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MIDDLE AND UPPER PLEISTOCENE SEA LEVEL HIGHSTANDS ALONG THE TYRRHENIAN COAST OF BASILICATA (SOUTHERN ITALY) *

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ABSTRACT - *Middle and upper Pleistocene sea level highstands along the Tyrrhenian coast of Basilicata (Southern Italy)* - Il Quaternario, 4(1a), 1991, p. 173-202 - A research having the purpose of finding out ancient Quaternary shorelines has been carried out along the coast of Basilicata. The coast is high, indented, with rare beaches. The slopes are steep and with talus debris and alluvial fans of different ages at their foot. There are only few small terraces. Caves are very frequent because rocks are prevailingly limestones and dolomitic rocks. A typical abrasion platform stretches out discontinuously along the coast at elevations less than 10 m a.s.l. Algal biocalcarenites containing *Cladocora coespitosa* are very common, whose age has been determined using the $^{230}Th/^{234}U$ method. The D/L ratio for *Glycymeris, Arca* and *Astralium* shows that the transgressive deposits on *Cladocora* -bearing biocalcarenites belong to the last interglacial interval. A particular care in studying and describing the stratigraphical and morphological features of the study area allowed us to distinguish various shorelines, stratigraphically subdivided into pre-*Cladocora*, *Cladocora* and post-*Cladocora* levels. The study has highlighted some problems regarding the nomenclature and depth of sedimentation of the *Cladocora* -bearing biocalcarenites, and the number of sea highstands during Upper-Middle Pleistocene. The individuation of ancient shorelines allowed some remarks on the recent tectonics of the study area, on climatic variations, eustatic fluctuations of sea level and, finally, on the coast morphogenesis during Quaternary.

RIASSUNTO - *Stazionamenti del livello marino lungo la costa tirrenica della Basilicata (Italia meridionale) nel Pleistocene medio e superiore* - Il Quaternario, 4(1a), 1991, p. 173-202 - E' stata condotta una ricerca lungo la costa della Basilicata allo scopo di riconoscere le antiche linee di riva del Quaternario. Si tratta di una costa alta, frastagliata, quasi priva di spiagge; i versanti sono ripidi e ai loro piedi sono presenti falde detritiche e coni di deiezione di età diversa. Le superfici terrazzate sono scarse e di limitata ampiezza; frequenti le grotte marine, in quanto le rocce affioranti sono in prevalenza calcari e dolomie. Una caratteristica piattaforma di abrasione si estende in maniera discontinua lungo la costa a quote inferiori ai 10 m. Biocalcareniti algali a *Cladocora coespitosa* sono molto diffuse ed è stato possibile datarle con il metodo Th^{230}/U^{234}. Mediante l'analisi del grado di racemizzazione degli aminoacidi di *Glycymeris, Arca e Astralium* è stato possibile attribuire all'ultimo interglaciale i depositi trasgressivi sulle biocalcareniti a *Cladocora*. Particolare cura è stata posta nella descrizione e nella rappresentazione degli aspetti stratigrafici e morfologici delle località esaminate. Sono state così riconosciute diverse linee di riva, stratigraficamente suddivise in livelli pre-Cladocora, livelli a Cladocora e livelli post-Cladocora. Lo studio ha evidenziato alcune problematiche relative alla nomenclatura, alla profondità di sedimentazione delle biocalcareniti a *Cladocora*, al numero degli alti stazionamenti del mare durante il Pleistocene medio-superiore. Il riconoscimento delle antiche linee di riva ha permesso di trarre considerazioni sulla tettonica recente dell'area, sulle variazioni climatiche, sulle variazioni eustatiche del livello del mare e, infine, sulla morfogenesi della costa nel corso del Quaternario.

Key-words: Pleistocene, Holocene, geochronology, climatic variations, ancient shorelines, neotectonics, eustatism, Basilicata
Parole chiave: Pleistocene, Olocene, geocronologia, variazioni climatiche, antiche linee di riva, neotettonica, eustatismo, Basilicata

1. INTRODUCTION

The Tyrrhenian coast of Basilicata (Southern Italy), between Torre di Mezzanotte and the river Noce-Castrocucco (Fig. 1), has been studied with the purpose of distinguishing Pleistocene sea level highstands and comparing them with the results obtained in contiguous coast zones.

The sea level highstands have been correlated with the eustatic sea level changes occurred during Middle and Upper Pleistocene and with the stages of the palaeoclimatic curves. The obtained results served to the reconstruction of the neotectonic pattern of this part of the coast.

With the purpose of distinguishing and interpreting any evidence of ancient sea levels, a thorough survey of the sea forms and deposits was carried out. The continental deposits that might be useful for better determining the shoreline chronology were also taken into account. Sampling of deposits and fossil mollusks was carried out both with the purpose of sedimentological and palaeontological analyses, and age determinations.

A precision altimeter was used in the case of high (1st-order) terraces. Topographical maps at the scale 1:10,000 and aerial photographs (scales 1:33,000 and 1:10,000) were also used.

"Sea level indicators" were carefully scanned in order to precisely determine old sea level stands (and thus, their present altitude). Generally, average sea level is not evidenced by marine deposits with enough precision. On the contrary, wave-cut notch and inner margin of abrasion platforms show it very well. In dubious

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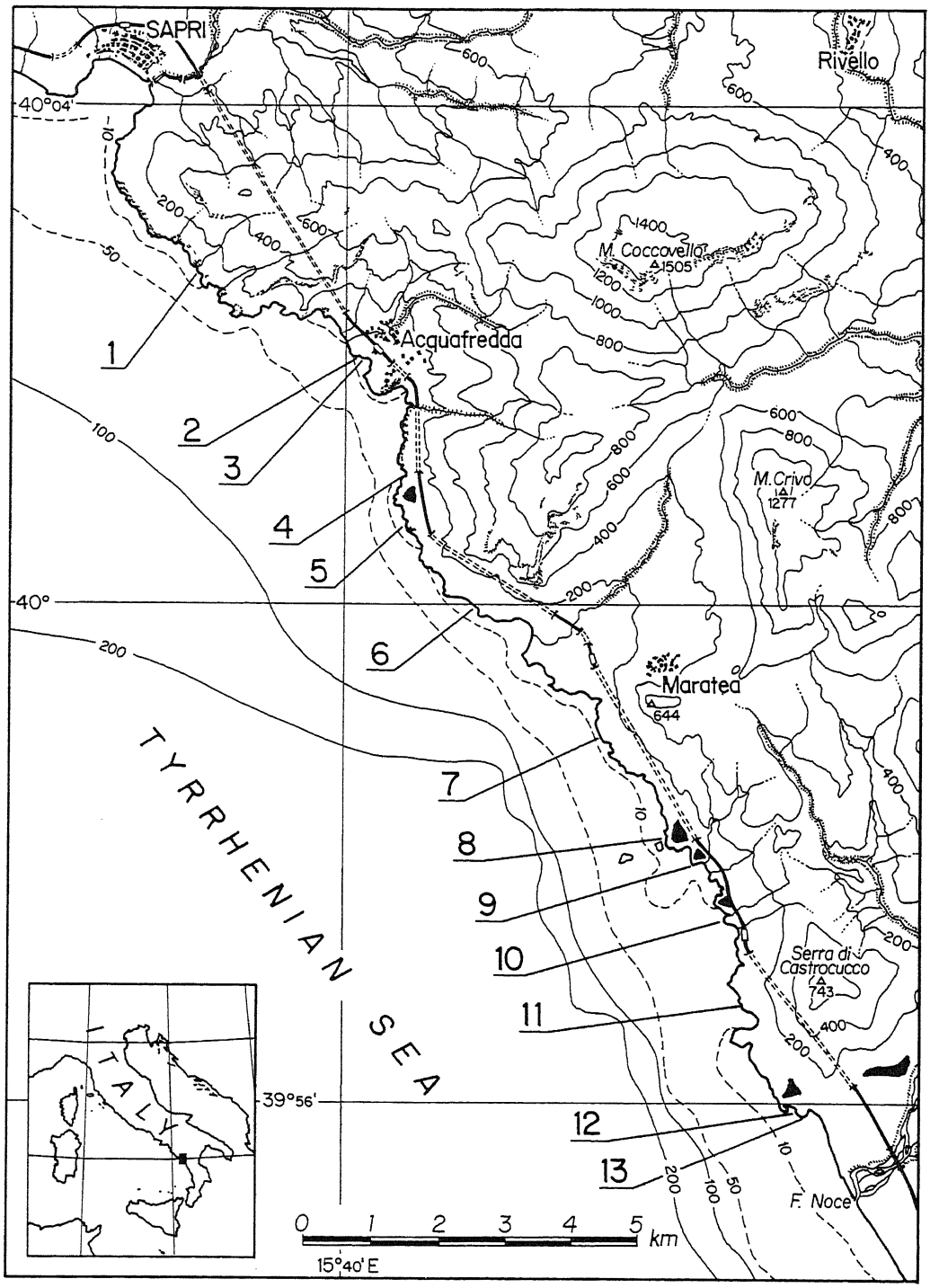


Fig. 1 - Location map of study sites. 1) Torre di Mezzanotte; 2) Acquafredda Nord; 3) Acquafredda Sud; 4) Cersuta-Fosso Pisciotta; 5) Cersuta-Capo la Nave; 6) Ogliastro; 7) Torre del Porto; 8) Punta della Matrella; 9) Marina di Maratea Nord; 10) Marina di Maratea Nord; 11) Punta Iudia; 12) Capo la Secca; 13) Porticello di Castrocucco.

Posizione geografica delle località esaminate. 1) Torre di Mezzanotte; 2) Acquafredda Nord; 3) Acquafredda Sud; 4) Cersuta-Fosso Pisciotta; 5) Cersuta-Capo la Nave; 6) Ogliastro; 7) Torre del Porto; 8) Punta della Matrella; 9) Marina di Maratea Nord; 10) Marina di Maratea Nord; 11) Punta Iudia; 12) Capo la Secca; 13) Porticello di Castrocucco.

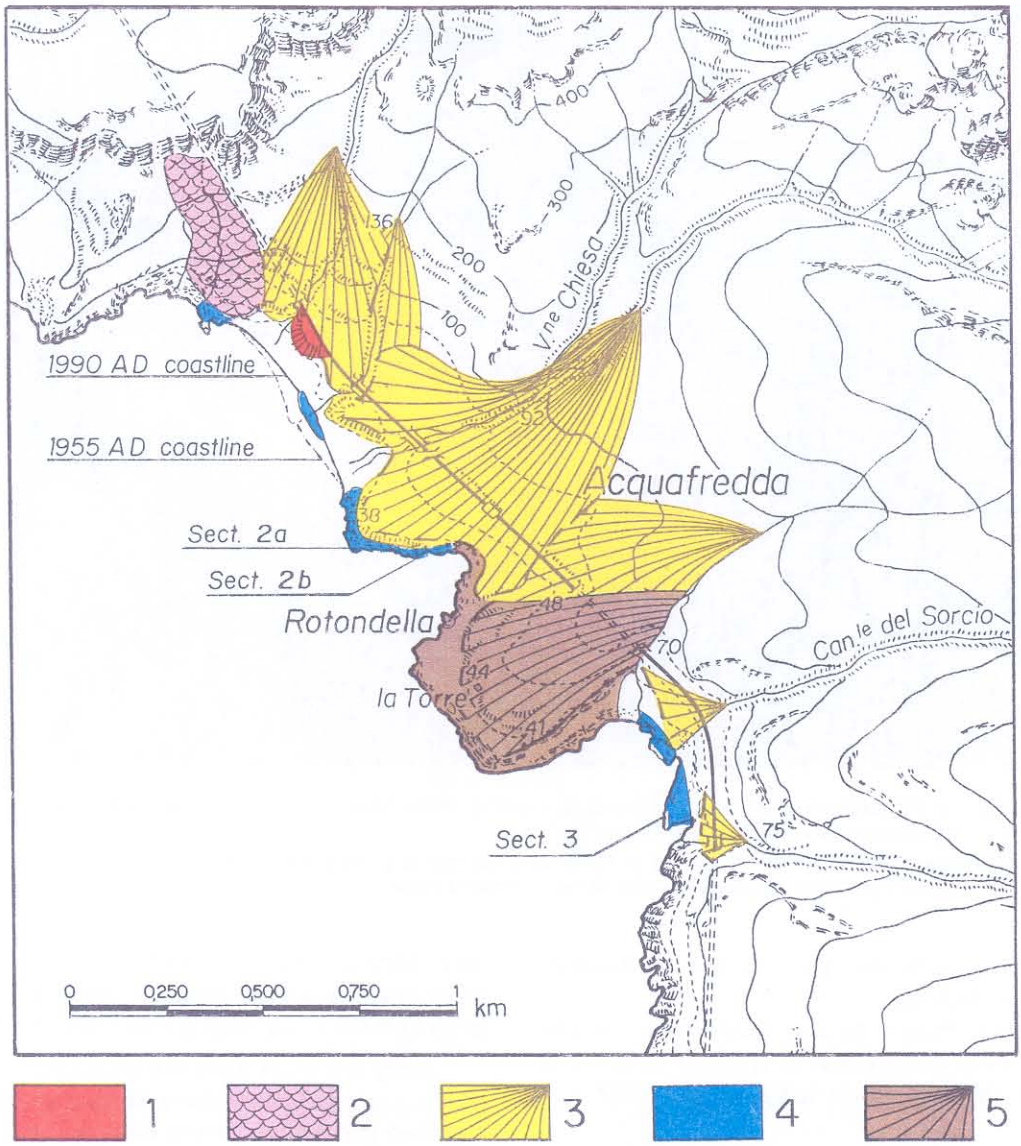


Fig. 2 - Acquafredda alluvial fans. 1) waste soil; 2) rock fall; 3) Würmian alluvial fans; 4) *Cladocora*-bearing biocalcarenite; 5) pre-*Cladocora* alluvial fans.

Conoidi di deiezione di Acquafredda. 1) terreno di risulta; 2) frana di crollo; 3) coni di deiezione würmiani; 4) biocalcarenite a Cladocora*; 5) coni di deiezione pre-*Cladocora.

cases, the elevation of the old sea level highstands has been indicated as greater or lesser than that of the morphological element taken into account (Table 3).

No surveys were carried out on those parts of the coast which could not be easily reached from the land and on large marine caves which are very difficult to explore. However, the about 20 kilometres of surveyed coast have been studied well in 13 localities (Fig. 1) where tens of cross-sections — some of them shown in this paper — were made.

Recognition and definition of old sea level highstands were hindered by the diversity and discontinuity of morphological and sedimentological features of ancient shorelines together with their difficult interpretation, correlation and age determination. Moreover, a precise separation between shorelines of different age was prevented by the slight uplift occurred in this part of the coast, so that various shorelines can be confused with one another.

U-series age determinations on specimens of *Cladocora coespitosa* and D/L ratio determinations on various mollusks (*Glycymeris, Arca* and *Astralium*) were carried out. Obtained ages conform to field data and have been used for a chronological comparison with contiguous coast zones (Brancaccio *et al.*, 1990; Carobene *et al.*, 1986; Carobene and Dai Pra, 1991).

Studies on the Quaternary of the study portion of coast are scarce. A few information on ancient shorelines are found in Bousquet (1973), Compagnoni and Damiani (1971), Damiani and Pannuzi (1979) and in Lirer

Fig. 3 - Landscape of the northern coast (between sections 1 and 6). In the background, the Cersuta detritic slope, Acquafredda, steep rocky cliffs, and structural surfaces dipping seawards.

Aspetto della costa settentrionale (tra le sez. 1 e 6). In secondo piano il versante detritico di Cersuta; sullo sfondo, oltre Acquafredda, ripidi versanti in roccia e superfici strutturali inclinate verso mare.

et al. (1967). Data on elevation and age are however scarce or even lacking.

A general sketch of the Quaternary tectonic evolution is given in Ciaranfi *et al.* (1983), Palmentola *et al.* (1981) and in the Neotectonic Map of Italy (1987).

2. MORPHOLOGICAL AND GEOLOGICAL LINEAMENTS

2.1 General morphological features

The study coast portion is an indented very steep up to vertical high coast with small promontories and bays, and with very few beaches (Fig. 1). It is very different from the Calabrian coast on the south of Noce-Castrocucco river characterized by terrace flights and wide gravel-sandy beaches.

This *cliff morphology* would not be a recent character but, as suggested by Damiani and Pannuzi (1979) it would have characterized Pleistocene in its whole. In our opinion, it is indeed the consequence of the strong subsidence occurred in the Sapri basin during Quaternary and of the contemporaneous uplifting of the inland area between Sapri and the river Noce (see § 2.3).

Slopes are for the most part steep with an average inclination (from the watershed to the shoreline) ranging up to 25°-35°. The watershed stretches from north to south at elevations between 500 and 1,500 m at a distance from the coast ranging from 1,200 to 4,000 m.

