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TITOLO:

Quaternaria - ²³⁰Th ²³⁸U Dating of Corals from a Tyrrhenian Beach in Sorrentine Peninsula (Southern Italy)

- **LIVELLO BIBLIOGRAFICO:** Periodico
- **TIPO DI DOCUMENTO:** Testo a stampa (moderno)
- **AUTORE:** AA.VV.
- **LUOGO DI PUBBLICAZIONE:** Roma
- **DATA DI PUBBLICAZIONE:** 1978
- **EDITORE:** Istituto Italiano di Paleontologia Umana
- **TIPOGRAFIA:** /
- **LUOGO DI STAMPA:** Roma
- **DATA DI STAMPA:** 1978
- **EDIZIONE:** 1978
- **LINGUA DI PUBBLICAZIONE:** Inglese, Italiano

- **DESCRIZIONE FISICA:**
 - **FORMATO:** (19 cm x 14 cm)
 - **VOLUMI:** 1 **TOMI:** /
 - **PAGINE:** 10
 - **TAVOLE:** 1
 - **ALLEGATI:** /

- **ISBN:**
- **NOTE GENERALI:** Copia fotostatica di un numero della rivista "Quaternaria". Scheda redatta da Francesco Foti il 16/10/2015

QUATERNARIA

E. BRANCACCIO *, G. CAPALDI **, A. CINQUE *
R. PECE **, I. SGROSSO *

²³⁰Th - ²³¹U Dating of Corals from a Tyrrhenian
Beach in Sorrentine Peninsula (Southern Italy)

L. BRANCACCIO *, G. CAPALDI **, A. CINQUE *
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²³⁰Th - ²³⁴U Dating of Corals from a Tyrrhenian Beach in Sorrentine Peninsula (Southern Italy)

INTRODUCTION

During the geomorphological study of the Sorrentine Peninsula, the remains of ancient shore-lines were noticed in several points along the coast. The above-mentioned traces, found at heights ranging from the present sea-level to about 15 meters, are sometimes related to interesting geomorphological factors connected to the physiographic evolution of the host slopes and of the whole Peninsula. Therefore, it was decided to date them in order to set the certain chronological data in the reconstruction of the neo-tectonic and geomorphological evolution of this area.

Everybody is aware of the difficulties of dating following the paleontological criterion in a relatively recent interval of time; it has also been widely demonstrated that the altimetric criterion is not at all reliable, especially for interregional correlation. Therefore, the only possible valid alternative was absolute dating, notwithstanding its limits. Some coral-fossil samples drawn from two different localities of the Sorrentine Peninsula were dated in this way; both samples were connected with a shore-line whose sediments are situated at about 4-5 meters above the present sea-level. Although, as has already been mentioned, numerous ancient shore-line traces outcrop along the Amalfi coast, the most frequent and the best represented of them is at the same level. It is often rich in mollusc shells and fragments, but only in the two studied outcrops does it contain the coral fossilization necessary for reliable absolute dating.

