exception can be found in the distribution of a bivalve mollusk, i.e. the date mussels (*Lithophaga lithophaga* Linné). This bivalve settles only on calcareous rocks, from low tide level, usually to no more than 20 m water depth, with a net preference for the first meters (till to 1600 specimens per square meter at 0–2 m). It invariably and continuously bores holes on the substrate. Growth is relatively slow (according to KLEEMAN 1973a, 8 cm are attained in 80 years). Our sample contains only specimens of less than 4 cm, addressing to an age of the date mussels of no more than a few tens years at the moment of their death. Settling on the definitive substrate is



at the larval (veliger) stage, preferably on nude substrates (it is considered a pioneer species) or in empty cavities of dead and removed specimens (JACCARINI *et alii*, 1968; KLEEMANN, 1973b). These aspects of its ecology, make the fossil rests of the date mussel, good marker of the sea level changes. Already Lyell (1877) discussed the geological implications of the presence of date mussel holes on the pillars of a building at Pozzuoli (Napoli, Italy). Eustatic sea level changes together with sinking and subsequent elevation of the land acted to produced such a pattern. Imamura (1926) correlated the presence of holes by the Japanese date mussel *Lithophaga nasuta* Philippi on uplifted bands, with a series of earthquakes. Both cases correlate emerged rests with earth uplifting. Anyway, the ecology of the date mussel allows the use of its fossil submerged rests as good markers of the very earliest stages of land submersion during eustatic sea level change. On the speleothemes sampled in the Scaletta-Punta Iacco cave complex, fossil date shells are relatively common in the inner layers and holes penetrate the very continental cores of the speleothemes. No living *L. lithophaga* have been encountered on the speleothemes, neither on the walls of the caves,

below 10 m depth. The fossil shells are preserved in holes entirely comprised in the continental core, and sealed by the successive (but earliest) encrusting layers. According to these evidences and to the ecology of the species, such specimens are considered as pioneer colonizers of the nude (or nearly so) speleothemes at the earliest stages of submersion.

#### 4.2. - $^{14}\text{C}$ DATING

A date shell was sampled (fig 4) in the speleothem, in a hole entirely comprised in the continental core, and sealed by the successive (including the inner) encrusting layers. This specimen is considered a good marker of the earliest stages of submersion of the speleothem (that is of the arriving of sea at that level). The carbonatic shell has been  $^{14}\text{C}$  AMS dated. The resulting (punctiform) date of  $10,253 \pm 72$  years BP is in agreement with the results ( $8230 \pm 105$  years BP and  $8550 \pm 75$  years BP: ALESSIO *et alii*, this volume) of the same analyses carried out on analogous date shells sampled on speleothemes from the same cave at 27 and 41 m water depth respectively. The data indicate a nearly perfect stratigraphical coherence.