Along the coast there are wide *talus covers* at the slopes toe, and alluvial fans at the valleys mouth. At least two generations of breccias can be distinguished as based on their cementation degree and stratigraphical relationship (Fig. 2). At present, the breccia deposits are largely truncated seawards and cut through by water courses (Fig. 3).

The trend of *streams* is strongly conditioned by the bedrock carbonatic nature, the slopes inclination, tectonics and stratification. In particular, they are steep and deep in the study area northern sector; whereas they display an angulate drainage pattern on the south of Maratea. There are no water courses on Serra Castrocucco.

Maratea valley is worth mentioning because it is characterized by deep gravitational deformations of the *sackung* type in the calcareous-dolomitic slopes of the Maratea mountains, and by the sliding of large calcareous-dolomitic blocks and alluvial fans (Guerricchio *et al.*, 1987). Guerricchio *et al.* do not give information about when the sliding phenomena started, while recent activity is well documented. In our opinion the *sackung* genesis may be attributed to the beginning of the pleistocenic uplift of the area (Ch. 6).

Table 1 - Analytical data and U-series ages of the *Cladocora coespitosa* specimens collected in the study area (Y2 shoreline) and at Grotta del Prete, 8 km on the SE of Noce river. The analyses were provided by M. Gewelt and C. Hurtgen (CEN/SCK, Mol. Belgium).

Dati analitici ed età ottenute col metodo Torio-Uranio su Cladocora coespitosa *raccolta nell'area in studio (linea di costa Y2) e a Grotta del Prete, 8 km a SE del fiume Noce-Castrocucco. Le analisi sono state effettuate da M. Gewelt e C. Hurtgen (CEN/SCK, Mol, Belgio).*

Location	Elev. m	Sample No.	[U] (ppm)	$^{234}U/^{238}U$	$(^{234}U/^{238}U)_o$	^{230}Th ^{232}Th	$^{230}Th/^{234}U$	Age (kyr)
Grotta d. Prete	15	LB 96	2.272±0.055	1.111±0.038	1.283±0.380	340±54	0.986±0.030	329^{+196}_{-64}
Punta d. Matrella	12	LB 110	2.686±0.063	1.111±0.037	1.182±0.079	126±14	0.804±0.027	172^{+26}_{-20}
M. di Maratea N	3.6	LB 111	2.695±0.068	1.105±0.039	1.189±0.106	340±52	0.866±0.029	208^{+44}_{-29}
Cersuta C. la Nave	2.5	CER 3	2.768±0.072	1.091±0.040	1.143±0.077	535±99	0.774±0.026	159^{+23}_{-17}

Terrace surfaces along this portion of the coast are few and of limited extent; their elevation is never higher than 50-60 m a.s.l. Terraces (some of which interpreted as of marine origin, see Ch. 3) can be seen near Acquafredda, Cersuta, Punta Ogliastro, Punta della Matrella, Timpa Tenaglia and Capo la Secca. Damiani and Pannuzi (1979) say that there are terraces also within the Maratea large *sackung;* for such reason, we have not considered these terraces for this study.

2.2 Morphological features of ancient shorelines

Traces of old sea stands are visible well only below the elevation of 15 m above sea level. The most conspicuous morphological element is the presence of an *abrasion platform*, from a few metres to 40-50 m wide, that is high on the sea up to about 9 m. The occasional presence of fossils on its surface made it possible to date the platform (see Tables 1 and 2). There are also many *marine caves* that may be either totally emersed or drowned, which have been studied only partially; however a more thorough study of them is worth being carried out because they represent sea stands of various age and elevation.

When cliffs are formed of the carbonatic rocks of the mesozoic bedrock, both the present wave-cut notch and the old one can be present at their base; the height of the notches is always less than 1 m. It may occur that the cliff wall may display an horizontal notch at a height more than 1-2 m; in this case, it may be the trace of a broken out marine cave (see, footnote 1). Because notches may have various origin and form (Pirazzoli, 1986; Ozer *et al.*, 1987), they may not be always a precise evidence of sea stand. In the case of true wave-cut notches, the methodology proposed by Carobene (1972) has been adopted.

Ancient shorelines can be distinguished not only by means of the above mentioned forms, but also through the analysis of littoral deposits, such as a biocalcarenite with *Cladocora coespitosa* which is the most important and widespread deposit in the study area. This biocalcarenite has been dated with the $^{230}Th/^{234}U$ method applied to specimens of *Cladocora* sampled in several places (Table 1). Thus, it has been a precious key bed for the chronology of shorelines.

The more than 300,000 yr old B.P. organic deposits of Peninsula Salentina called "Calcari bioclastici" (bioclastic limestone) (Dai Pra and Stearns, 1978) can very well be associated with the *Cladocora*-bearing biocalcarenite of our study area both because of its age, stratigraphic position and facies affinity: the deposits occur immediately before the *Strombus bubonius* horizon. Other deposits (conglomerate, sandstone, calcarenite) are described in Ch. 3; however, they never show the precise level of the old sea stand, and are useful for environment considerations.

Finally, *continental breccias* are of particular bearing because their deposition occurred during glacial periods alternating with marine and littoral sediments of the interglacial periods.

2.3 Lineaments of geology and neotectonics

Platform carbonate sequences formed mainly of 1) Early Lias-middle Trias stratified or massive dolomite and dolomitic limestone which has a blackish colour fading up towards the top of the series, and which contains clay intercalations; and subordinately of 2) blackish limestone with grey dolomitic intercalations of early Cretaceous-Titonic (Sh. 220 "Verbicaro" and Sh. 210 "Lauria" of the Geological Map of Italy). Such carbonatic sequences form the "cover units of southern Apennines, affected by

orogenic transport during Burdigalian and Langhian times" (C.N.R., *Synthetic structural-kinematic map of Italy*, 1989).

Carbonatic units are strongly tectonized, both as a consequence of the compressive phases giving rise to the southern Apenninic chain in Miocene times (Pescatore, 1982), and of the extension tectonics in Pliocene-Pleistocene associated with the isostatic uplifting of the chain itself (*Neotectonic Map of Italy*, 1987).

3. STRATIGRAPHICAL AND MORPHOLOGICAL FEATURES OF THE STUDY SITES

Data collected in the various localities can not immediately compared to and correlated with one another because of the marked variability of morphological and altimetric features of the sea level stands evidence along the Tyrrhenic coast of Basilicata. In this chapter identified shorelines will be described separately, whereas a general discussion will be presented in the conclusions chapter.

A point by point description is preferable also because of the complexity of the coast, the presence of cliffs, the difficulty in reaching from the land the Quaternary deposits which outcrop a few metres above sea level. Thus, we could not describe without interruption the whole coast; all the available elements were analysed, anyway.

Both marine and continental deposits and forms have been considered; the various features are shown in sections 1 through 13. The correlations between the various localities has been made easier: 1) by the presence of *Cladocora*-bearing biocalcarenite whose outcrops in the more southern portion of the coast have already been described (Carobene *et al.*, 1986; Carobene and Dai Pra, 1991); 2) by the presence of a typical abrasion platform and associated deposits that was formed after the sea stand corresponding to the deposition of the *Cladocora*-bearing biocalcarenite; 3) by the superposition of slope breccia deposits often including *Helix*-bearing silt layers and pyroclastic materials over the abrasion platform (Fig. 4). These latter can be correlated with the pyroclastic horizons of Würm age according to Lirer *et al.* (1967) on the basis of physico-chemical analyses and stratigraphic correlations.

To recognize such relative chronology has made possible to get over the difficult interpretation due to variable elevations, forms and deposits in the various sections. Radiometric age determinations (U-series on Corals) and the D/L ratio on fossil mollusks confirmed the field results.

Cladocora coespitosa from the above mentioned biocalcarenite has given U-series ages ranging from 159 to 329 kyr (Table 1), which suggest that the *Cladocora*-bearing biocalcarenite did not form during the last interglacial period. It is well known that the main sea level highstand in the last interglacial period dates back to 124 kyr B.P. (Broecker and Denton, 1990). So, the *Cladocora*-bearing biocalcarenite was deposited during previous interglacial periods (Dai Pra and Stearns, 1978; Carobene *et al.*, 1986). Variability in age data depends upon sample conditions, namely upon coral recrystallization and opening of the system favouring decrease in U concentration. As far as problems connected with the method are concerned, see Gewelt in Carobene *et al.* (1986).

Table 2 - Isoleucine epimerization ratios (D/L) for *Glycymeris*, *Arca* and *Astralium* shells from raised marine deposits in the study area. *Glycymeris* ratios in brackets are derived from *Arca* and *Astralium* ratios converted to *Glycymeris* equivalent ratios; *Gly/Arca* = 1.31; *Gly/Astralium* = 0.71. See Hearty *et al.*, 1986. Aminozone E corresponds to the last interglacial period. Analyses were provided by the INSTAAR Amino Acid Geochronology Laboratory (Colorado University).

Valori dell'epimerizzazione dell'Isoleucina (D/L) su Glycymeris, Arca *ed* Astralium *provenienti da depositi marini dell'area in studio. I valori su* Glycymeris *fra parentesi quadre derivano dal rapporto* Gly/Arca e Gly/Astralium *di 1,31 e 0,71rispettivamente. Si veda Hearty et al.,1986. L'Aminozona E corrisponde all'ultimo interglaciale. Le analisi sono state effettuate da INSTAAR, Amino Acid Geochronology Laboratory (Colorado University).*

Sample No.	Location	Elevation m	ISOLEUCINE EPIMERIZATION			AMINOZONE
			Glycymeris D/L	Arca D/L	Astralium D/L	
LBX1	Acquafredda	5.50	0.437(4)			E
LB113	M. di Maratea Sud	5.00	[0.35]		0.497(4)	E
LB115a	M. di Maratea Sud	9.30	[0.42]	0.318(3)		E
LB115b	M. di Maratea Sud	9.30	[0.40]	0.305(1)		E
LB126	M. di Maratea Sud	9.00	[0.43]	0.327(4)		E

Fig. 4 - Marina di Maratea (sect. 10). Brown muddly layer at the base of the breccia deposit (Sb) covering the inner margin of the Eutyrrhenian abrasion platform. Propably, it is a reworked eolic deposit containing fine-grained sand, small fragments of marine shells, pyroclastic materials, and unbroken *Helix* shells.

Marina di Maratea (sez. 10). Livello limoso marrone alla base delle brecce (Sb) che coprono il margine interno della piattaforma di abrasione eutirreniana. Si tratta propabilmente di un deposito eolico rimaneggiato, che contiene sabbia fine, piccoli frammenti di gusci marini, materiale piroclastico e gusci interi di Helix .

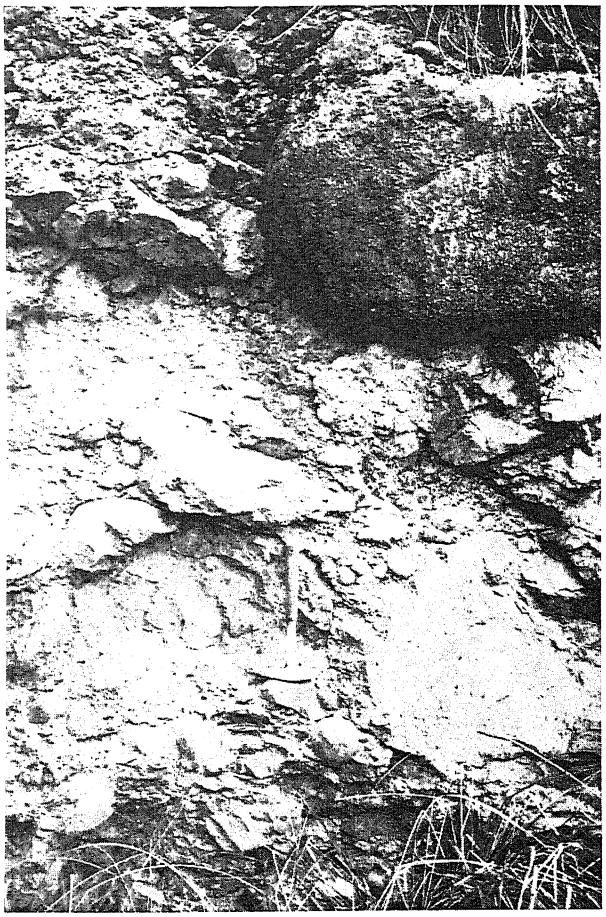


Fig. 5 - Heterometric conglomerate covering a wave-cut platform relic 45 m a.s.l. at Torre di Mezzanotte (sect. 1). The mainly carbonatic clasts are well rounded (W-order terrace in Table 3).

Conglomerato eterometrico che copre un relitto di piattaforma di abrasione a 45 m di quota, in località Torre di Mezzanotte (sez. 1). I clasti, in prevalenza carbonatici, sono molto arrotondati (ordine W di Tabella 3).

Aminoacid analyses of the deposits that are transgressive over the *Cladocora*-bearing biocalcarenite have given D/L ratios close to 0.40 (Table 2) falling within the aminozone E, which corresponds to the equivalent results obtained for mollusks from the Eutyrrhenian classical deposits of Tunisia, Spain and Italy, if the different local mean annual temperatures (MAT) at the different latitudes are taken into consideration (Hearty *et al.*, 1986; Miller *et al.*, 1986). Thus, we can say that the above mentioned sediments emplaced during the last interglacial period — probably during the main peak — even if there are not comparison radiometric ages and if morphostratigraphic and lithostratigraphic relationships are taken into account.

Therefore, 13 sites from north to south will be described hereafter; it is to keep in mind that the illustrations show *actual sections* and, thus, they do not explain all the features mentioned in the text and all the data given in Table 3.

3.1 Torre di Mezzanotte

a) *Marine forms and deposits*

- At km 220 of the State Route no.18, it can be seen the inner margin of a marine terrace at about 45 m elevation a.s.l. The abrasion surface cut into layered grey limestone is still covered by a conglomeratic deposit with well-rounded heterometric pebbles, whose top is reworked and covered by slope breccia. The small promontory on the south where Torre di Mezzanotte is located, is probably a relic of such terrace.
- A wave-cut notch is visible at 14 m a.s.l. (maximum retreat point) (Figs. 6 and 7). The relics of *Cladocora*-bearing biocalcarenite at el. 12 m a.s.l., *Lithodomus* holes at el. 7.8 m a.s.l. and some large caves (however not surveyed) opening at elevations below 15 m a.s.l. testify this sea level stand.

Table 3 - Chronology and correlation of the sea level highstands. T) marine terrace; P) wave-cut platform; C) sea cave; N) wave-cut notch; H) *Lithodomus* holes; Co) marine conglomerate; D) beach deposits; Cl) *Cladocora*-bearing biocalcarenite.

Cronologia e correlazione degli alti livelli di stazionamento del mare. T) terrazzo marino; P) piattaforma di abrasione; C) grotta marina; N) solco di battente; H) fori di litodomi; Co) conglomerato; D) deposito di spiaggia; Cl) biocalcarenite a Cladocora.

CHRONOLOGY	MIDDLE PLEISTOCENE				UPPER PLEISTOCENE		HOLOCENE
ISOTOPIC STAGE	21 - 13 ?		11 - 9 - 7		5e 5a/c?		1
STRATIGRAPHY	PRE-CLADOCORA SEA LEVEL STANDS		CLADOCORA SEA LEVEL STANDS		POST CLADOCORA SEA LEVEL STANDS		
ORDERS / SITES	W (m)	X (m)	Y2 (m)	Y1 (m)	Z2 (m)	Z1 (m)	H (m)
1 Torre di Mezzanotte	~45 Co T		14 N (12 Cl)		≥7 P C	5.00 N P (5.30 D)	
2 Acquafredda N			~15 N H (9.30 Cl)		6.90 N P (5.50 D)		
3 Acquafredda S			(6.00 Cl)		>6.00 D P		
4 Cersuta Pisciotta			14-15 H (8.60 Cl)		≥6.40 P	5.00 N Co	
5 Cersuta Capo la Nave	~50 T	20-25 T Co	(4.50 Cl)		>5.00 D P	>1.70 D	
6 Ogliastro	~55 T		(8.50 Cl)		>5.60 P		<3.80 C Co
7 Torre del Porto			16.20 N (8.00 Cl)	11.5 H N	~8.00 P (8.00 D)		
8 Punta della Matrella	~55 Co T	20-25 T Co	≥15 T (14.30 Cl) H	≥11.5 H NCo	~8.00 D C H		
9 Marina di Maratea N			10.50 P Cl		≥8.65 P	5.5 D C H N	
10 Marina di Maratea S			(9.30 Cl)		≥9.30 D P		
11 Punta Iudia			~19.00 H P (14 Cl)		~9.50 P		
12 Capo la Secca	≥50 T		(13.50 Cl)		~9.00 D N		
13 Porticello Castrocucco	45 Co H	23 C H		12 C	9.50 D C N		

- A large abrasion platform never higher than 7 m a.s.l. and wide up to 20-30 m, cuts dolomitic limestone dipping seawards and the *Cladocora*-bearing biocalcarenite. This latter deposit is still visible as scattered strips on the abrasion surface (Figs. 6 and 8). A groove or cave at elevations 5.5 to 7 m a.s.l. (Fig. 6) can be ascribed to the formation of the abrasion platform.
- Another wave-cut platform joined to a wave-cut notch at 5. m a.s.l. (maximum retreat point) (Fig. 8) cuts the above mentioned platform in many places and is partially covered by a 50 cm thick cemented conglomerate which turns, towards the top, into a coarse-grained yellow-pink biocalcarenite.

b) *Continental forms and deposits*

At the slope toes there are stratified cemented breccia deposits (dip = 25°) which locally cover the platform inner margin. Such breccia deposits are what is left of a deposit filling the valley upstream and overlying the above mentioned wave-cut platforms. The deposit has mostly been destroyed by the sea and river erosion. The situation is that typical of many other studied areas (see § 6.2).