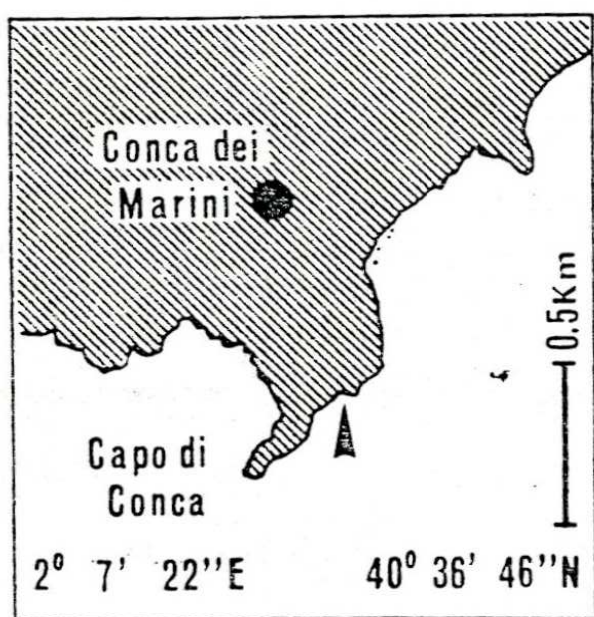
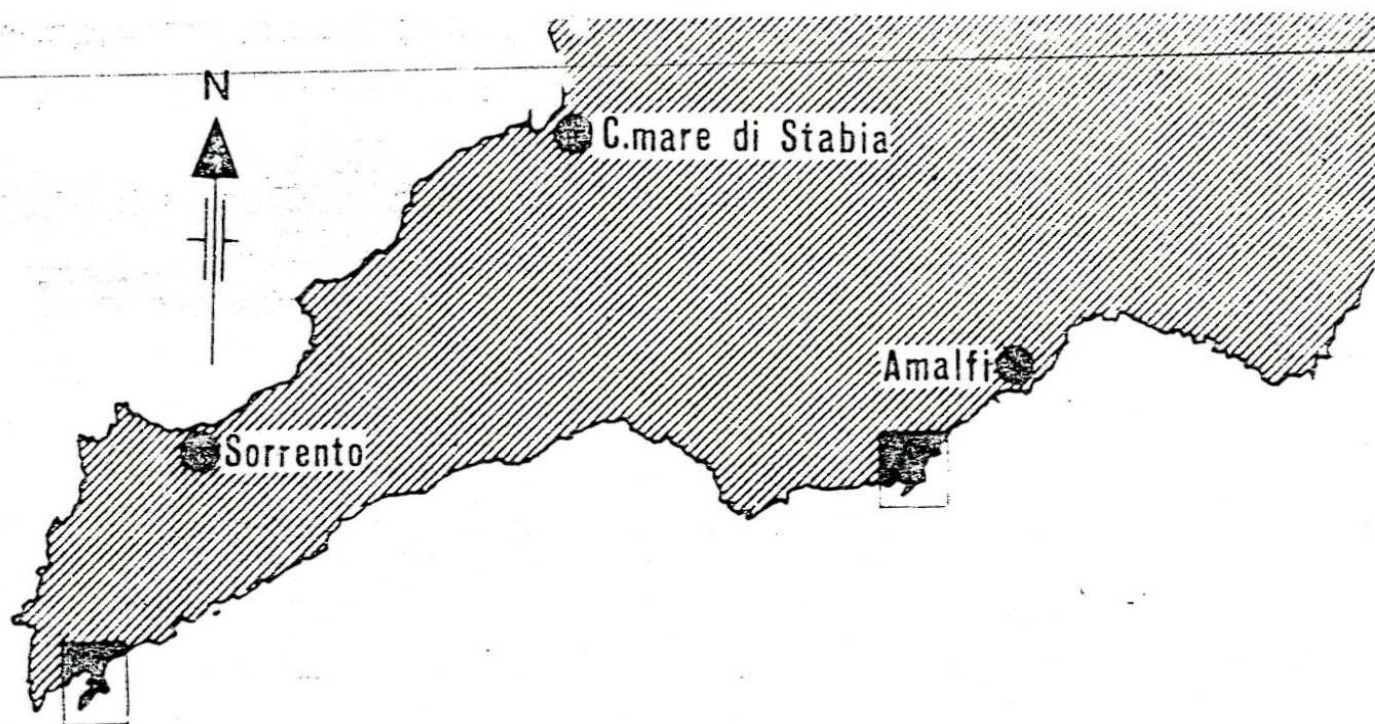
THE CONCA DEI MARINI OUTCROP

On the Eastern slope of Cape Conca, south of the village of Conca dei Marini, there is a biogenic body outcrop in a coastal niche. Its areal extension is about