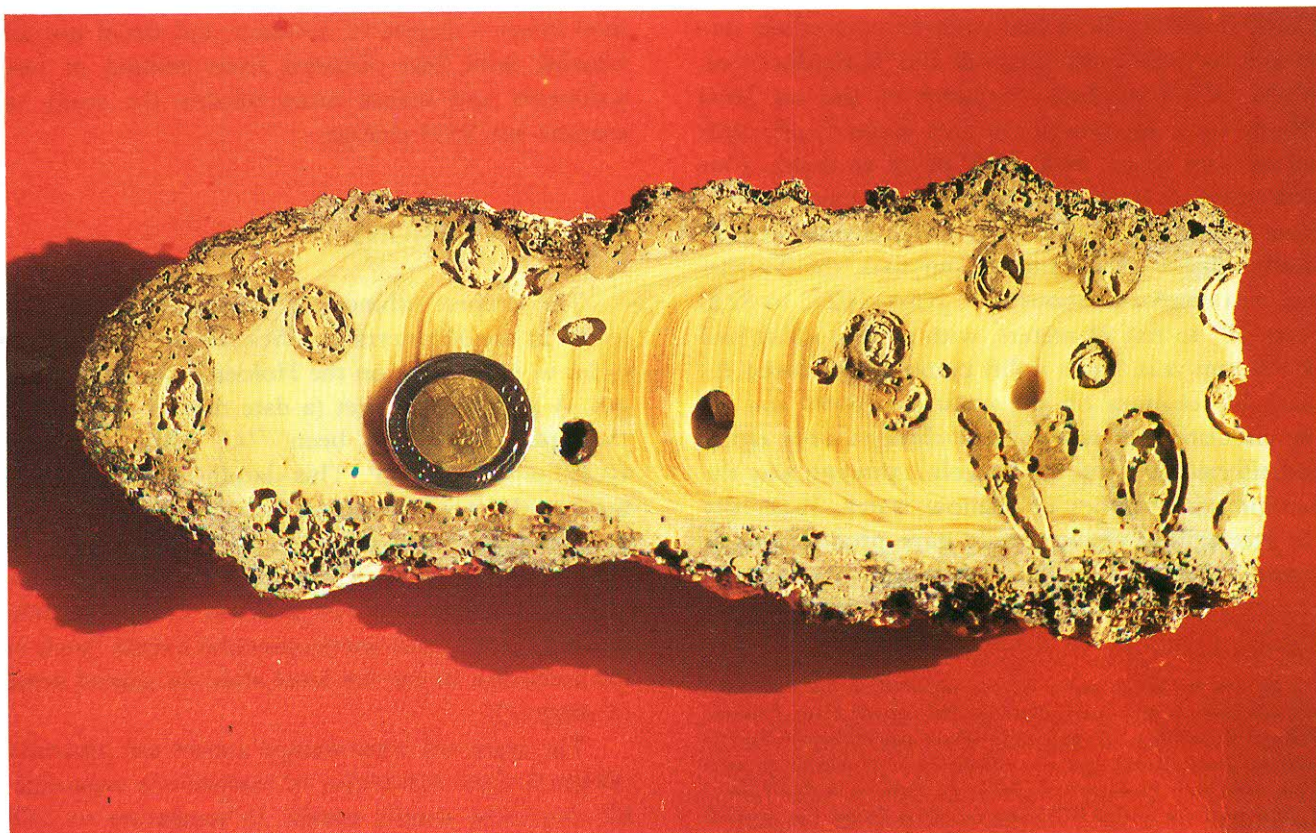


Fig 4 - Particular of longitudinal section of -48 stalagmite sampled in the Scaletta and Punta Iacco cave complex (note the date mussels shells 10,253 years old).

Particolare della sezione longitudinale della stalagmite dei -48 m campionata nel complesso della Scaletta - Punta Iacco (notare le valve del bivalve di 10.253 anni).



## 5. – DISCUSSION

The stalagmite sampled at 48 m water depth in the Scaletta-Punta Iacco submerged cave complex, is up to now the deepest speleothem, sampled, studied and dated from the Mediterranean Sea. The  $^{14}\text{C}$  AMS dating provided an estimate of the arrival of the sea at that level of  $10,253 \pm 72$  years BP.

It is plausible that the sea entered the cave repeatedly since from its formation (there have been at least 8 cold isotopic stages during the Middle Pleistocene). Nevertheless, the availability of the dating of the last continental deposit ( $13,700 \pm 295$  years BP; ALESSIO *et alii*, this volume), allows to exclude that the present external organogenic layer was deposited in a time preceding the last post-glacial rising.