3.2 Acquafredda Nord

a) *Marine forms and deposits*

- *Lithodomus* holes and wave-cut notches are visible on the walls of broken marine caves at 15 m a.s.l. The *Cladocora* deposit is widespread and is locally cut by a wave-cut platform (see *infra*); elsewhere, it is still visible as relic strips up to 9.30 m a.s.l. Also in this case (such as in section 1) *Cladocora*-bearing biocalcarenite may be associated with the presence of a notch at a higher elevation. The difference in elevation between this deposit and the notch correlable with it, is constant in all outcrops (see Ch. 4, and § 5.2). At Acquafredda Nord, the bedrock underlying the *Cladocora*-bearing biocalcarenite is formed of the "old breccia" deposit (Figs. 9 and 10).
- A wide abrasion platform cuts both the "old breccia" bedrock and the *Cladocora*-bearing biocalcarenite (Fig. 9). The inner margin of the platform is locally covered by a recent alluvial fan deposit that is truncated by a

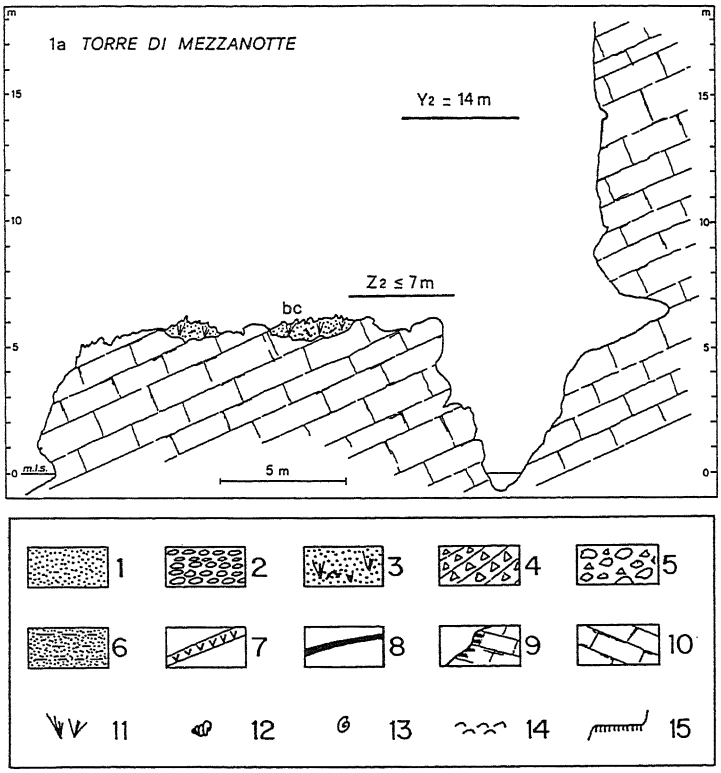


Fig. 6 - Wave-cut notch at el. 14 m a.s.l. corresponding with the sea level stand during which sedimentation of the *Cladocora*-bearing biocalcarenite occurred. The lower (Z2) sea level stand almost totally eroded the *Cladocora*-bearing biocalcarenite giving rise to a wide abrasion platform, notches and grooves. Legend - Marine deposits: sandstone or calcarenite (fs = fossiliferous sandstone; cs = coarse-grained sandstone; os = organic sandstone; ls = laminated sandstone); 2) conglomerate (fco = fossiliferous conglomerate; cco = coarse-grained conglomerate; sco = stratified conglomerate); 3) *Cladocora*-bearing biocalcarenite (bc). Continental deposits: 4) recent stratified breccia (rb); 5) old alluvial fan breccia (ab); 6)silty colluvium (mc); silty colluvium with *Helix* shells (mcH); 7) layer of fine-grained pyroclastic materials; 8) calcareous incrustations; 9) *Lithodomus* holes; 10) carbonatic bedrock. N.B. - This legend is valid also for section 1 through 12.

Solco di battente a 14 m corrispondente allo stazionamento marino durante il quale si é deposta la biocalcarenite a Cladocora. *Lo stazionamento marino più basso (Z2) ha eroso quasi completamente il deposito a* Cladocora *formando un'estesa piattaforma di abrasione, solchi o grotte. Legenda - Depositi marini: 1) arenarie o calcareniti (fs = arenarie fossilifere; cs = arenarie grossolane; os = arenarie organogene; ls = arenarie laminate); 2) conglomerato (fco = conglomerato fossilifero; cco = conglomerato grossolano; sco = conglomerato stratificato); 3) biocalcarenite a Cladocora* (bc). Depositi continentali: 4) breccia stratificata recente (rb); 5) breccia di cono di deiezione antico (ab);:6) colluvium limoso (mc); colluvium limoso con Helix (mcH); 7) livello di piroclastite fine; 8) crosta calcarea; 9) fori di litodomi; 10) substrato carbonatico. Questa legenda vale per tutte le sezioni (da 1 a 12).

high cliff seawards. Where the erosion of the recent alluvial deposit has been deeper, the exhumed wave-cut notch (on the platform inner margin) is visible. The maximum retreat point is at 6.90 m .s.l. (Fig. 9). The exhumed deposits overlying the wave-cut platform consist of a conglomerate which turns laterally and upwards into a sand with *Glycymeris* (sampled for the D/L ratio analysis), *Astralium* and *Spondylus* (Fig. 11).

b) *Continental forms and deposits*

- The coast sector including Acquafredda and Rotondella promontory (Fig. 1) is characterized by a strongly cemented "old breccia" deposit. The corresponding alluvial fans (Fig. 2), today partially destroyed by sea erosion and weathering, have been identified by means of aerial photographs. The "old breccia" alluvial fan is formed by large limestone and dolomite subrounded clasts up to 50 cm (rarely 100 cm) in diameter which are immersed in a heterometric breccia formed of clasts a few centimetres in diameter joined to one another by a reddish cement (Fig. 12). More information on their origin and age can be found in Ch. 6.
- A recent poorly cemented and badly stratified breccia deposit (younger than the wave-cut platform) with horizons displaying various occasionally classed and washed-out grain-sizes, and rubified colluvial horizons is also common there; a 5 to 10 cm thick pyroclastic layer is worth noting. In the past, breccia deposits formed alluvial fans and talus debris which are today partially demolished by erosion.

3.3 Acquafredda Sud

a) *Marine forms and deposits*

- A *Cladocora*-bearing biocalcarenite deposit overlying an uneven bedrock formed by a dolomitic limestone, terminates with a wave-cut platform at 5-6 m a.s.l. and

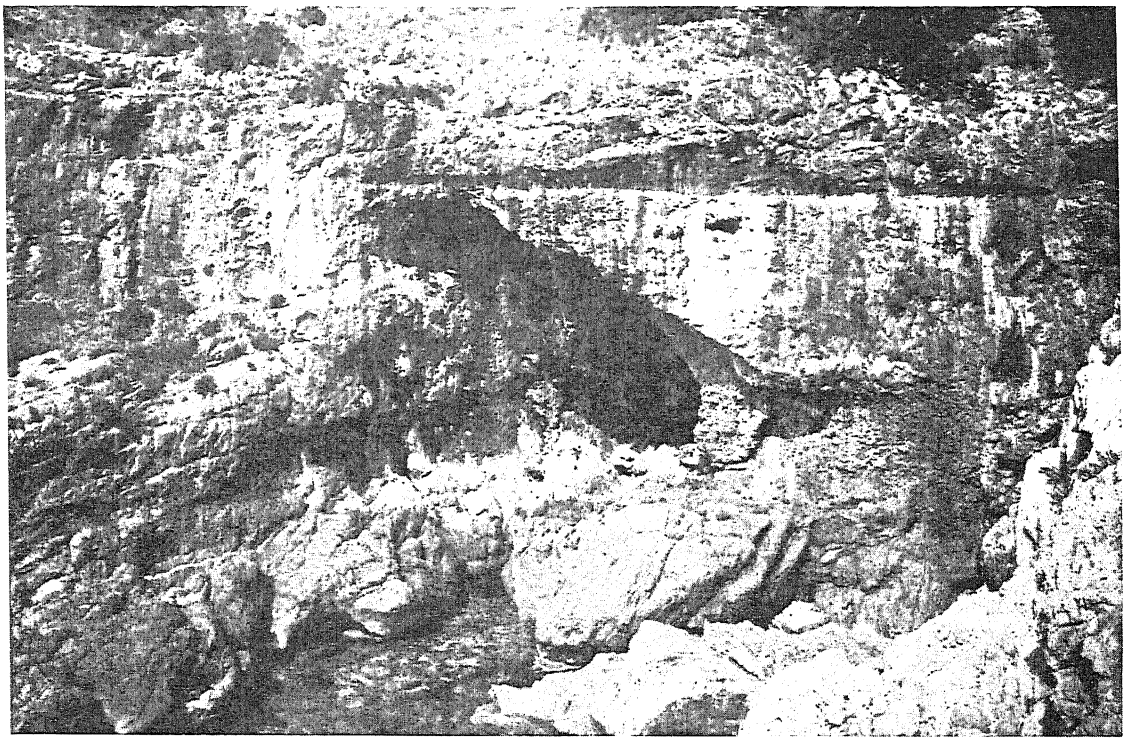


Fig. 7 -Wave-cut notch 14 m a.s.l. at Torre di Mezzanotte (see Fig. 6). This sea level highstand corresponds with the deposition of the *Cladocora*-bearing biocalcarenite.

Solco di battente a 14 m in località Torre di Mezzanotte (vedi Fig. 6). Questo stazionamento marino corrisponde alla deposizione della biocalcarenite a Cladocora.

forms a slab up to 2 m in thickness. Toward the bottom, the biocalcarenite fades into a heterometric conglomerate with rounded clasts (Fig. 13).

- The portion of coast on the south of Rotondella promontory (Fig. 2) is formed by a wide and well-preserved abrasion platform, whose inner margin is covered by recent alluvial fans truncated on their front. On the south of section 3 on the contrary the coast is formed of high limestone cliffs and badly preserved strips of wave-cut platforms. In the case of Rotondella we deal with a "exhumed platform"; in the second case, with "platform relics".

The abrasion platform cuts both the bedrock limestone, *Cladocora*-bearing biocalcarenite and, locally, also the "old breccia" deposit. The platform elevation is around 5-6 m a.s.l. Its maximum elevation cannot well be measured anyway because of the presence of alluvial fans (Fig. 13).

3.4 Cersuta - Fosso Pisciotta

a) *Marine forms and deposits*

- The *Cladocora*-bearing biocalcarenite deposit is truncated by a wave-cut surface, and cannot be found at elevations higher than 8.6 m a.s.l. Its thickness ranges up to some metres. This deposit overlies a stratified highly fractured dolomitic rock, the contact between the two formations being uneven. The *Lithodomus* holes visible up to 14-15 m a.s.l. and the *Cladocora*-bearing biocalcarenite could represent the same sea level highstand.
- The very wide wave-cut platform whose inner margin is hidden by slope breccia deposits (Fig. 14) can be seen up to the maximum elevation of 6.40 m a.s.l., cutting both the *Cladocora*-bearing biocalcarenite and the bedrock dolomite.
- Wave-cut notches whose maximum retreat point is at 5 m a.s.l. (Figs. 15 and 16) Are well visible, and are related to small abrasion surfaces cutting both biocalcarenite (Fig. 15) and the dolomitic bedrock (Fig. 16). Such surfaces are generally covered by a conglomerate deposit with large pebbles up to 1-2 m thick, which may occasionally turns into A fine-grained gravel and organic sand deposit towards the top.

b) *Continental forms and deposits*

- A breccia deposit outcrops at the slope toes, and is the remnant of a large alluvial fan which probably filled the Fosso Pisciotta valley. Nowadays, this fan is truncated seawards by a cliff and has largely been taken away by the valley erosion. The deposit is layered, and layers with large angular blocks alternate with layers of fine-grained breccia at times having an abundant matrix, at times washed away. A some 10 cm thick pyroclastic

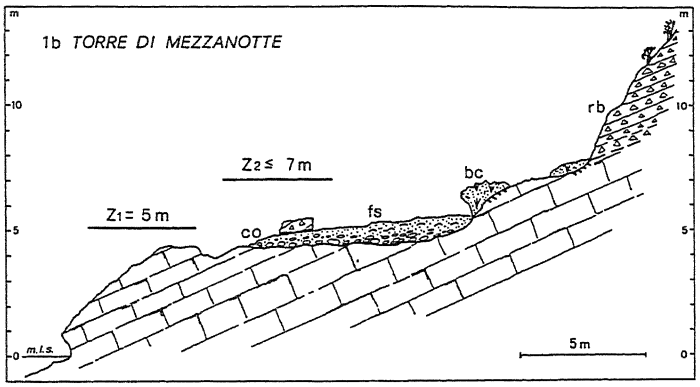


Fig. 8 - Z1 sea level is well evidenced by beach sediments and a wave-cut notch 5 m a.s.l. The inner margin only of the platform at el. 7 m a.s.l. that is considered of Eutyrrhenian age is shown in the section. Biocalcarenite (bc) strips are evidence of the pre-Tyrrhenian transgression and not of its maximum elevation.

Il livello Z1 è ben rappresentato da sedimenti di spiaggia e da un solco di battente a 5 m. La piattaforma a 7 m, considerata eutirreniana è qui rappresentata solamente dal margine interno. I lembi di biocalcarenite (bc) testimoniano la trasgressione pretirreniana, ma non la quota massima.

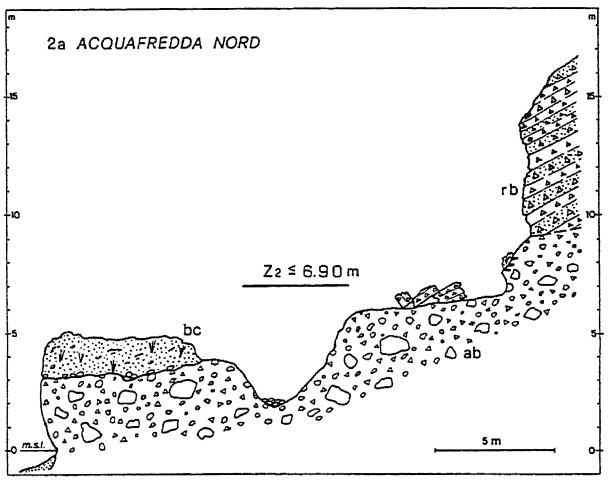


Fig. 9 - Abrasion platform younger than the *Cladocora*-bearing biocalcarenite. The substratum is formed of alluvial fan breccia (Fig. 10). The platform was exhumed by the erosion of recent breccia.

Piattaforma di abrasione successiva al deposito a Cladocora. *Il substrato è costituito da brecce antiche di conoide (Fig. 10). La piattaforma è stata esumata a seguito dello smantellamento delle brecce recenti.*

layer is also present.

The wave-cut platform that once was covered by breccia deposits, is now deeply karstified, particularly where the *Cladocora*-bearing biocalcarenite outcrops (Fig. 17).

3.5 Cersuta - Capo La Nave

a) *Marine forms and deposits*

- A terrace between 42 and 50 m a.s.l. cuts the bedrock formed of stratified limestone. The marine origin is not sure, and is inferred by the long-shore position of the terrace that is deeply eroded and with no deposits.

-The small Capo La Nave promontory has a wave-cut platform between 20 and 30 m a.s.l. The same considerations reported for the terrace are valid also for this small abrasion surface.