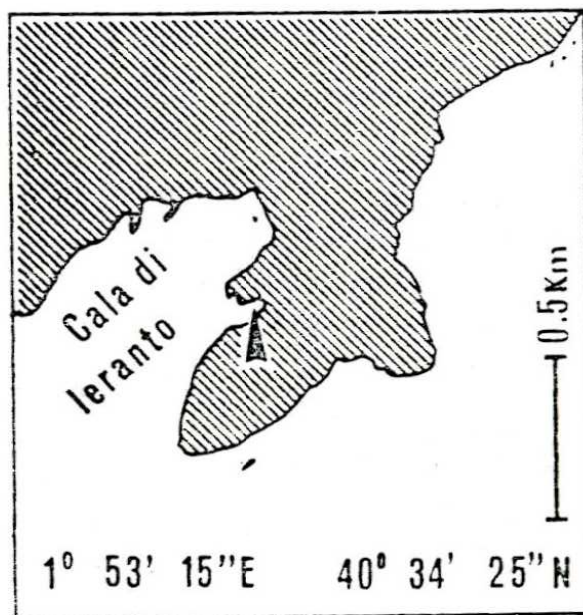
* Istituto di Geologia e Geofisica Università di Napoli.
** Osservatorio Vesuviano, Ercolano (Napoli).



6 square meters and it stretches up to 4-5 meters above the present sea-level. It contains *Cladocora coespitosa* coralline skeletons and numerous mollusc shells in a compact calcareous matrix cemented by calcite of a probably secondary origin. Laterally, this deposit gradually transits into sands and more or less laminated calcareous puddings at times rich in organic fragments.



Place of origin of the samples C1; C2



Place of origin of the samples C3; C4; C5

FIG. 1. — Location of the studied auctrops.

The above-mentioned marine sediments partly overlie Jurassic dolomitic limestones and partly a conglomerate of doubtful origin, which, all the same, presents some characteristics (subparallel lamination of the thinnest fraction; horizontal position of the debris —landslide material— surface) which show that they are probably the result of deposition at the foot of the cliff. The clasts of

this conglomerate sometimes present angularities which may be due to the extremely rapid accumulation and thus to the rapid demolition of the dolomitic-calcareous cliff which, in this case, becomes into a particularly fractured lithotype.

Apart from the sediments described so far, the trace of a notch hollowed out in the limestones about 7.5 meters a.s.l. is present in this locality (see the description of the Cala di Ieranto outcrop for the relation between the above notch and the described marine deposits). The stratigraphic section ends with slope breccia bodies with an abundant pyroclastic matrix, lying both on the sediments of 4.5 meters and on the notch. (fig. 2).