Pirazzoli (1991) shows for the Mediterranean Sea some curves obtained by several authors with radiocarbon analysis on mollusk shells recovered by cores, submerged and coastal deposits and on archaeological record. Incidentally, Fairbanks' (1989) reconstruction of the Holocene sea level changes, based on  $^{14}\text{C}$  dating of corals from Barbados, produced at 48 m depth as estimate of ca. 9600 years BP. Bard *et alii* (1990), based on Th/U dating reconstructed for the same site an estimate of ca. 11.000 YBP(1). Both had to make corrections due to the tectonic instability of the Barbados area. Aloisi (1993) produced a curve of the sea level change for a Mediterranean area (Lion Gulf), with an estimate of ca. 9800 YBP at 48 m depth. Our data originate from a tectonically stable site (at least from 5e stage). Thus present water depth is eustatically reliable. According to our data, the Tyrrhenian Sea employed about 2000 years (10253 to 8230 years BP) to rise 21 meters, with a mean uplift rate of 9.8 mm/year. Such uplift certainly produced remarkable changes on the coastal patterns and on the circulation of water. Such changes were rapid, and affected in some, still largely unknown way the benthic communities of shallow water. Especially the accelerating phases would have produced more remarkable effects on the landscape than a constant

rate over the entire time. Microevolution and present biodiversity patterns in organisms largely depending on water circulation, have been deeply influenced by such rapid environmental variations (see e.g. OLIVIERO, 1995).

The dating of submerged speleothems has recently provided very interesting data (LUNDBERG & FORD, 1994) but only referred to cold stages, with sea levels lower than present one. Such multidisciplinary investigations, based on underwater speleological approach, open new opportunities in the Mediterranean palaeoclimate studies. The main sea level change curves are presently obtained, from researches on continuous organogenic materials, such as the corals. Given the absence in the Mediterranean Sea of such reefs, the study of continuous organogenic encrustations, and of pumiform fossil skeletons on submerged speleothems (especially when sampled in tectonically stable sites), permits to recover detailed and precise information, otherwise unavailable in the Mediterranean area which lacks well developed coral reef. The reliability of the pumiform datum relies entirely on the settlement time of the date mussel and on its ecology. The study of marine organic deposits (especially where sampled in stable areas) on speleothems, permits in fact a degree of accuracy and detail not attainable with data obtained from drilling or loose sediments and makes more reliable the study of eustatic sea level change.

## 6. – CONCLUSIONS

The deepest submerged speleothem so far collected in the Mediterranean Sea has been studied in order to investigate on the Holocene sea-level changes. A pumiform target (a date mussel shell) from the speleothem has been  $^{14}\text{C}$  AMS dated at  $10,253 \pm 72$  years BP. This datum is in full agreement with previous analyses carried out on similar samples from shallower sites.

Dating skeletons of Holocene fossils, whose location be reliable, allows a better comprehension of very recent palaeoenvironmental events (such as the ascension of the sea level after the glacial acme of stage (2)).

The main sea level change curves are presently obtained, from researches on continuous organogenic materials, mainly corals. In temperate to cold areas where such reefs are absent, carbonatic samples are provided by organogenic encrustations and single fossil skeletons. The analysis of such samples

(1) The preliminary survey was accomplished on July, 6-10 1994, by Fabio Barbieri, Rito Cusati, Domingo Principe and Marco Oliverio. During such diversions, the hypothesis of the connection of the two caves has been verified, and two stalagmites at 47 and 48 m water depth respectively have been sampled in the karstic tube (See Barbieri *et alii*, in prep. for a detailed description and a definitive survey of the cave complex)

(2) After the publication of the works of Fairbanks and of Bard *et alii*, it is currently accepted that  $^{14}\text{C}$  dating produces younger results, whilst the Th/U dates are closer to the real ones.



recovered from submerged speleothems, permits to recover detailed and precise information, otherwise unavailable. The study of marine organic deposits (when sampled in tectonically stable areas) on speleothems, permits infact a degree of accuracy and detail not attainable with data obtained from drilling or loose sediments and makes more reliable the study of eustatic sea level change. Boring bivalves such as the date mussel (and similar organisms) are commonly found world-wide. The reliability of the puntiform datum relies entirely on the settlement time of the date mussel and on its ecology.