- A *Cladocora*-bearing biocalcarenite outcrops up to 4.50 m a.s.l. and is truncated by an abrasion platform. The deposit heterotopically turns laterally into a prevailingly conglomeratic deposit (Fig. 18). This fact is due to the conveyed amount of terrigenous material conditioning the growth of *Cladocora coespitosa.*
- On this portion of the coast, a moderately wide wave-cut platform can be seen at elevations never higher than 5 m a.s.l., because its inner margin is hidden by a thick breccia deposit and its elevation is not visible. An organic conglomerate, overlaid by a laminated sand deposit, locally covers the platform (sample CER3).
- Twenty metres on the south of Capo La Nave, in a narrow bay, there is a marine cave carved into a *Cladocora*-bearing biocalcarenite at elevations from below sea level up to 3.70 m a.s.l. that is filled by conglomerate with clasts up to 30÷40 cm in size. The conglomerate is covered by a 40 cm thick layer of organic calcarenite rich in fossils (mostly, small *Conus* and *Astralium*). A fine-grained eolic sand —which forms nowadays a cemented brown-reddish sediment— deposited over the organic calcarenite. Because of its relative position, the conglomeratic deposit can be attributed to a sea level stand subsequent to that which produced the more than 5 m high wave-cut platform above mentioned.

b) *Continental forms and deposits*

- The thick breccia deposits at the slope toes represent old alluvial fans, which today have been truncated seawards. Two pyroclastic layers (Fig. 19) and a silt horizon with *Helix* are worth noting in particular.

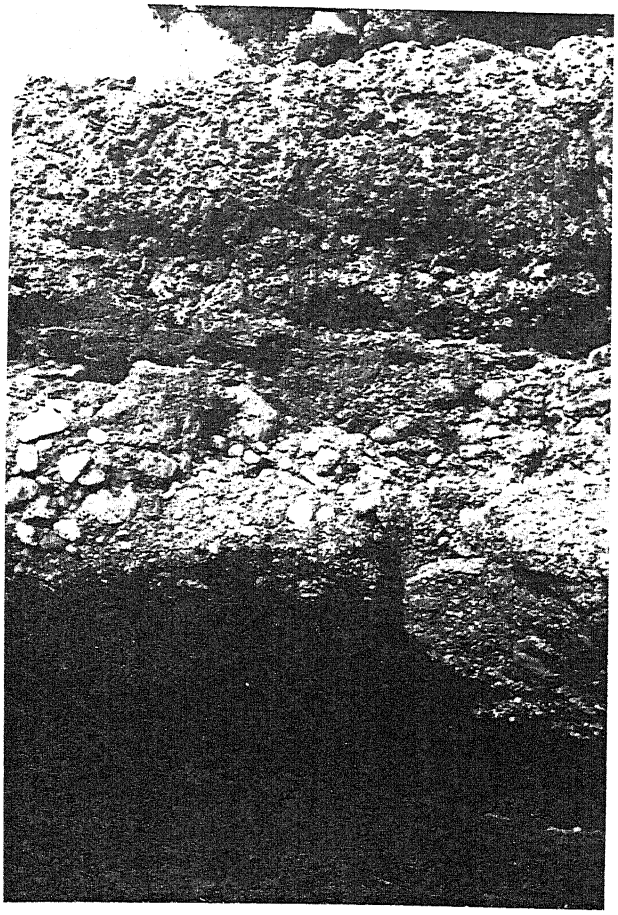


Fig. 10 -Acquafredda Nord (sect. 2a). *Cladocora*-bearing biocalcarenite overlying an old alluvial breccia

Acquafredda Nord (sez. 2a). Biocalcarenite a Cladocora *poggiante su brecce di conoide antico.*

3.6 Ogliastro

a) *Marine forms and deposits*

- The Punta Ogliastro promontory is characterized by a terrace some 100 m wide and ranging in elevation from about 50 to 55 m a.s.l., which can be considered of marine origin for its long-shore position.
- A *Cladocora*-bearing biocalcarenite deposit turning into a well cemented conglomerate outcrops on this site. The deposit is cut by abrasion platforms and is hindered uphill by slope breccia deposits; the observed maximum elevation is 8.540 ma.s.l. The biocalcarenite overlies a bedrock at times made up of a stratified limestone, at times of the "old breccia" deposit.
- Narrow (width on the order of 10-20 m) and low (2-3 m a.s.l. on the average) wave-cut platforms characterize about 700 m of the Ogliastro coast. The abrasion surfaces cutting limestone, "old breccia" and *Cladocora*-bearing biocalcarenite vary in elevation from 2 m up to 5.60 m a.s.l. at the most. Their inner margin is generally covered by thick deposits of recent breccia (Fig. 20).
- A deposit of stratified cemented gravel, 50-60 cm in thickness and formed of rounded clasts, can locally be seen at el. 3.80 m. The deposit can be related to a sea level stand that incised the slope breccia at the foot and gave rise to deep horizontal furrows into which beach gravel deposited at an elevation undoubtedly higher than the corresponding sea level.

b) *Continental forms and deposits*

- A highly cemented "old breccia" deposit testifies the presence of alluvial fans before the sea level stand correlated with the *Cladocora*-bearing biocalcarenite sedimentation, such as it has been reported for Acquafredda (Fig. 2).
- A heterometric recent breccia deposit covers the slope toe for a thickness of tens of metres. Occasionally, red silt layers are present.

3.7 Torre del Porto

a) *Marine forms and deposits*

- Strips of a *Cladocora*-bearing biocalcarenite are found on wave-cut platforms of younger age at elevations up to 8 m a.s.l. (Fig. 21 B). Sometimes, cave walls or the inside of fractures are lined with this deposit. The *Cladocora*-bearing biocalcarenite turns, from bottom to top, into a heterometric conglomerate to an algal biocalcarenite, and eventually to a calcarenite with small pebbles. This deposit is thought to be associated with the wave-cut notch at 16.20 m a.s.l. Only a few small marine caves open beneath such elevation.
- A small cave with the walls rich in *Lithodomus* holes is opened between 10 and 12 m a.s.l., which suggests a sea level stand at about 11.5 m above present sea level.
- An up to 8 m high wave-cut platform cuts both the bedrock stratified dolomitic rock and the *Cladocora*-bearing biocalcarenite. The inner margin is locally concealed by a slope breccia deposit (Fig. 21A). Some 300 m on the south of Torre del Porto there is a depression on the platform filled by a layered calcarenitic deposit whose bottom is formed of a conglomerate with *Spondylus*, that is covered by a coarse-grained biocalcarenite displaying a cross-lamination followed by a fine-grained laminated calcarenite (Fig. 21B). The deposit, that is surely younger than the *Cladocora*-bearing biocalcarenite and has an outcropping thickness of 4 m, has been correlated with the abrasion platform at 8 m a.s.l.

b) *Continental forms and deposits*

- A recent breccia deposit locally borders the slope toe. The presence of breccia at the slope foot in this site as

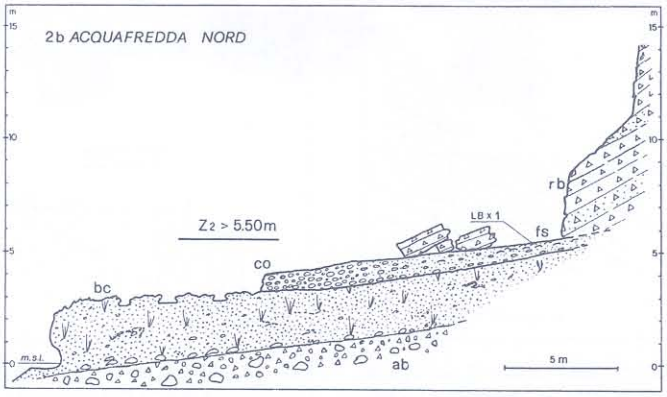


Fig. 11 - Abrasion platform cutting the *Cladocora*-bearing biocalcarenite covered by beach deposits with *Glycymeris*. The inner margin is concealed by a würmian recent breccia deposit.

Piattaforma di abrasione che taglia il deposito a Cladocora, *ricoperta da depositi di spiaggia a* Glycymeris. *Il margine interno è mascherato dalle brecce recenti del Würm.*

elsewhere, is consequent to the coast morphology (convex or concave coastline), presence of valleys, and slope inclination.

3.8 Punta della Matrella

a) *Marine forms and deposits*

- Three small promontories characterize the coast sector between Punta della Matrella on the NW and Timpa Tenaglia on the SE (Fig. 22). All of them are modelled by terraces of limited extent between the elevations 45 and 55 m a.s.l. The wave-cut surface cuts the bedrock which is formed of a dolomitic limestone dipping 35°. Over one of the wave-cut platforms there are rounded pebbles whose nature is not carbonatic. The inner margin at Punta della Matrella is not clearly visible because it is covered by a slope breccia deposit.
- On the northernmost promontories there are terraces between the elevations 20 and 25 m a.s.l. (Fig. 23), which have been interpreted as of marine origin, although the debris cover mantling the terrace surfaces prevented us from doing precise observations and measurements.
- Up to 14.30 m a.s.l. there are relic strips of *Cladocora*-bearing biocalcarenite and *Lithodomus* holes (Fig. 24 A). Small terraces at el. 15 m may be attributed to the same sea stand.
- A lower sea stand is shown by small caves between 10 and 13 m a.s.l. In particular, it is worth mentioning a 2 m high groove containing a conglomeratic deposit passing upwards to an organic coarse-grained sandstone (Fig. 24 B). This deposit may be an evidence of small wave-cut platforms at the el. 10-11 m.
- A deposit formed of conglomerate and stratified sandstone outcrops between 7 and 8 m a.s.l. (Fig. 24). It includes *Spondylus* fragments, and overlies a wave-cut platform connected with a groove in the carbonatic bedrock at 7-8 m a.s.l., that is rich in Lithodomus holes (Fig. 24 C).

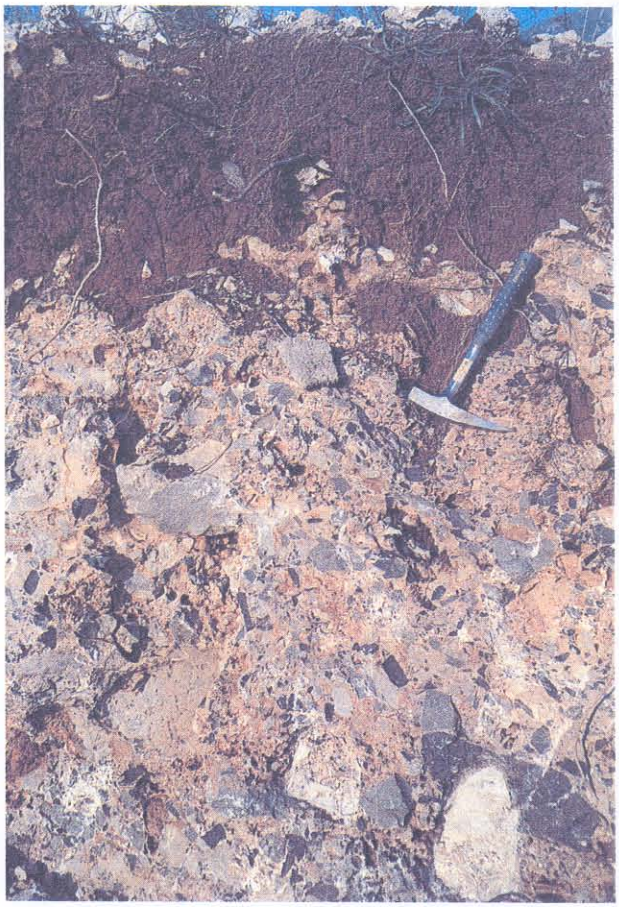


Fig. 12 -Fairly well cemented old breccia deposit at Rotondella at the elevation of 45 m a.s.l.

Brecce antiche ben cementate in località Rotondella a 45 m di quota (Fig. 2).

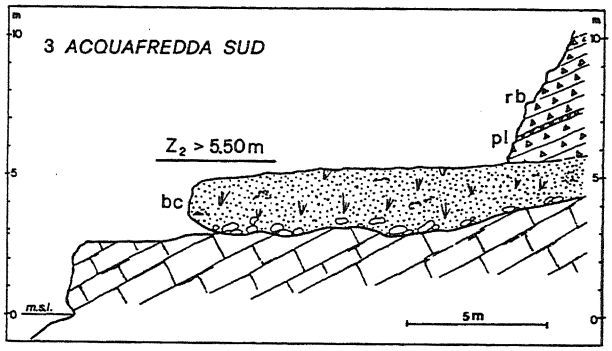


Fig. 13 - *Cladocora*-bearing biocalcarenite.(Y2 stand) cut by the Z2 sea level platform whose inner margin is hidden by recent breccia deposits.

Deposito a Cladocora *(livello Y2) inciso dalla piattaforma di abrasione del livello Z2, il cui margine interno è mascherato dalle brecce recenti.*

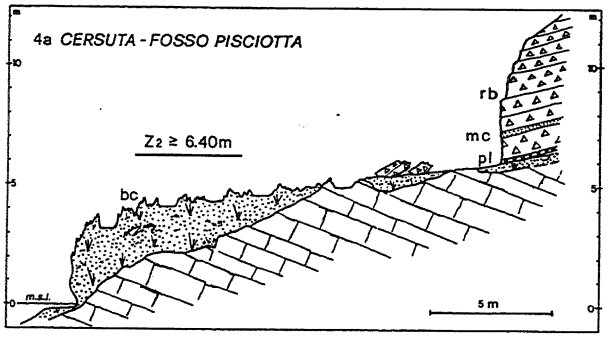


Fig. 14 -Abrasion platform cutting the *Cladocora*-bearing biocalcarenite and the dolomitic rocks of the mesozoic bedrock. The abrasion surface is generally karstified seawards.

Piattaforma di abrasione che incide il deposito a Cladocora *e le dolomie del substrato mesozoico. Verso mare la superficie si presenta quasi sempre carsificata.*

b) *Continental forms and deposits*

- A large breccia deposit covers the slope between el. 50 and 100 m, whereas reddish colluvial deposits outcrop at the lower elevations.

3.9 Marina di Maratea Nord

a) *Marine forms and deposits*

- Algal *Cladocora*-bearing biocalcarenite outcrops at the elevation 10.5 m and is covered by talus debris uphill. A *Cladocora* specimen (LB111) has been used for age determinations (Table 1). Where the deposit is well preserved, there is a coarse-grained conglomerate at its bottom.
- A wave-cut platform locally truncates *Cladocora*-bearing biocalcarenite at el. 8.65 m (Fig. 25), and is attributable to a higher or equal sea level stand.
- Wave-cut notches, small caves, *Lithodomus* holes and narrow wave-cut platforms are indicative of one or more sea level lowstands close to one another between the elevations 4.5 and 5.5 m a.s.l., as suggested by grooves superposed one upon the other in the marine caves (Fig. 26 A) (1). The cemented conglomerate that is over a narrow wave-cut platform at the el. 4 m a.s.l. can be referred to this lower sea stand (Fig. 25 A).

b) *Continental forms and deposits*

- The slope uphill Marina di Maratea makes a regular and ample amphitheater stretching up to the Serra di Castrocucco ridge with average inclination of 26°. Below the el. 100 m, the slope is gentler and is mantled by a detritic cover. The slope breccia covering the slope toe would form a deposit — that has now been truncated at its front by the Holocenic sea wave action — which might stretch well farther on than the present shoreline.

3.10 Marina di Maratea Sud

a) *Marine forms and deposits*

- The *Cladocora*-bearing biocalcarenite outcrops up to 9.30 m a.s.l., and is covered by slope breccia (Fig. 27). The biocalcarenitic deposit resting on an irregular surface may have various aspects: at times, it is a scarcely organic calcarenite; at times, it is an algal biocalcarenite; *Cladocora coespitosa* is irregularly distributed; moreover, at the bottom of the deposit there are depressions in the bedrock (formed of a stratified dolomitic rock) containing rounded pebbles 5-20 cm in diameter (Fig. 28).
- The *Cladocora*-bearing biocalcarenite is truncated by a wave-cut platform having the maximum elevation of 9.30 m (measured) above sea level (Fig. 29). The width of the platform is variable, ranging up to 50-60 m at the most. The higher portion is locally covered by a silt-sand deposit rich in not-reworked fossils; this deposit is closed upwards by a calcareous crust, 2-4 cm in thickness (Fig. 27). Among fossils, the genera *Lithodomus, Cladocora, Arca, Haliotis, Lima* and others have been recognized. Some specimens (samples nos. LB 115a and LB 115b) have been dated (Table 2).

The fill of a cave blow the just mentioned wave-cut platform has resulted to be formed by a heterometric conglomerate passing upwards to a sand with *Astralium* and *Spondylus*. The deposit, marine in nature, is overlaid

(1) Cave environment is much more preservative than open-air environment, an it is possible to find in it more numerous and detailed information on sea oscillation than outside the cave. It is worth reminding that caves preserve "subhorizontal grooves" shaped mainly by marine corrosion and *Lithophaga* activity, whereas there are no wave-cut notches (Carobene & Pasini, 1982). The sea level stand is not shown in this case by the maximum retreat point of the grooves; it has been shown instead, that the altitude of the groove upper rim and the *Lithodomus* holes belt coincide with the average high tide of the ancient sea level stand.