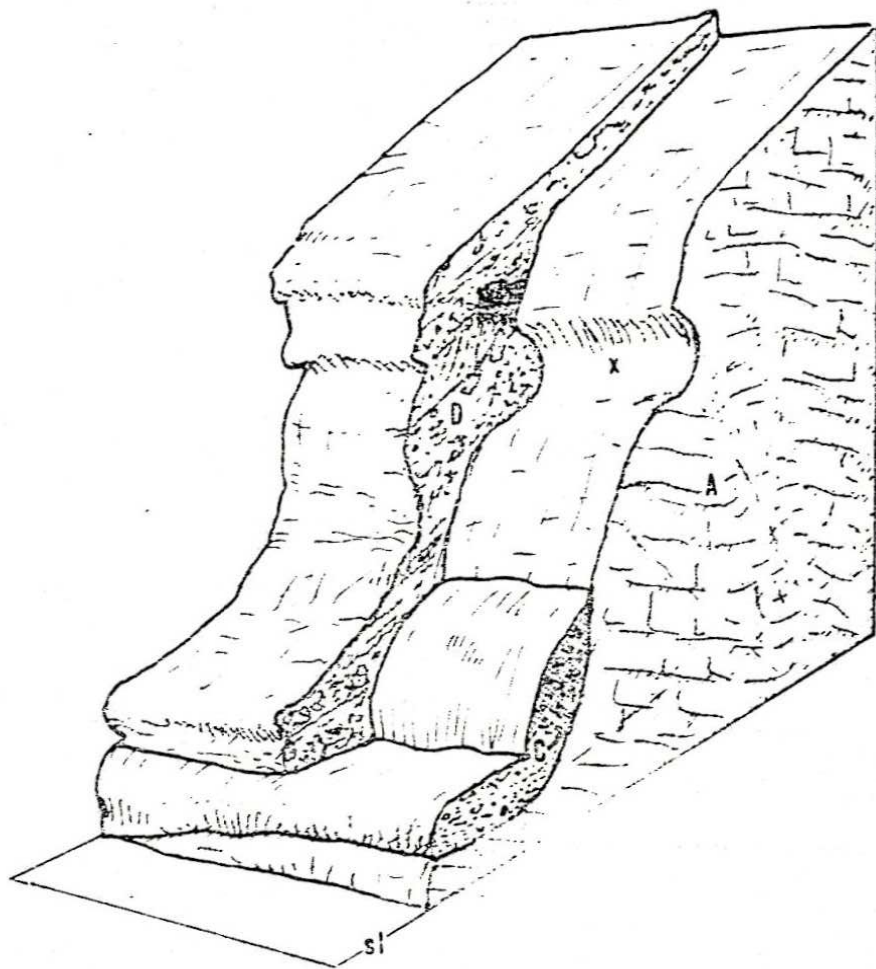


FIG. 2. — Blok-diagram showing the stratigraphic relations between the sediments present in the Conca dei Marini outcrop. A: Giurassic dolomitic limestones; C: Biogenic body and other marine sediments; D: Slope breccia bodies; X: Notch at 7.5 meters a.s.l.

THE CALA DI IERANTO OUTCROP

In a secondary inlet of the Cala di Ieranto, near Punta della Campanella, an edge of a reef with *Cladocora coespitosa* can be seen. Its areal extension does not exceed a few square meters and its position on the cliff appears as the *trottoir a Tenarea* at the base of the notches. It outcrops at a maximum of about 4.3 meters

above the present sea-level. The reef body is almost totally made up of well preserved coral skeletons with very rare interbedded arenite sediments. The importance of this outcrop consists in the fact that it overlies cryoclastic degradation slope breccias, set in place by gravity, very diffused in Sorrentine Peninsula. These slope breccias represent the debris (landslide material) forms corresponding to the fault-scarp recession. The stratigraphic section closes with other breccia bodies fully similar to the older ones, except for having an abundant pyroclastic matrix (produced by Campania volcanism) which, in some cases, assumes the aspect of interstratified thick layers (fig. 3). These breccia bodies lie also on a notch hollowed out in the Cretaceous limestones at about 8 metres above the present sea-level.