REFERENCES

- ALESSIO M., ALLEGRI F., ANTONIOLI F., BELLUOMINI G., IMPROTA S., MANFRA L. & PREITE M. (1994) - *La curva di risalita del Mare Tirreno negli ultimi 40 ka tramite datazioni di speleotemi e dati archeologici*. International Meeting on Underwater Geology: GEOSUB '94: 74-75.
- ALESSIO M., ALLEGRI F., ANTONIOLI F., BELLUOMINI G., FERRANTI L., IMPROTA S., MANFA L. & PROPOSITO A. (1992) - *Risultati preliminari relativi alla datazione di speleotemi somersi nelle fasce costiere del Tirreno centrale*. Giornale di Geologia, ser: 3, **54** (2): 165-193.
- ALOISI J. C. (1993) - *Holocene sea level data from the Mediterranean coast and shelf of France*. Workshop: "Holocene sea level change" (European Science Foundation", Rennes 2-4 Dic. 1993, Abstract.
- ALVISI M., BARBIERI F. & COLANTONI P. (1994) - *Le grotte marine di Capo Palinuro*. Memorie Istituto Italiano di Speleologia, **6**, ser. II: 143-181.
- ANTONIOLI F. & FERRANTI L., (in press) - *Le grotte sottomarine di Capo Palinuro (Campania): aspetti geomorfologici e implicazioni speleogenetiche*. Memorie della Società Speleologica Italiana.
- ANTONIOLI F., ASCIONE A., CINQUE A., FERRANTI L. & ROMANO P. (1994) - *Coastal and underwater geomorphology of Capo Palinuro Area, guidebook to the field-sea trip*. Convegno internazionale di Geologia Subacquea, GEOSUB '94: 7-58.
- BARD E., HARMELIN B. & FAIBANKS R. (1990) - *U-Th ages obtained by mass spectrometry in corals from Barbados: sea level during the past 130.000 years*. Nature, **346**: 456-458.
- FAIBANKS R. (1989) - *A 17000-year glacio-eustatic sea level record: inflence of glacial melting rates on the Younger Dryas event and deep-ocean circulation*. Nature, **342**: 637-642.
- GUIDA D., GUIDA M., LUISE D., SALZANO G. & VALLARIO A. (1981) - *Idrogeologia del Cilento (Campania)*. Geologica Romana, **19**: 348-369.
- IMAMURA A. (1926) - *On the recurrence of destructive earthquakes ...* Proc. Imp. Academy, Tokyo **2**: 264-267.
- JACCARINI V., BANNISTER W.H. & MICALLEFF H. (1968) - *The pallial glands and rock boring in Lithophaga lithophaga (Bivalvia, Mytilidae)*. Journal of Zoology, London, **154**: 397-401.
- KLEEMANN K.H. (1973a) - *Der Gesteisabbau durch Atzmuscheln an Kalkkusten*. Oecologia, **13**: 377-395.
- KLEEMANN K.H. (1973b) - *Lithophaga lithophaga (L.) (Bivalvia) in different limestone*. Malacologia, **14**: 345-347.
- LUNDBERG & FORD (1994) - *Late Pleistocene sea level change in the Bahamas from mass spectrometric U-series dating of submerged speleothem*. Quaternary Science Reviews **13**: 1-15.
- LYELL C. (1877) - *Principles of geology*. 12th ed., Appleton & Co., New York, 2 vols.
- MUSCIO G. & SELLO U. (1993) - *Le Grotte di Capo Palinuro (SA). Le Grotte d'Italia*. Atti XVI Congresso Nazionale Speleologia **16** (4), 1992-1993: 68-82.
- OLIVERIO M. (1992) - *Aspetti ecologici del popolamento bentonico di speleotemi sommersi*. Seminario di Geologia Subacquea (Napoli, 30 giugno 1992), Resoconto dei lavori: 24-25.
- OLIVERIO M. (1995) - *Contrasting developmental strategies and speciation in N.E. Atlantic prosobranchs: a preliminary analysis*. Journ. Moll. Stud., **64** (in the press).
- PIRAZZOLI P. A. (1991) - *Word atlas of Holocene sea level changes*. Elsevier Oceanographic Series, **58**.