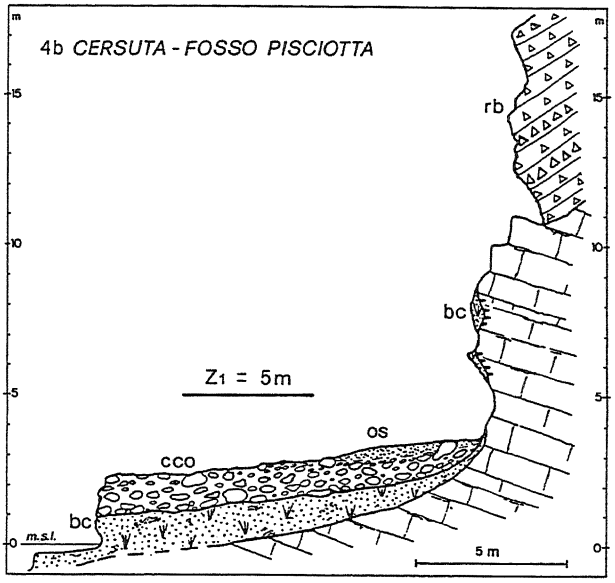


Fig. 15 - Conglomeratic beach deposit and wave-cut notch evidencing the Z1 sea level highstand.
Deposito di spiaggia conglomeratico e solco di battente che testimoniano il livello di stazionamento Z1.

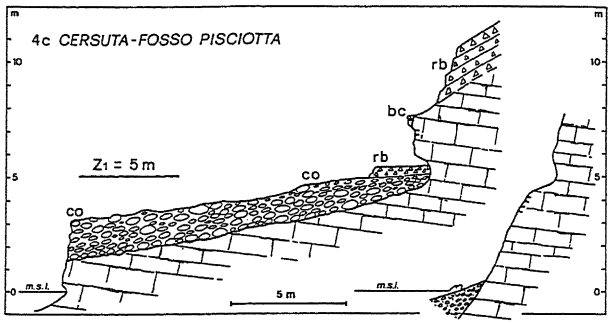


Fig. 16 - Forms and deposits evidencing the Z1 sea level.
Morfologie e depositi che documentano il livello Z1.

by a brown colluvial silt with *Helix* (see details in Fig. 27).

Sample LB113 has been used for the determination of the D/L ratio (Table 2). The obtained age indicates that the marine fill of the cave has the same age as the fossiliferous deposit at el. 9.30 m (last interglacial period).

b) *Continental forms and deposits*

- The cliff truncating the breccia deposit (see previous paragraphs in *Marine forms and deposits*) has made it possible to see the alternation of colluvial silt layers with breccia layers in the lowermost portion of the deposit. There is also a thin layer of pyroclastic materials.

3.11 Punta Iudia

a) *Marine forms and deposits*

- A *Cladocora*-bearing biocalcarenite outcrops along the coast on the SE of Punta Iudia. The situation is very similar to that described in Carobene *et al.* (1986) and Carobene (1987). The deposit is truncated by a wave-cut platform and can be seen up to 9.50 m a.s.l. (Fig. 30). Uphill, it is hidden by a slope breccia. Where the slope breccia is absent, *Lithodomus* holes and relic strips of biocalcarenite can be observed on the exhumed calcareous palaeocliff up to 19 m a.s.l. At this elevation it can also be seen a small strip of the wave-cut platform. The biocalcarenite has a local thickness of 2-3 m; at its bottom, it is generally found a transgressive coarse-grained conglomerate; toward the top, the deposit is rich in organic elements such as Vermetids, Algae, *Cladocora coespitosa* and Lamellibranchiata (*Spondylus gaederopus* is particularly abundant).
- A wave-cut platform up to 60 m wide is present between 4 and 9.50 m a.s.l. The upper portion of the platform cuts the *Cladocora*-bearing biocalcarenite (Fig. 30). Where breccia deposits are absent, the platform inner margin can be located at the elevation of 9.50 m a.s.l. (Fig. 31).

b) *Continental forms and deposits*

- This sector of the coast is in general characterized by the presence of a layered breccia with angular carbonatic elements. The deposit has a dip of 15°-20°. A typical cross-section is described in Carobene (1987): the bottom of the deposit is formed of alternating breccia and colluvial silt layers; there is also a pyroclastic layer (Fig. 32).
- The seaward lowermost portion of the wave-cut platform is deeply karstified with ponds and pinnacles modelling the dolomitic bedrock. The uphill portion of the platform is, on the contrary, better preserved (Fig. 30). This common feature of the wave-cut platforms along the studied coast suggests that: 1) the platform upper portion is scarcely karstified because talus deposits protected it; 2) the portion seawards was subjected to the action of a sea stand higher that the present sea level which would have completely eroded the *Cladocora*-bearing biocal-carenite.

3.14 Capo la Secca

a) *Marine forms and deposits*

- An about 200 m wide terrace between 40 and 50 m a.s.l. is carved in the dolomitic bedrock. Its inner margin, that is concealed by a talus breccia, may be correlated with the inner margin of another terrace which can be seen 1.5 km on the E, at km 243 of the State Route No. 18 (terrace W in Carobene & Dai Pra, 1991), where a conglomerate with pebbles with *Lithodomus* holes outcrops (Fig. 34).
- Strips of *Cladocora*-bearing biocalcarenite with *Lithodomus* holes can be seen up to 13.5 m a.s.l., that is an elevation surely lower than the equivalent sea

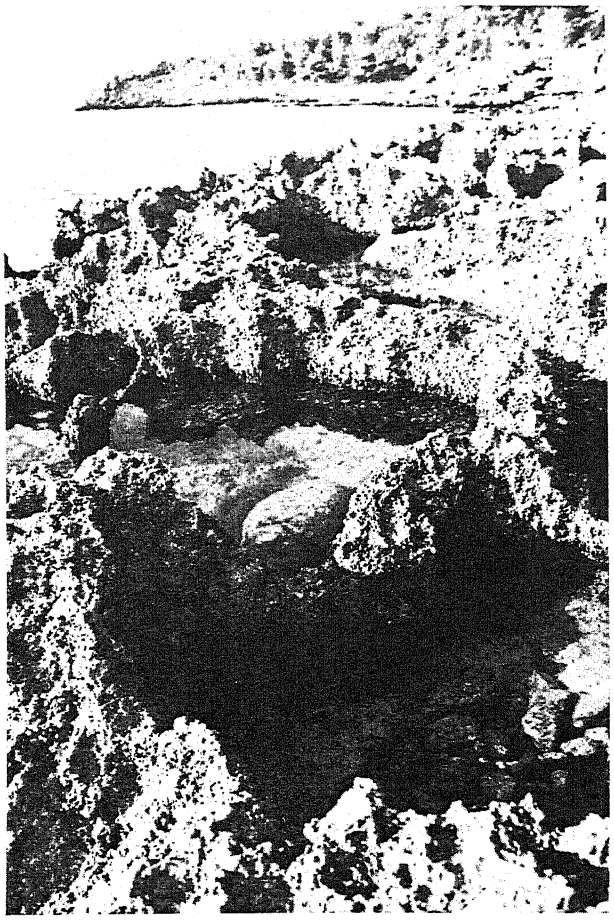


Fig. 17 - Weathered, karstified abrasion platform at an elevation of 2÷4 m a.s.l. (sect. 5). The rock is a *Cladocora* bearing biocalcarenite. In the background, the terrace at el. 20÷25 m (X-order in Table 3) forming the promontory of Capo la Nave.

Piattaforma di abrasione degradata e carsificata a 2÷4 m sul livelo del mare (sez. 5). La roccia è costituita dalla biocalcarenite a Cladocora. *Sullo sfondo il terrazzo a 20÷30 m di quota (ordine X di Tab . 3) del promontorio di Capo la Nave.*

stand (Fig. 33).

- Just on the N of Capo la Secca, a 200-m-deep bay delimited by steep rocky walls is filled by sediments forming a flat surface from 5 to 20 m above sea level. It may be explained as a fossil pocket beach formed by a sea stand whose level cannot be defined.
- A small (max width, 10 m) wave-cut platform is visible between 7 and 8 m a.s.l. Relic strips of *Cladocora*-bearing biocalcarenite covered by a younger conglomerate are visible on the surface. A wide notch with maximum retreat point 9 m a.s.l. may be related to the formation of this platform (Fig. 33).

3.13 Porticello di Castrocucco

a) *Marine forms and deposits*

- This side is the southernmost end of the studied rocky coast; the valley of Noce-Castrocucco river opens just on the E. This side is very interesting because of the presence of many grooves and caves of marine origin.
- A few metre thick conglomerate deposit with large cobbles with *Lithodomus* holes is visible on a high rocky cliff between 45 and 50 m a.s.l. There is also a large cave displaying a double indentation in the inner wall; its floor is at about 43 m a.s.l. It may be correlated with the conglomerate deposit outcropping about 1 km on the E at km 243 of the State Route No. 18 (Carboni *et al.*, 1988).
- Good evidence of a palaeo-sea level can be seen at about 23 m a.s.l., where there is a large cave with a subhorizontal floor that is 3.20 m high at the most. It is filled by a cemented breccia, and contains stalagmites, stalactites, and alabaster flowstones. *Lithodomus* holes mark the maximum retreat point and the vertical edge beneath the cave lower margin.

Small caves with marine wall grooves show a sea level stand at the elevation of about 12-13 m; pebbles with *Lithodomus* holes at the base of the caves are visible at an elevation of about 10 m. Moreover, a well marked wave-cut notch is visible 9.50 m a.s.l. (measured figure) on the cliff eastern end.

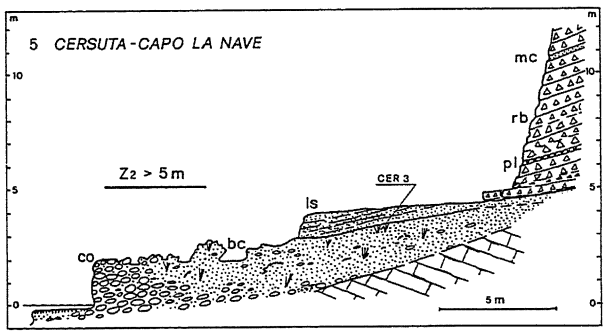


Fig. 18 -Alluvial breccia covering a portion of the eutyrrhenian abrasion platform, the visible portion being not higher than 5 m a.s.l.

In questa località le brecce della falda detritica ricoprono gran parte della piattaforma di abrasione eutirreniana. La parte visibile non supera pertanto la quota di 5 m.

4. ANCIENT SHORELINES

The point-by-point description of ancient shorelines (the 13 sections mentioned in Ch. 3), the diversity of observed morphological and sedimentary features and their variable elevations along the coast do not highlight their possible correlations.

The *Cladocora*-bearing biocalcarenite has been considered as the key-bed for age determinations: the obtained age values for this deposit range from 159 (+28-17) to 329 (+196-64) kyr (Table 1). Similar values have already been obtained for the coast of Calabria and in Apulia (Carobene *et al.*, 1986; Dai Pra & Stearns, 1978;

Fig. 19 - Just southwards of Capo la Nave (sect. 5). Yellow-brown pyroclastic layer within a Würmian breccia deposit. The deposit is light, porous and easily erodible. The pyroclastic layer is visible also elsewhere along the coast.

Località a Sud di Capo la Nave (sez. 5).. Livello piroclastico giallo intercalato alle brecce del Würm. Il deposito è leggero, poroso e facilmente erodibile. Questo livello è stato rinvenuto anche in altri punti lungo la costa.

Hearty & Dai Pra, 1985). Keeping in mind the factors which may have caused excess or defect errors, this deposit may be attributed to the interglacial peaks of stages 7 and 9 of the palaeoclimatic curve, although a possible attribution to stage 11 cannot be disregarded (Carobene & Dai Pra, 1991).

In the following paragraphs, the shorelines before and after the *Cladocora* biocalcarenite episode are distinguished according to stratigraphy, and not according to the elevation.

4.1 "Pre-*Cladocora* " sea levels

a) *The 55 m terrace (W)*

Terrace surfaces cutting the carbonatic bedrock and occasionally covered by non-carbonatic rounded pebbles (sections 1 and 8) are shown in sections 1, 5, 6, 8 and 12. In section 13, the sea level is evidenced by boulders with *Lithodomus* holes. Th e ancient shoreline corresponds with the terrace inner margin. It cannot easily be discriminated along this portion of the coast either because it has been eroded or has been concealed by talus breccia.

For this reason, the elevation of 55 m a.s.l. is an approximate figure: in fact, the present maximum elevation of an uplifted terrace is lesser than the elevation of the old sea level highstand (Carobene & Dai Pra, 1991). The horizontal attitude in the N-S direction of this terrace cannot thus be proved. If, however, elevation measurements taken in sections 1 and 8 are compared to one another, it is possible to infer that the elevation is higher and higher from north to south (from 45 m to about 55 m). This highstand level can be related to the W highstand level recognized along the Tyrrhenian coast of northern Calabria (Carobene & Dai Pra, 1991), which is at a generally constant elevation (45-65 m) between the rivers Noce on the north and Lao on the south. Such highstand level corresponds to the first great eustatic transgression of Middle Pleistocene (probably the stage 21).

b) *The 20÷25 m terrace (X)*

Small terraces cutting the Mesozoic bedrock at an elevation between 20 and 25 m are described in sections 5 and 8 (Table 3). All the remarks made in the previous paragraph are valid also for these terraces. Moreover, in section 13, marine caves and *Lithodomus* holes 23 m a.s.l. are a clear evidence of the sea level highstand. The elevation 23 m a.s.l. perfectly matches with the level X recongnised at an elevation 20÷35 a.s.l. along the Tyrrhenian coast of northern Calabria. It refers to stage

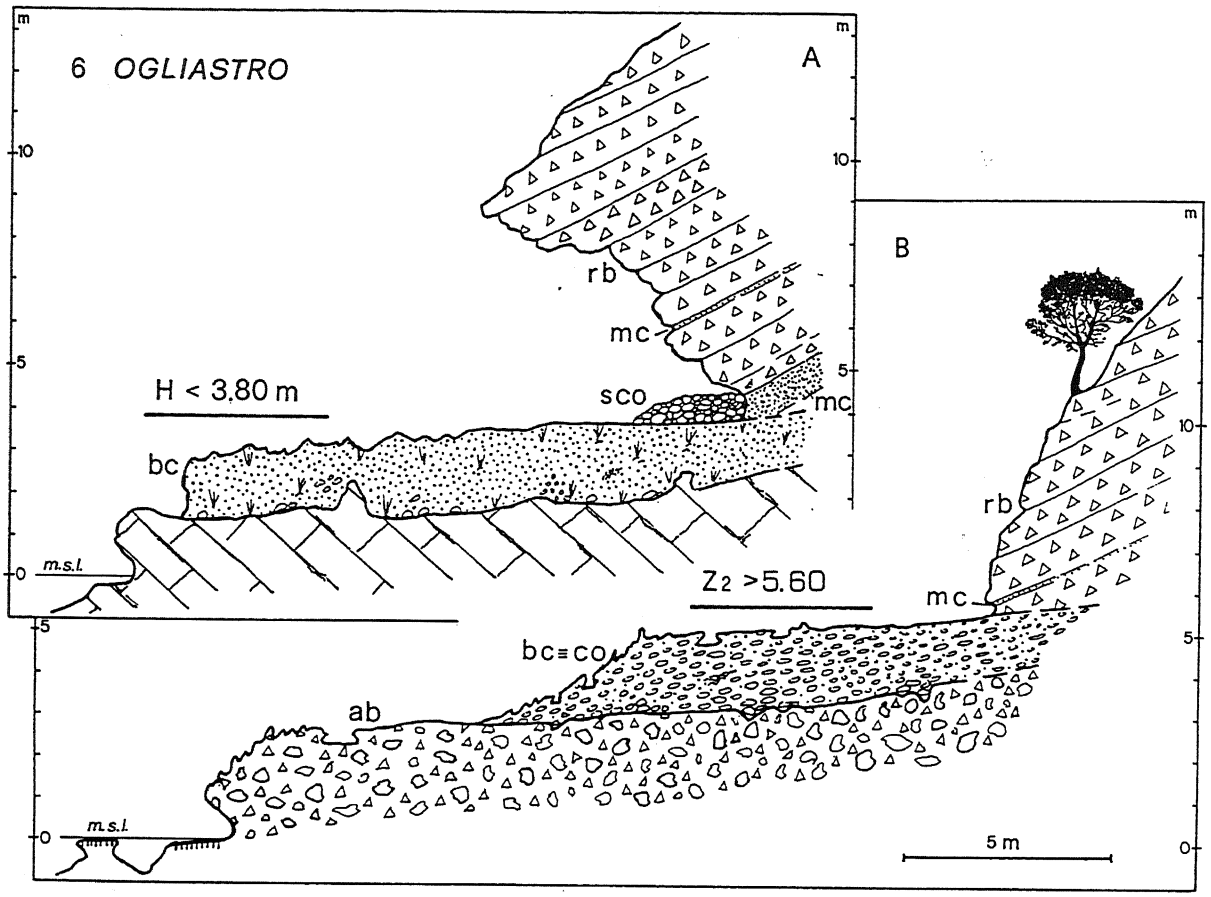


Fig. 20 - *Cladocora*-bearing biocalcarenite.laterally passing to a fairly well cemented coarse-grained conglomerate. The wave-cut platform seem to be lower than it is actually because its inner margin is covered by a recent breccia deposit. The wave-cut notch in the würmian recent breccia and the cemented stratified gravel (A) show the mechanism of the denudation of the eutyrrhenian platform by the Holocenic sea wave action.