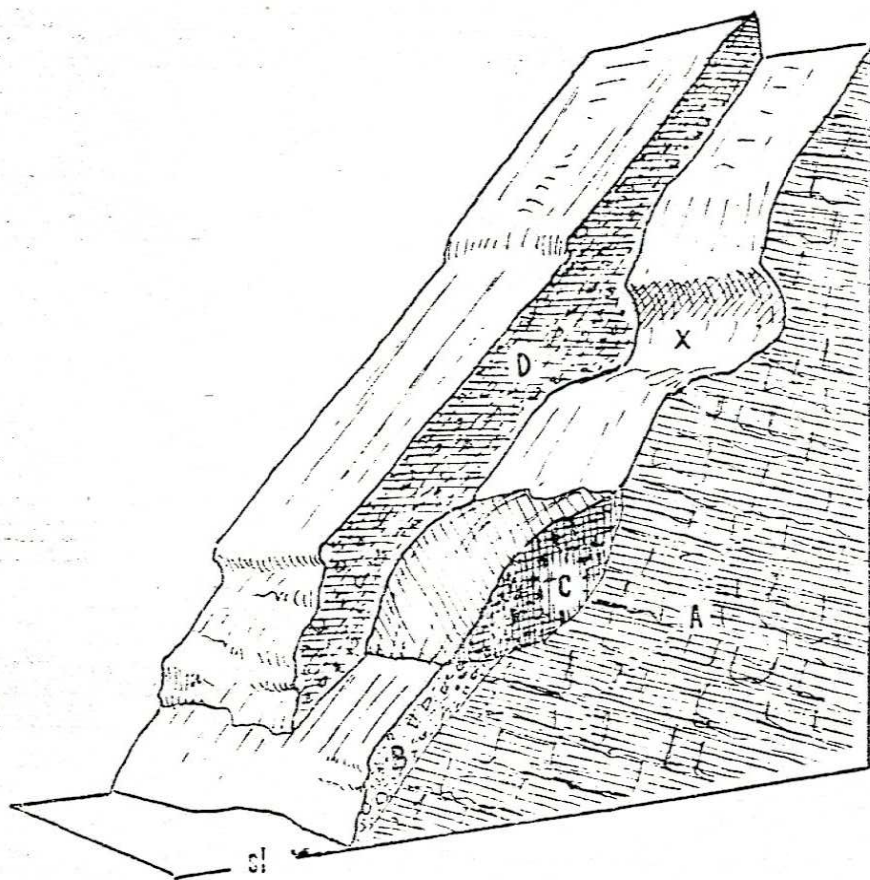


FIG. 3. — Block-diagram showing the stratigraphic relations between the sediments present in the Cala di Ieranto outcrop A: Cretaceous limestones; B: Cryoclastic degradation slope breccias; C: Biogenic body; D: Pyroclastic matrix slope breccia bodies; X: Notch at 7,5 meters a.s.l.

ABSOLUTE DATING OF THE DESCRIBED OUTCROPS

Four coral samples of the *Cladocora coespitosa* species and one mollusc sample of the *Natica* species were drawn from the two outcrops previously described (fig. 1); they were dated by measuring the $^{230}\text{Th}/^{238}\text{U}$ activity ratio.

This method, based on the measurement of the radioactive disequilibrium between ^{230}Th and ^{238}U , already described by Blanchard *et al.* (1967), permits the

dating of marine carbonates which are not older than about 300,000 years, as long as the following hypotheses are satisfied: 1) the carbonates must contain measurable contents of uranium; 2) initially ($t=0$) they must not contain ^{230}Th ; 3) after the death of the organisms the carbonates should behave as a closed system in respect to the uranium and thorium. Following these hypotheses the ages were calculated by means of the equation:

$$\frac{^{230}\text{Th}}{^{338}\text{U}} = (1 - e^{-\lambda_0 t}) + \left[\left(\frac{^{234}\text{U}}{^{338}\text{U}} \right)^0 - 1 \right] \cdot \frac{\lambda_0}{\lambda_0 - \lambda_4} (e^{-\lambda_4 t} - e^{-\lambda_0 t})$$

where:

- $^{230}\text{Th}/^{238}\text{U}$ is the activity ratio measured today (time t);
- $^{234}\text{U}/^{238}\text{U}$ is the initial activity ratio ($t=0$); the value 1.15 (the mean value of the sea-waters) was attributed to it;
- $\lambda_0 = \lambda_{^{230}\text{Th}} = 9.217 \times 10^{-6} \text{ years}^{-1}$ ($T_{1/2} = 75,200 \text{ years}$);
- $\lambda_4 = \lambda_{^{234}\text{U}} = 2.795 \times 10^{-6} \text{ years}^{-1}$ ($T_{1/2} = 248,000 \text{ years}$).

The table shows the radiometric data relative to the corals and mollusc and to a recent coral (C_0) taken from the waters of the Bay of Naples and used as control sample.