In questa località le biocalcareniti a Cladocora *passano lateralmente a conglomerati grossolani ben cementati. La piattaforma di abrasione appare bassa in quanto il margine interno è coperto dalle brecce recenti. Il solco inciso nelle brecce recenti würmiane e le ghiaie stratificate cementate (A) chiariscono il meccanismo dell'esumazione della piattaforma eutirreniana ad opera dell'azione marina del mare olocenico.*

15 (Carobene & Dai Pra, 1991).

4.2 "*Cladocora* " sea levels

a) *The 14÷19 m shoreline (Y2)*

Cladocora coespitosa bearing biocalcarenite is present along almost the entire studied portion of the coast. The deposit appears as a relic of the original one after the action of the marine erosion. It is either an organic bioherm or a cemented mainly organic clastic deposit, rich in calcareous algae (*Lithothamnium* sp.) and, secondarily, in small Gasteropods, abundant Lamellibranchiata, Corals, Annelids, Bryozoa, and Foraminifera. It is truncated seawards by the present cliff and in its upper part by a wave-cut platform whose elevation is up to 9.5 m a.s.l. Relic strips of *Cladocora*-bearing biocalcarenite, however, have been found event at the elevation of 14.30 m a.s.l. (Table 3).

The present elevation of the *Cladocora*-bearing deposit has always been considered As lesser than the corresponding sea level highstand keeping in mind that: 1) marine erosion and abrasion have lowered the original maximum elevation of the deposit; 2) the sediment formed at a shallow depth below sea level (§ 5.2); 3) an alluvial fan or talus deposit dating back to the last glacial period often covers the uphill portion of the biocalcarenite deposit.

Thus, the *Cladocora*-bearing biocalcarenite may be associated to the ancient shoreline immediately above it. For instance, in sections 1, 2 and 7 it corresponds to a wave-cut notch, while in sections 8 and 11 it corresponds to the inner margin of a terrace. The discriminated shoreline has an inclination ranging from 14 m on the N (in section 1) up to 19 m on the S (in section 11). Such elevation corresponds quite well to that measured further on the south along the coast of Calabria, tween the rivers Noce and Lao, where the *Cladocora*-bearing bed (Y) is at an elevation of 18-20 m a.s.l. (Carobene & Dai Pra, 1991).

At the beginning of this paragraph there are some

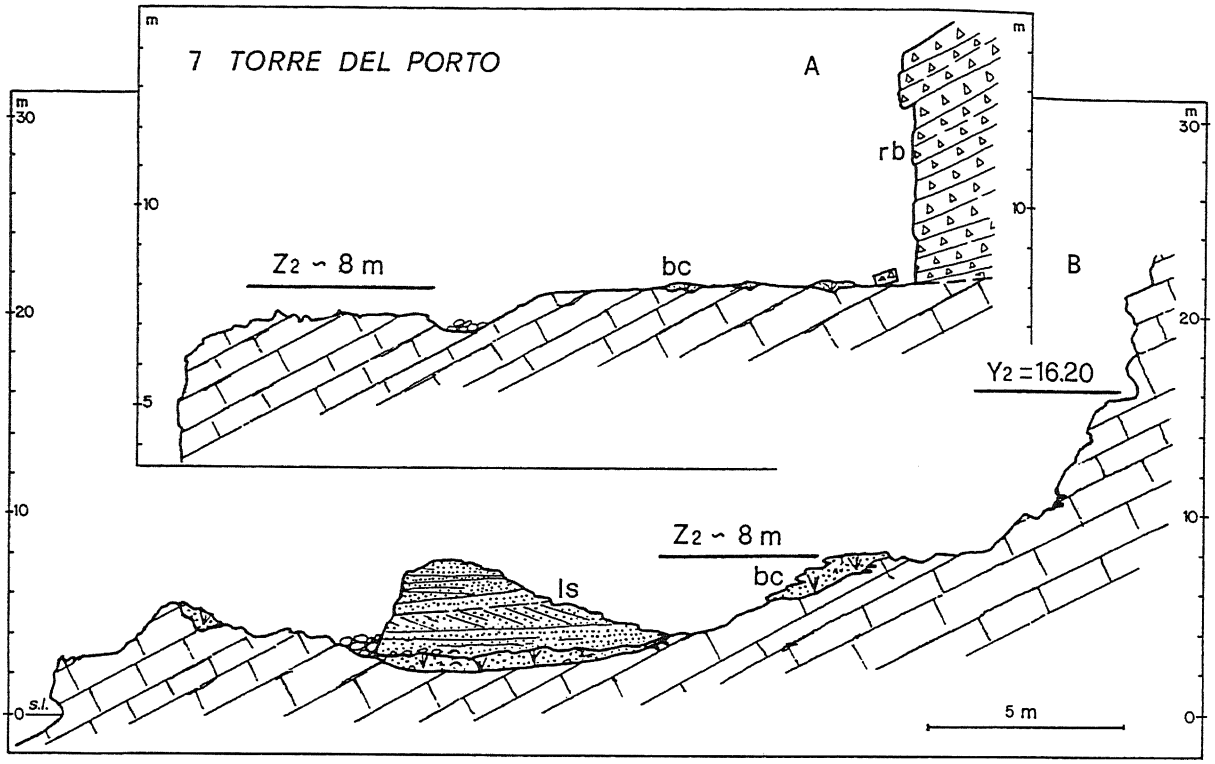


Fig. 21 - Wide wave-cut platform up to the elevation of 8 m a.s.l. (Z2). Only relic strips of *Cladocora*-bearing biocalcarenite are visible; the deposit has been correlated with the wave-cut notch at 16.2 m a.s.l. (Y2). Marine sand (ls) of section B evidence the formation of the Z2 platform.

Ampia piattaforma di abrasione che si eleva fino a 8 m s.l. m. (Z2). La biocalcarenite a Cladocora *è ridotta a lembi relitti; il deposito è stato correlato al solco di battente situato a 16,2 m s.l. m. (Y2). Le sabbie marine (ls) della sezione B sono state correlate alla formazione della piattaforma di abrasione Z2.*

considerations on the age of this deposit. The age was confirmed by field observations and age determinations carried out both in Calabria (Carobene *et al.*, 1986) and in Apulia (Dai Pra & Stearns, 1977; Hearty & Dai Pra, 1985; Dai Pra & Hearty, 1988).

b) *The 12 m shoreline (Y1)*

In an intermediate position between Y2 shoreline and the subsequent Z2 one (see § 4.3) there is another shoreline. It is at about 12 m a.s.l. (sections 7, 8 and 13), and is evidenced by wave-cut notches, caves and *Lithodomus* holes (Table 3). It is intermediate between Z2 And Y2 also for its genesis as based on morphological evidence. It seems to have been a scarcely important episode, and thus it has not been attributed to the last interglacial eustatic peak (stage 5e).

If the traces in the three above mentioned sections are supposed to be joined with one another, an horizontal line is obtained. This fact is in contrast with the inclination of both the upper (Y2) and lower (Z2) shorelines. Thus, these traces might be related to sea level highstands close to but different from one another.

4.3 "Post-*Cladocora*" sea levels

a) *The 7÷9.50 m abrasion platform (Z2) (substage 5e - Eutyrrhenian)*

This morphological element is typical of the coast of Basilicata and is present in almost all the study sections (1 through 7, and 9 through 11). In sections 1a and 7, the abrasion platform cuts the Mesozoic bedrock; in sections 3, 9 and 10 it cuts the *Cladocora*-bearing biocalcarenite, and in section 2b the "old breccia" alluvial fan. A conglomerate and cemented sand deposit locally covers the abrasion platform. The deposit contains *Glycymeris* and *Arca* used for D/L ratio determinations. The D/L ratio is equal to about 0.40 (Table 2) falling in the aminozone E (Hearty *et al.*, 1986) corresponding to stage 5e (Shackleton & Opdyke, 1976) (128,000 yr B.P.). This age suggests that the platform should be dated back to the main peak of the last interglacial period (Eutyrrhenian). This sea level highstand is evidenced by wave-cut notches (Figs. 9 and 33), caves, and *Lithodomus* holes (Figs. 6 and 24).

The platform elevations given in Table 3 correspond to the maximum measured elevation. Because the platform inner margin is often covered by continental breccia deposits, the elevation values may vary from place to place. If only the extreme values are taken into account (sections 1 and 2 through 13), the Eutyrrhenian shoreline increases in elevation from 7 m northwards to 9.5 m

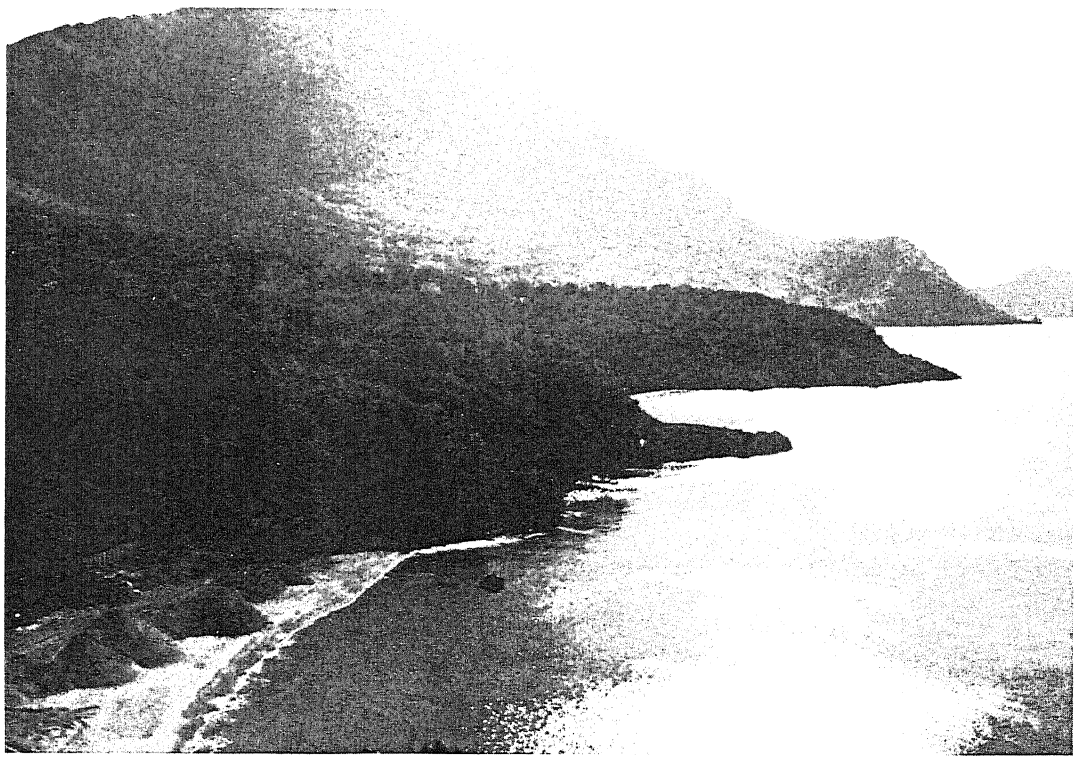


Fig. 22 - The terrace of Timpa Tenaglia seen from NNW. The terrace surface, about 200 m wide, stretches from 40 to 50 m a.s.l. (W-order in Table 3) and cuts the 30°NE-dipping Mesozoic bedrock.

Il terrazzo di Timpa Tenaglia visto da NNW. La superficie, larga circa 200 m, si estende da 40 a 50 m di quota (ordine W) e taglia gli strati del substrato mesozoico, inclinati di 30° verso NE.

southwards. This trend conforms to the trend of the higher shoreline (Y2).

Age and elevation of this shoreline are similar to those obtained by Carobene and Dai Pra (1991) for the Calabria coast between the rivers Noce and Lao.

b) *The 5÷5.50 m shoreline (Z1) (substages 5a/5c ?)*

A sea stand lower than Z2 and subsequent to it, is well evidenced by abrasion platforms cutting the previous ones (sect. 1b, and 9). The platform at el. 5÷5.50 m a.s.l. is generally covered by a marine conglomerate-sand deposit (Figs. 8, 15, 16, 25). Wave-cut notches and small caves — inside which there is a conglomerate deposit covered by a fossiliferous sand overlaid by continental brown deposits — are also present.

The wave-cut platform at 5-5.50 m a.s.l. cuts the stage 5e platform and is covered by last Glacial deposits and breccias. Thus, it can be attributed to the last interglacial period. Because the platform is well distinguishable, it should correspond to an eustatic peak distinct from the main stage (5e). It may correspond to either substage 5a or 5c, as suggested by an abrasion platform at 5 m a.s.l. and younger than a 15 m terrace of Eutyrrhenian age (D/L ratio on *Glycymeris* = 0.33) near Sapri (Brancaccio *et al.*, 1990).

Moreover, in Sardinia Carobene & Pasini (1982) recognized a shoreline at el. 4.5 m a.s.l. which was attributed to the Tyrrhenian III, that is meant as the sea level highstand immediately before the great Würm 1 regression.

The actual elevation of Z1 shoreline cannot be well documented because field data are fragmentary. It seems, however, that the Z1 shoreline elevation is higher southwards (from 5 to about 5.5 m). Such A slight difference in elevation points to a young age of this shoreline.

c) *The < 3.80 m Holocenic shoreline*

Near Ogliastro, a continental breccia deposit covering the above mentioned Eutyrrhenian abrasion platform is deeply cut by the sea which carved wave-cut notches and caves (sect. 6A). A stratified cemented conglomerate (see § 6) is locally present beneath the talus breccia deposit. The conglomerate is at 3.80 m a.s.l. which emphasises a sea level stand that, although not higher than present sea level, is surely older.

As the breccia deposits are attributed to würmian times (see § 6.2), the sea level corresponding to the above mentioned conglomerate deposit is to be dated back to Holocene. It is impossible to define whether the actual elevation of such sea level was higher than the present one because the conglomerate is a back-beach deposit which surely sedimented above the mean sea level. Moreover, the literature does not provide us with evidences of a Holocenic sea level highstand. Takao

Fig. 23 - Northwest view of the coast from Timpa Tenaglia (sect. 8). The wave-cut platform at the el. 6÷8 m (Z2-order in Table 3) preserving relic strips of *Cladocora* bearing biocalcarenite and the terrace at el. 20÷25 m a.s.l. (X-order in Table 3) are visible, in the background, the terrace at el. 50÷55 m (W-order in Table 3) is visible.

La costa a NW vista da Timpa Tenaglia (sezione 8). Sono visibili la piattaforma di abrasione a 6÷8 m (ordine Z2 di Tabella 3) che conserva lembi di biocalcarenite a Cladocora*; il terrazzo a 20÷25 m (ordine X) e, in secondo piano, il terrazzo a 50÷55 m (ordine W).*

Miyata *et al.* (1990) and Searle & Woods (1986) are to be mentioned on this regard. Carobene & Pasini (1982) assumed a Holocenic sea level highstand in Sardinia on the basis of a wave-cut notch in a würmian eolic sandstone. Traces of a Versilian (Flandrian) transgression in Sardinia were also recognized by Ulzega & Ozer (1982).

5. PROBLEMS CONNECTED WITH THE STUDY OF ANCIENT SHORELINES

5.1 Sea level markers and nomenclature problems

When the elevation of ancient shorelines is used in order to get information on recent coast movements and to make comparisons between localities, the position (thus, the present elevation) of old sea level stands must be determined with great accuracy and precision. This requires that forms or littoral deposits suggesting ancient shorelines are distinguished.

The literature on this topic is very rich: from Zeuner (1962) and Gill (1968) to de Plassche (ed.) (1986) and Kelletat (1988).

Marine notches may have various origins (chemical, physical, biological or mechanical). Pirazzoli (1986) thus distinguishes mid-littoral, tidal, surf, infralittoral, and supra-littoral notches which must not be confused with abrasion and structural notches.

In this paper, the use of tidal wave-cut notches in the sense of Carobene (1972) has been preferred because the low tidal range in the Tyrrhenian Sea prevents errors. Tidal wave-cut notches can easily be distinguished from bioerosional notches, caused by endolithic organisms such as *Lithophaga* living mainly in sea caves (see Footnote 1).

We made also a careful use of *abrasion platform.* In fact, such platforms may end landwards with a shore-platform which in part may stretch also above the mean sea level (wave-cut bench) (Bradley & Griggs, 1976; Kern, 1977; Kelletat, 1988).

As to marine organisms, *Lithophyllum*, Barnacles and Vermetidae are good water-level markers.

A last observation refers to *raised ancient marine terraces.* As a matter of fact, it is worth remembering that: 1) the terrace surface being inclined seawards may result at elevations varying with the observation point; 2) the terrace inner margin may be concealed by talus deposits; 3) the marine deposits over the abrasion platform

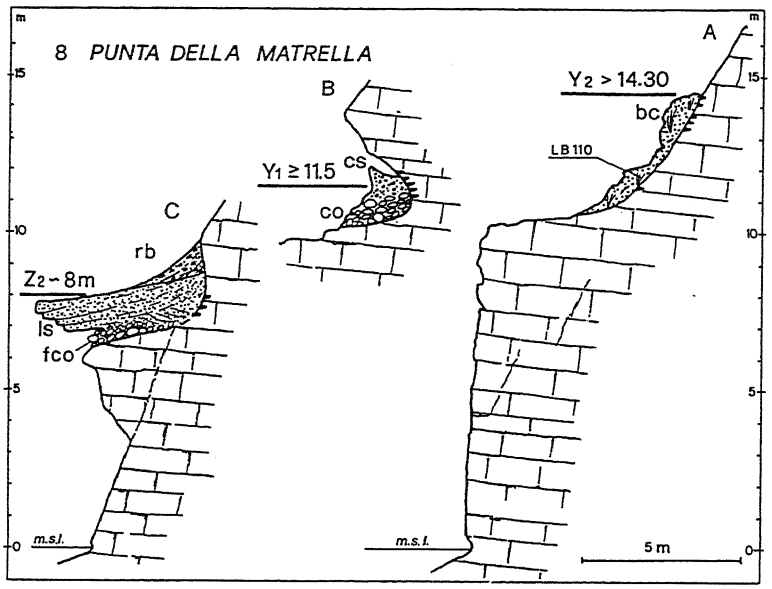


Fig. 24 - In A, relic strips of the *Cladocora*-bearing biocalcarenite attributable to Y2 sea level. In B, a groove that may be referred to a small marine cave evidences a Y1 sea level intermediate between the previous one and the Z2 eutyrrhenian sea level. In C, forms and deposits referable to the Z2 sea level.

In A lembi relitti del deposito a Cladocora *riferibili al livello Y2. In B un incavo, riferito ad una piccola grotta marina, documenta un livello Y1 intermedio tra quello precedente e quello eutirreniano Z2. In C morfologie e depositi relativi al livello Z2.*

may have partially or totally been eroded; 4) marine deposits may have been covered or replaced by continental deposits. For all these reasons, errors in evaluating the elevation of the oldest (and highest) sea level stand — namely, the elevation of the sea maximum transgression — are common. So, the elevation of the W-order terraces (Table 3) has been ascertained case by case.

5.2 *Cladocora coespitosa*-bearing biocalcarenite: the problem of its sedimentation depth

The *Cladocora coespitosa* biocalcarenite belonging to the Y2 shoreline, is the most common Quaternary marine deposit of the study coast.

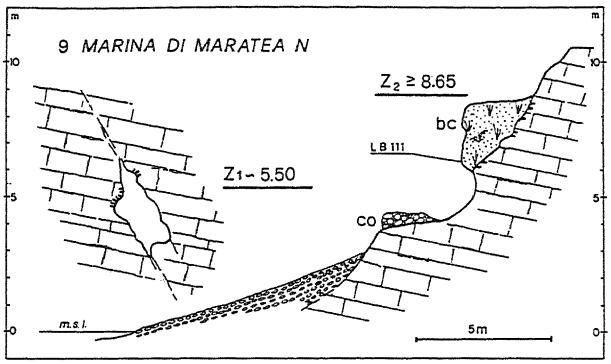
Cladocora coespitosa is a coral whose shape may vary as a function of depth and environment. The significance of this coral as sea depth marker has, therefore, to be evaluated on each case by considering the deposit in its whole. In the case of the studied portion of the Tyrrhenian coast, the *Cladocora* biocalcarenite always outcropping close to the palaeocliff, is over a slightly seaward-inclined platform whose surface is irregular almost everywhere (sections 10 and 11). This platform seems to represent a sea floor which was mildly eroded by the wave action. This fact suggests that the sea level highstand was several metres higher than the platform surface.

The *Cladocora coespitosa*-bearing biocalcarenite (see § 4.2) that in many cases has a conglomerate deposit with scarcely rounded pebbles at its bottom, is mostly formed of a biocalcarenite (which in many cases may be algal)(2) including more or less abundant individuals of *Cladocora coespitosa.* In a few cases, inorganic sand and cemented gravel with rounded clasts are the main component (sect. 6B).

The *Cladocora coespitosa* deposit is truncated uphill by a wave-cut platform, so that the observable thickness is of only 2-3 m; relic strips on the palaeocliff walls, however, suggest that the original thickness was greater. An important element for the evaluation of the sedimentation depth of the deposit is the constant presence of *Lithodomus*, a bivalve living at shallow depth at the contact with calcareous cliffs. The biocalcarenite strips at higher elevations (sections 8A and 12) always show *Lithodomus* holes. Therefore, the corresponding sea level highstand has been attributed to the wave-cut notch that is visible on the palaeocliff a few metres above (see § 4.2).

In conclusion, macro- and microscopic analyses and environmental considerations constantly point to sedimentation conditions of shallow and agitated sea.

(2) In thin sections, encrusting coralline Algae are abundant. The genus *Dermatolithon* is the most common both in thin crusts and nodules. *Lithothamnium* and *Lithophyllum tortuosum* are, on the contrary, scarce. Genera *Amphyroa* and *Jania* among *Corallinacae Articulatae* are also present. The *Articulatae* indicate shallow bathymetric and rather hydrodynamic conditions, whereas genus *Dermatolithon* does not give precise bathymetric information (in the Mediterranean Sea, it lives at depths ranging from 0 to 100 m). Analyses on Algae were carried out by Prof. Grazia Vannucci of Genoa University.



Flg. 25 - In A, inner margin of a platform cut into the *Cladocora*-bearing biocalcarenite. A lower sea level (Z1) is suggested by cave morphological features and deposits.

In A margine interno della piattaforma di abrasione incisa nella biocalcarenite a Cladocora. *Un livello più basso (Z1) è ben documentato da morfologie di grotta e depositi.*

Thus, the Carboni *et al.*'s (1988) conclusions indicating that the sea level highstand was "at least 30 m higher" the the *Cladocora coespitosa* biocalcarenite cannot be accepted.

5.3 The number of old sea level stands, and the problem of the interglacial peaks elevation

The pleistocenic shorelines (corresponding to eustatic sea level highstands) may tentatively be correlated to the oxygen palaeoclimatic curve warm peaks (= interglacial periods), although the shorelines number is always lower than the peaks number. The reason of this fact can be sen in the different altitudes of eustatic highstands which may superpose to one another and become confused with one another as a consequence of the coast uplift rate — that may vary in time and space.

Where the uplift rate is high, the shorelines vertical discrimination is better: *e.g.*, Dumas *et al.* (1988) distinguished in southern Calabria 8 shorelines in the elevation interval 27-177 m a.s.l., the 4th, 5th and 6th of which belonging to the last interglacial period; the uplift rate in the area has been estimated equal to 0.9 mm/yr. Analogously, on the Ionic Sea side of Basilicata there are 9 pleistocenic shorelines for an estimated uplift rate equal to 0.7 mm/yr towards the Apennines (Dai Pra & Hearty, 1988). In the case of the study coast, the uplift rate has been much lower (see § 6.1) and the well visible shorelines are few.

The literature on the relationship between oxygen isotope records and sea level changes is very reach (*e.g.*, Shackleton, 1987). Although all the authors agree in giving to stage 5e and original sea level of 5 ± 1 m above the present sea level they, however, disagree as to the elevations to assign to the other stages (Ward, 1985). The Y2 shoreline that is now at el. 19 m a.s.l. (sect. 11) can be attributed to stage 7 only if the original

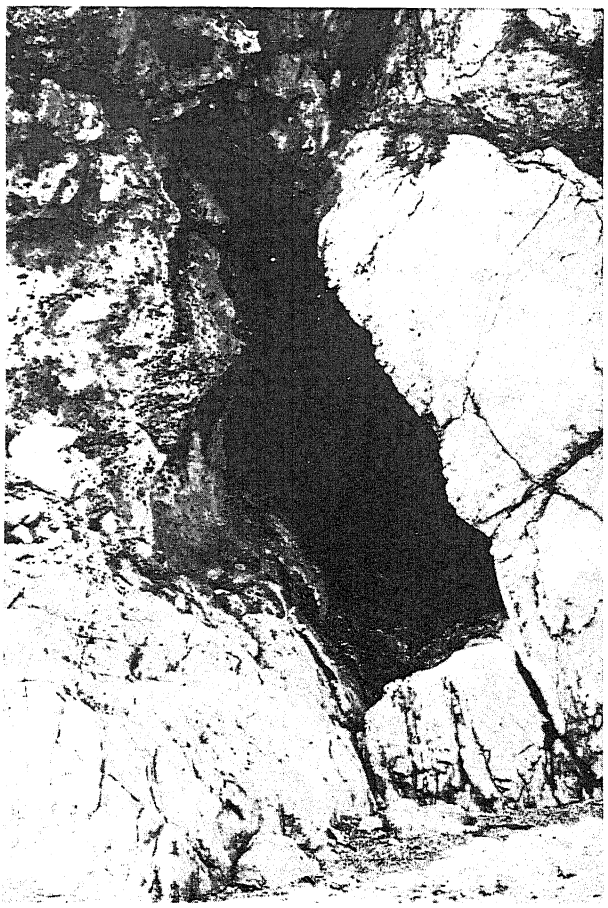


Fig. 26 - Small marine cave at Marina di Maratea (sect. 9) (elevation 3.5÷6 m a.s. l.). The cave walls are bored by *Lithodomus* up to 5.50 m a.s.l.; the notch was largely caused by lithophagous organisms. The cave evidences a sea level stand at an elevation, between 4.50 and 5.50 m (Z1 shoreline in Table 3).

Piccola grotta marina in località Marina di Maratea (sez. 9) compresa fra 3,50 e 6 m circa sul l.m. Le pareti della grotta presentano fori di litodomi fino alla quota di circa m 5,50; il solco è in gran parte stato formato dall'attività degli organismi litofagi. La grotta testimonia stazionamenti marini compresi tra 4,50 e 5,50 m circa (livello Z1).

sea level is assumed to have been several meter higher than the present sea level. This is, however, in disagreement with the majority of authors who indicate a sea level very near the present one or 1-2 m higher at the most for stage 7 (Harmon *et al.*, 1983; Pillans *et al.*, 1988, and others). To indicate a lower sea level (at least 15 m below present sea level) for substages 5a and 5c is a common opinion (Dodge *et al.*, 1983; Ku *et al*, 1990; Broeker & Denton, 1990, and others). This common conclusion makes it difficult to attribute the Z1 shoreline to the above mentioned substages, although there are some authors (Vacher & Hearty, 1989) who hypothesize a rise of sea level to the present sea level at the end of substage 5a. This hypothesis seems confirmed in the Mediterranean are (Butzer & Cuerda, 1962; Carobene & Pasini, 1982; Hearty, 1986).

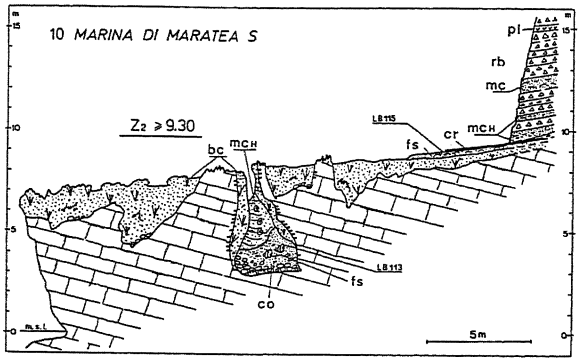


Fig. 27 -Wide wave-cut platform locally covered by fossiliferous sand suggesting an Eutyrrhenian age. The deposits filling the small cave is coheval of the fossiliferous sand. The alluvial fan breccia deposit contains colluvial, eolic and pyroclastic horizons.

Ampia piattaforma di abrasione ricoperta localmente da sabbie fossilifere che ne hanno permesso l'attribuzione all'Eutirreniano. Il deposito di riempimento della piccola grotta è risultato coevo alle sabbie fossilifere. Le brecce della falda detritica contengono livelli colluviali, eolici e piroclastici.

The sea did never reach the present level during the interglacial stages 13-21 (Shackleton, 1987; Williams *et al,* 1988, and others). This fact has been taken into account in estimating the uplift rate of the X and W shorelines.

6 THE GEODYNAMIC AND MORPHOLOGICAL EVOLUTION OF THE COAST

6.1 The coast uplift in Pleistocene

The terraces and shorelines on the Tyrrhenian coast of Basilicata can be correlated with those which have been recognized southwards along the Calabria coast (Carobene & Dai Pra, 1991). Their age dates back to middle-late Pleistocene age (see Ch. 4). These forms testify — even for a limited time interval — the recent evolution of an area having a complex tectonic pattern whose outstanding feature is the presence of shear zones with different orientation and mechanism. The main surface structure is the Pollino fault system, marked by either tectonic troughs or compressive structures, both deforming plio-pleistocenic sedimentary sequences (Ghisetti & Vezzani, 1983).

The study coast is located between the Sapri Basin — which was rapidly subsiding during Pliocene and Quaternary times with a high accumulation rate — and the hinterland which was prevailingly uplifting during Pliocene-Quaternary (Neotectonic Map of Italy, 1987). A situation of nearly continuous uplift is recorded also along the NW-SE trending alignment Mt. Pollino-Mt. Alpi-Mt. Zaccana-Mt. Sirino, which are the highest mountains of the South Apennines chain where up to 1,000 m uplifts in the last million years (Ciaranfi *et al,* 1983) and a large number of historical earthquakes (Ghisetti & Vezzani, 1983) have been recorded.

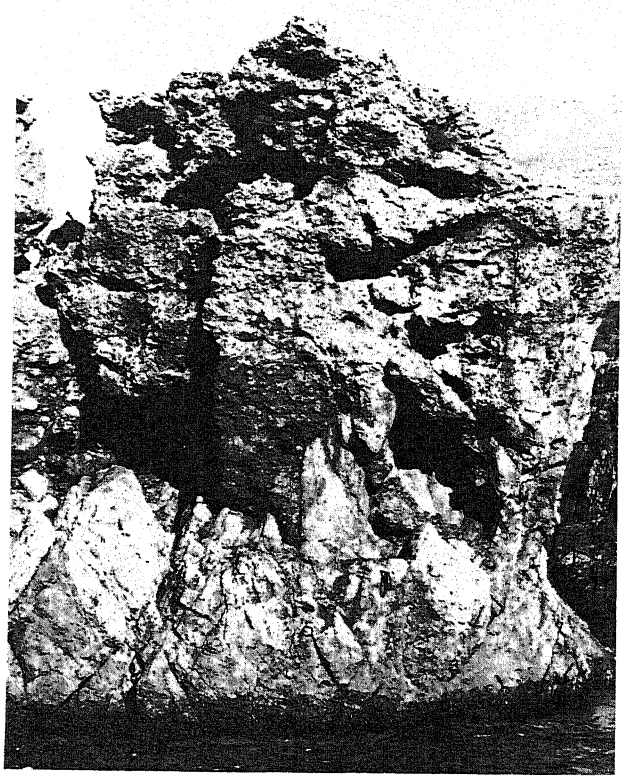


Fig. 28 -Bedrock dolomitic rocks covered by *Cladocora*-bearing biocalcarenite. The contact surface is in many places irregular; at the bottom of the biocalcarenite there are rounded clasts (Fig. 7).

Dolomie del substrato ricoperte da biocalcarenite a Cladocora. *La superficie di appoggio è spesso irregolare; il deposito presenta alle base ciottoli arrotondati (Fig. 7).*

Fig. 29 - On the south of Marina di Maratea. *Cladocora* bearing biocalcarenite corresponding to the Y2-order shoreline in Table 3, overlying the Mesozoic dolomitic bedrock. The deposit is conglomeratic at its base, and is cut by the Tyrrhenian abrasion platform (Z2-order coastline) at an elevation of 6÷7 m a.s.l. (section 10).