The determination of the thorium and uranium concentrations was carried out by alpha-spectrometry using the isotope dilution technique; a solution of 3N HCl containing ^{332}U and ^{228}Th in radioactive equilibrium provided by the Amersham Radiochemical Centre (U.K.) was used as spike; an ORTEC surface barrier detector (450 mm^2 depletion area) was employed; it was connected to a FET pre-amplifier and to a LABEN 1024 channel pulse height analyzer. The chemical procedure adopted for the extraction of thorium and uranium from the carbonates, their separation and purification, is essentially that described by Ku (1965). The calcite contents were determined by means of the X-ray diffraction using the Davies and Hooper method (1963).

The ages calculated for the three corals from Cala di Ieranto coincide with one another within the limits of errors, and provide a mean value of 129,000 years, equal to the age calculated for the coral from Conca dei Marini. This age should be considered reliable since the obtained data were compared following the criteria of reliability suggested in literature. In fact, the analyzed corals show no signs of recrystallization as indicated by the almost complete absence of calcite. The $^{230}\text{Th}/^{232}\text{Th}$ activity ratios are sufficiently high in respect to the values ranging from 1 to 2 measured in the continental waters (Stearn and Thurber, 1965); thus, a possible extraneous ^{230}Th is negligible. The $^{234}\text{U}/^{238}\text{U}$ ratios measured in the corals and corrected for age provide the initial values which do not differ significantly from the value 1.15.

The age calculated for the Conca dei Marini mollusc is lower than the one obtained for the coral co-existing in the outcrop. This discordance is not surprising; in fact, Kaufmann *et al.* (1971) have shown that molluscs can, more easily than corals, behave like open systems, exchanging thorium and/or uranium with the surrounding environment after their death. As for the corals, the mollusc sample has a low calcite content and an activity ratio $^{230}\text{Th}/^{232}\text{Th}$ which exclude any significant influence by extraneous ^{230}Th on the calculated age. The $^{234}\text{U}/^{236}\text{U}$ ratio is, however, relatively high. Therefore, these data show that the age discordance between the mollusc and the coral from Conca dei Marini should be due to the fact that the mollusc was subjected to an exchange of uranium with the outside environment.

DISCUSSION OF DATA

The mean age of 129,000 years obtained for the samples collected from the Cala di Ieranto outcrop coincide almost perfectly with the age of 128,000 years obtained for the sample drawn from Conca dei Marini. Both correspond, within the limits of analytical errors, to the age of one of the Tyrrhenian glacio-eustatic highs of the interglacial Riss-Wurm, well known in literature (Lalou *et al.*, 1971, Ambrosetti *et al.*, 1972; Stearn and Thurber, 1965).

As regards the height of the sea level represented by the studied sediments, it should be noted that the *Cladocora coespitosa* found here belongs to the « *Astraea* » variety: a form of growth, typical of rough seas, currently living at a depth of 4 to 35 meters. It was also found in the Bay of Naples at a depth of about 3 to 4 metres (Abel, 1959).

Taking the above into consideration, we maintain that the sea level, as witnessed by the outcrops in question, must have been about 6-8 meters above the present. This height also corresponds to the quota of some traces found along the Amalfi coast and analogous to the dated ones, also as regard their relation with continental formations and geomorphological elements.

A correlation with the 8 meters notch situated above the coral deposits is obvious.

The estimated height for the dated sea level falls into the value range found in literature for the glacioeustatic high of 120,000 years B. P. (Broecker and Ku, 1969; Osmond *et al.*, 1965; Ambrosetti *et al.*, 1972; Ku and Kern, 1974). However, we do not give much importance to the altimetric correlations, especially to those carried out on an interregional scale. Apart from the well known interferences caused by crustal movements, it can be presumed that the same sea level was not constantly parallel with itself during the glacio-eustatic variations because of the complications due to « geoidal eustasy » (Mörner, 1976). However, the possibility of correlation is real for the levels outcropping in one