Marina di Maratea Sud. Biocalcarenite a Cladocora *(riferita all'ordine Y2) poggiante su dolomie mesozoiche del substrato. Il deposito, conglomeratico alla base, è tagliato dalla superficie di abrasione eutirreniana (Z2) a 6÷7 m di quota (sez. 10).*

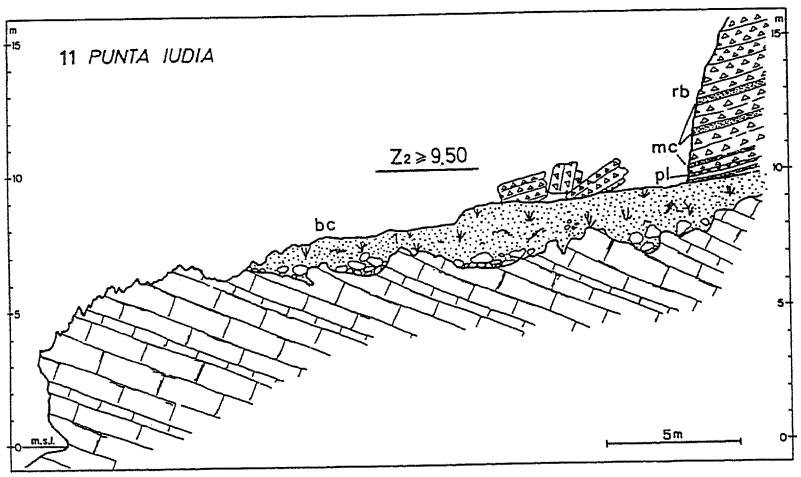


Fig. 30 -Wide wave-cut platform up to the elevation of 9.5 m a.s.l. The inner margin is locally covered by allluvial fans; the outer margin is in many places not covered by the *Cladocora*-bearing biocalcarenite, and is karstified.

Ampia piattaforma di abrasione che si eleva fino alla quota massima di 9,5 m. Il margine interno è localmente coperto dalla falda detritica; il margine esterno è spesso privo del deposito a Cladocora *ed è carisificato.*

Along the coast, the uplifting is evidenced by the recognized ancient shoreline: the W-order terrace has been attributed to the middle Pleistocene first interglacial sea level highstands (stages 21, 19, 17); on the basis of its present elevation (45-55 m a.s.l.) its uplifting rate has probably been more than 0.08 mm/yr, as based on the fact that the original eustatic sea levels referring to these stages are assumed to have been lower than the present sea level (Shackleton & Opdyke, 1976; Shackleton & Hall, 1984).

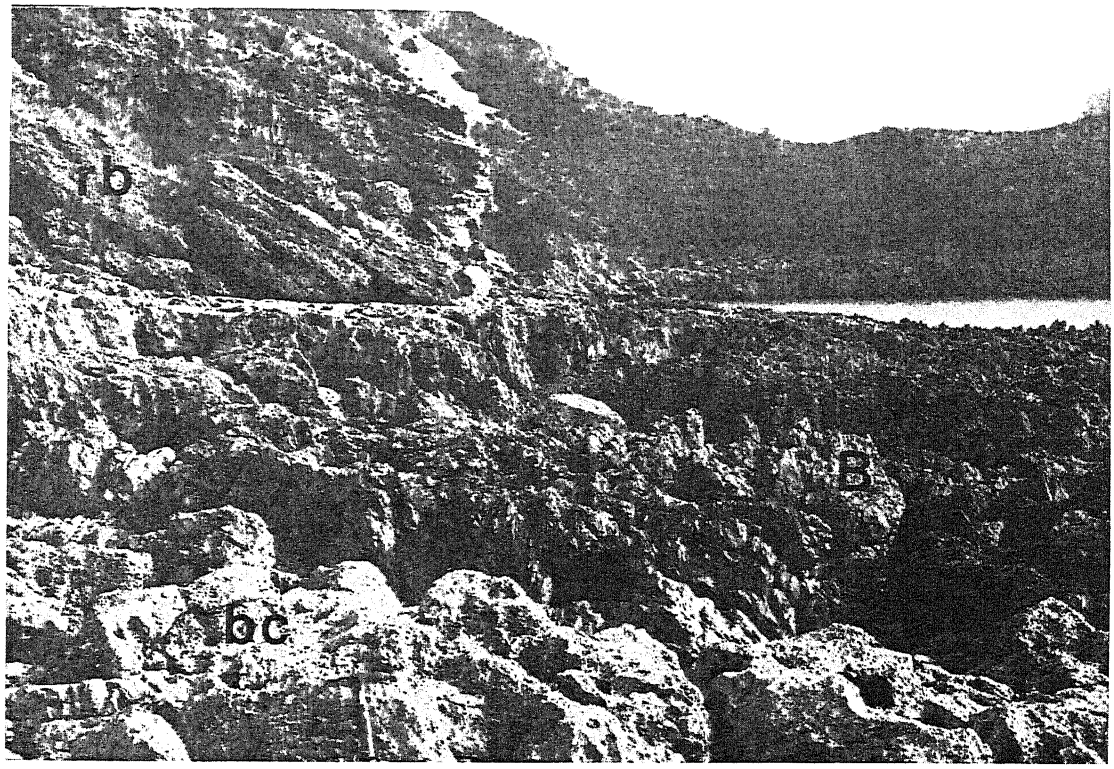


Fig. 31 - Punta Iudia. Section 11: B) bedrock; bc) *Cladocora*-bearing biocalcarenite; rb) würmian breccia. On the left, the eutyrrhenian abrasion platform is clearly visible beneath the breccia deposit.

Punta Iudia. L'immagine illustra la sez. 11. B) substrato; bc) biocalcarenite a Cladocora; *rb) brecce würmiane. Sulla sinistra, alla base delle brecce, è ben visibile la piattaforma di abrasione eutirreniana.*

The uplift of the Tyrrhenian shoreline (Z2) that has an elevation of 9.5 m a.s.l. on the southern part, can be assumed to have been about 3.5 m a.s.l. — if the original elevation is assumed to be equal to 6 m a.s.l. Therefore, the average uplifting rate in the last 125,000 years is equal to 0.03 mm/yr. This value, however, is lesser on the northern portion of the coast where the 72 shoreline has an elevation of about 7 m a.s.l. (Table 3).

It can thus be concluded that:

- the mean uplifting rate decreased from middle to late Pleistocene;
- the values of uplifting rate were on the average lower northwards;
- uplifting rates were on the average higher landwards than on the coast.

The absence of high terraces such as, in particular,the wide V-order terrace — recognized by Carobene & Dai Pra, 1991, in northern and attributed to early Pleistocene (Emilian-Sicilian) — may be indicative of the coast uplifting evolution also in early Pleistocene . As a matter of fact, the formation of the V-terrace can be correlated with a slow subsidence: the extensive wave-cut platform would have formed because of the cumulative effect of repeated transgressions corresponding to several interglacial peaks which are evidenced in the oxygen isotope curves. On the contrary, along an uplifting shoreline the same interglacial highstands might give rise to terrace flights, subsequently destroyed by erosion during middle and late Pleistocene. Moreover, as we are dealing with a cliff-coast, the absence of drift and lack and lack of sedimentation during sea level highstands might have played an important role.

6.2 Coast morphogenesis and climatic variations

Coast morphogenesis during Pleistocene was caused mainly by a continuous although weak uplifting as shown by raised shorelines, by the fault recent activity as evidenced by morphological features, and by numerous climatic variations and their consequent sea level fluctuations.

During *early Pleistocene* (1.7-0.8 Myr), the interglacial sea level highstands corresponding to the oxygen isotope curve stages from no.57 to no.25 (Williams *et al.*, 1988) modeled the coast, but the traces of corresponding shorelines have not been identified. The mostly isostatic uplifting of the area favoured their erosion, well evidenced by very thick coarse-grained clastic sediments within tectonic depressions (Palmentola *et al.*, 1981).

The *middle Pleistocene* times (0.8-0.125 Myr) were characterized by more intense climatic variations than early Pleistocene. In particular, three important glacia-

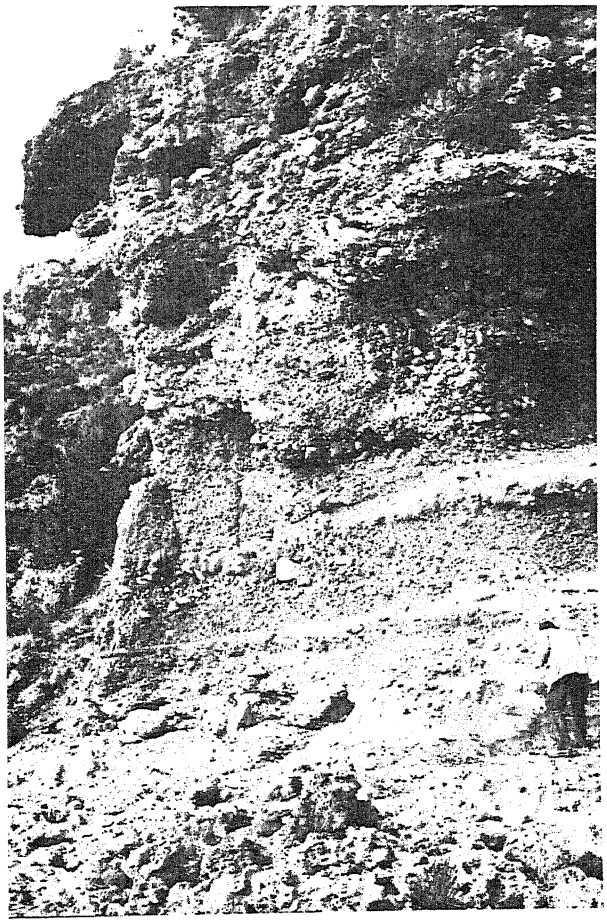


Fig. 32 -Punta Iudia. In the foreground, Cladocora-bearing biocalcarenite overlain by the würmian continental breccia deposits and underlain by colluvial and pyroclastic horizons.

Punta Iudia. In primo piano biocalcarenite a Cladocora *sopportante la serie delle brecce continentali würmiane che presenta alla base livelli colluviali e piroclastici.*

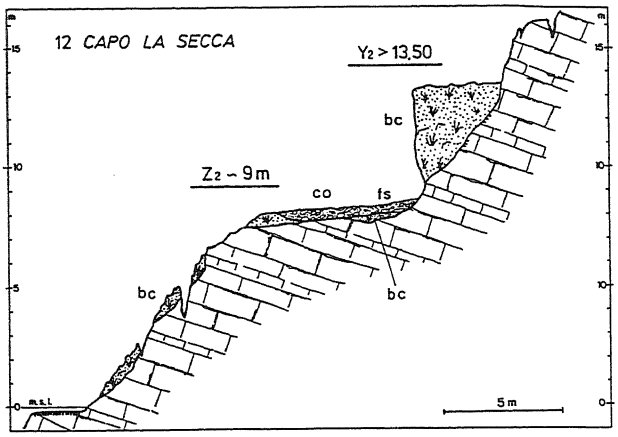


Fig. 33 - Well preserved*Cladocora*-bearing biocalcarenite horizons up to the elevation of 13.50 m evidence a 19÷20 m a.s..l. sea level highstand. The Z2 post-*Cladocora* sea level stand is shown by the inner margin of the wave-cut platform that is covered by beach deposits, and by the large wave-cut notch at 9 m a.s.l.

I livelli di biocalcarenite a Cladocora, *qui conservati fino alla quota di m 13,50, sono la testimonianza di uno stazionamento marino a circa 19÷20 m s.l.m. Lo stazionamento marino post-*Cladocora *(Z2) è documentato dal margine interno della piattaforma di abrasione, coperta da depositi di spiaggia, e dall'ampio solco a circa 9 m.*

tions have occurred, *i.e.* stages 22, 16 and 12 (Shackleton, 1987). During these glaciàl stages cryoclastic actions on highly fractured limestone and dolomite (which are the predominant rock types in the zone) have given rise to very thick debris deposits which, at the valley mouths, formed very wide alluvial fans widespread along the coast (Fig. 2). The last sea level highstands of middle Pleistocene (stages 11, 9 and 7) largely eroded and washed away the clastic deposits; the *Cladocora* bearing biocalcarenite deposit related to Y2 shoreline locally overlies "old breccia" deposits (see § 3.3, 3.4 and 3.7) which may be attributed to the above mentioned clastic deposits.

The continuous uplifting characterizing middle Pleistocene favoured landsliding, the most important example being the Maratea *sackung* (Guerricchio *et al.*, 1987).

In *late Pleistocene* the sea level highstand corresponding to stage 5, nowadays 10 m lower than the previous shoreline, modeled wide abrasion platforms (figs. 29, 31), step cliffs and marine caves along all the coast.

During the following glacial period (Würm) talus and alluvial fans probably stretching offshore, formed and possibly covered the previous Z and Y shorelines with hiding them. The würmian cold period is well shown by morainic deposits, cirques and periglacial deposits in the hinterland mountains (Mt. Sirino, Mt. Alpi and Mt. Pollino) where the snow limit had descended below 1,600 m (Boenzi & Palmentola, 1984). The last 125,000 yr tectonics is shown by both the slight differential uplift of the eutyrrhenian coast and tilting of lacustrine deposits (*e.g.*, between rivers Tanagro and Noce).

In *Holocene* about 6,000 yr B.P., a sea level uprise (Flandrian transgression) brought sea level back to a position near the present one (probably higher, see § 4.3). During this latter time span, the continental breccia deposits were deeply eroded so that, along the coast, the wave-cut platforms of the last interglacial period now outcrop (exhumed platforms). The platforms not covered by würmian breccia deposits would have been largely destroyed (platform relics) (§ 3.11). Finally, also the karstic activity played and important role as the outcropping rocks are mostly carbonatic in nature.

The coast present uplifting cannot be proved; the decrease of average uplift rate As deduced from the ancient shorelines analysis (§ 5.1) suggests that *no uplift* is occurring along the study coast area at present.

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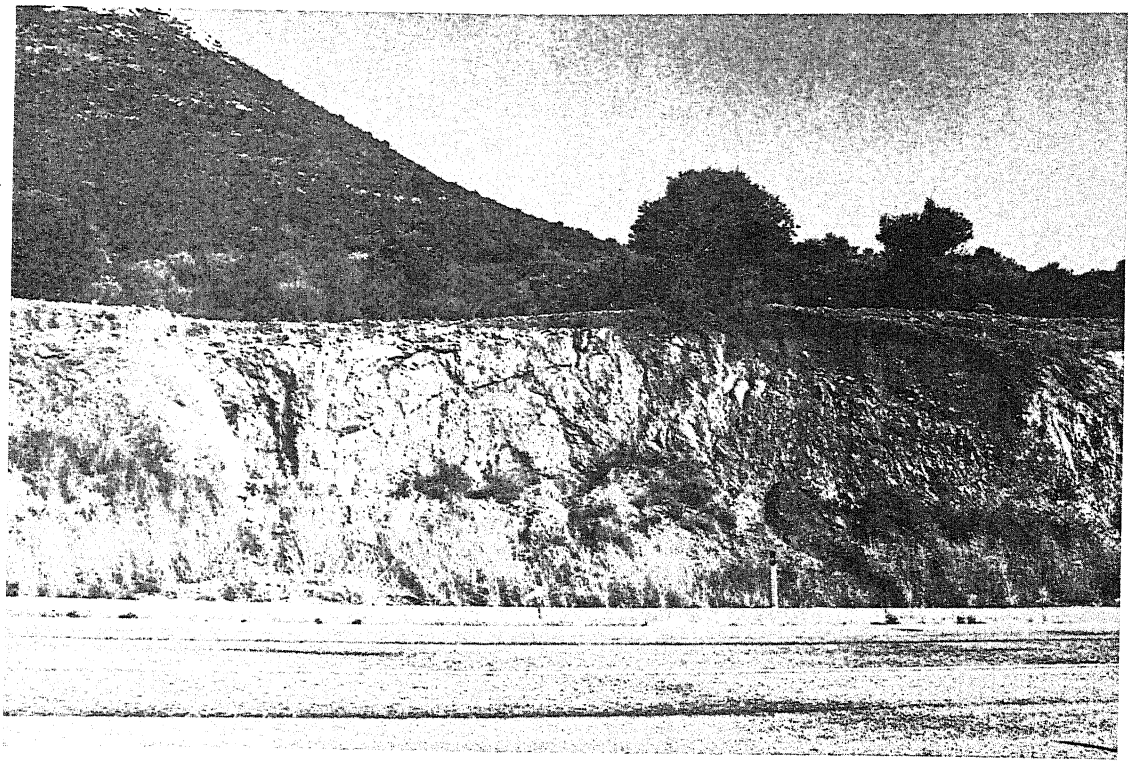

Fig. 34 - A road cut bringing to light the marine conglomerate overlying the abrasion cut platform at the elevation of 45 m a.s.l. (W-order in Table 3). The conglomerate containts rounded pebbles with *Lithodomus* holes and is covered by a red soil (km 243 of the State Route n. 18).

Al km 243 della S.S. 18, in destra fiume Noce-Castrocucco, il taglio stradale ha messo in evidenza il conglomerato marino che poggia sulla piattaforma di abrasione a 45 m di quota (ordine W di Tab. 3) . Il conglomerato, che presenta ciottoli arrotondati con fori di litodomi, è coperto da suolo rosso.

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