ANALYTICAL RESULTS RELATIVE TO THE MOLLUSC AND CORALS OF THE SORRENTINE PENINSULA

Sample description	Calcite %	U (ppm)	$\frac{^{234}\text{U} (*)}{^{238}\text{U}}$	$\frac{^{230}\text{Th} (*)}{^{232}\text{Th}}$	$\frac{^{230}\text{Th} (*)}{^{238}\text{U}}$	$\frac{^{230}\text{Th}}{^{238}\text{U}}$ ages (x 10 ³ years)
C—0 Recent coral (C.c.)	≲ 1	2.90 (±0.03)	1.15 (±0.01)	2.0 (±0.2)	0.007 (±0.001)	< 1
C—1 Coral (C.c.)	≲ 1	3.30 (±0.03)	1.12 (±0.01)	30 (±1)	0.78 (±0.01)	128 (± 5)
C—2 Mollusc (N.)	≲ 3	2.58 (±0.06)	1,21 (±0.02)	24 (±3)	0.68 (±0.04)	37 (±10) (**)
C—3 Coral (C.c.)	≲ 1	2.86 (±0.02)	1.11 (±0.01)	28 (±1)	0.79 (±0.01)	131 (± 6) ^{Age}
C—4 Coral (C.c.)	≲ 1	2.84 (±0.03)	1.12 (±0.01)	28 (±1)	0.79 (±0.01)	133 (± 6)
C—5 Coral (C.c.)	≲ 1	2.59 (±0.05)	1.11 (±0.01)	44 (±1)	0.76 (±0.02)	123 (± 5)

(*) - activity ratios

(**) - age calculated by substituting $[(^{234}\text{U}/^{238}\text{U})^0 - 1]$ with $(^{234}\text{U}/^{238}\text{U} - 1) e^{-\lambda t}$ - the numbers in brackets are the standard deviations (1 Σ)(C.c.) = *Cladocora coespitosa*; (N.) = *Natica*

structural unity, as seems to be demonstrated by the notable coincidence in quota between the two sampled outcrops which are situated at a distance of 25 km from one another in a highly active neotectonic zone.

On a local level, the greatest importance of these datings lies in having, at least, set an upper limit to the tectonic uplift phase, which, during the Pleistocene, produced the present morpho-structural features of the Sorrentine Peninsula, at least as far as its southern side is concerned.

On a wider scale, a study of this ancient beach (which we are extending to the whole South-Tyrrhenian littoral) will allow the verification of a possible synchronism of shore traces analogous to those described and/or to evaluate the successive uplift movements.

Work sponsored by the C.N.R., Progetto Finalizzato Geodinamica, publ. n. 128.

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RIASSUNTO

In questo lavoro vengono riportate le età $^{230}\text{Th}/^{234}\text{U}$ di quattro coralli ed un mollusco raccolti in due affioramenti di vecchie linee di spiaggia della Penisola Sorrentina.

Per i fossili esaminati si è ottenuta un'età di 129.000 anni che corrisponde ad un alto glacio-eustatico tirreniano del periodo interglaciale Riss-Wurm.

Alcune caratteristiche e la posizione dei coralli suggeriscono che, 129.000 anni fa, il livello del mare doveva trovarsi 6-8 metri sopra l'attuale. Inoltre, l'età ottenuta pone un limite superiore alla fase tettonica di risalita che, durante il Pleistocene, ha interessato la parte meridionale della Penisola Sorrentina.

RESUME

Dans cet article est exposé l'âge $^{230}\text{Th}/^{234}\text{U}$ de 4 coraux et d'un mollusque recueillis dans deux couches affleurantes de vieilles plages de la péninsule de Sorrento.

On a établi pour les fossiles examinés un âge de 129.000 ans qui correspond à un haut glaciaire-eustatique Tyrrhénien de la période interglaciaire Riss-Wurm.

Des caractéristiques et la position des coraux examinés nous apprennent qu'il y a 129.000 ans le niveau de la mer était de 6-8 mètres plus haut qu'aujourd'hui. En outre, cet âge établit une limite supérieur à la phase tectonique de remontée qui pendant le Pléistocène a intéressé la partie méridional de la péninsule de Sorrento.

