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SOME INFRA– AND CIRCALITTORAL ECOSYSTEMS OF THE EASTERN PART OF THE SOUTH ADRIATIC SHELF

(17 Figs., 1 Tab.)

A b s t r a c t : The paper gives a brief description of recent ecosystems and their biocenoses determined on sea-floor profiles in eastern parts of the South Adriatic Shelf. Special attention is devoted to the composition of biocenoses of the facies with *Posidonia oceanica,* as well as to the composition of shallower and deeper infracoralligene. It gives also some biocenologic characteristics of the supralittoral, mediolittoral, trottoir and pseudotrottoir. The work is a following of earlier contributions of the author concerning the study of the North Adriatic Shelf ecosystems carried out with the aim of its application in facial evaluation of fossil marine sediments.

Р е з у м е : Статья содержит описание рецентных экосистем и их биоценоз определенных на профилах на морском дне на востоке югоадриатического шельфа. Особенное внимание уделяется составу биоценоз фации с *Posidonia oceanica,* так как составу мелкого и более глубокого инфракораллигена. Статья тоже дает характеристики супралитторала, медиолитторала, тротуара и псевдотротуара. Работа является продолжением статей автора касающихся изучения экосистем североадриатического шельфа с целю применения в изучении фаций фоссильных морских осадочных пород.

The contributions concerning similar topics hitherto published in this journal dealt with basic analyses of above all fossilizable benthos collected from submarine profiles on the North Adriatic Shelf as a part of the joint research programme of the Geological Institute of the Slovak Academy of Sciences in Bratislava and Centar za Istraživanje Mora Jugoslavskej Akademii Znanosti i Umjetnosti (Marine Research Centre of the Yugoslavian Academy of Sciences and Arts) in Rovinj (S e n e š, 1973, 1988 a, b, c, 1989). Before concluding this analytical series (as a basis for further applications in the study of fossil marine facies in geology) I would like to mention briefly the ecosystems and biocenoses of the South Adriatic Shelf which even in the territorially rather restricted area of our study display certain differences from the North Adriatic Shelf facies.

Our investigations of the eastern island region of the South Adriatic Shelf were in the years 1966–1982 concentrated above all on the southern part of the peninsula Pelješac. The reason for the differences in the biocenoses compared with North Adria are above all some hydrographic factors. Some of them can be explained also by data obtained already on the first expedition of the research ship "Andrija Mohorovičić" in the year 1973 (S t i r n et al., 1974).

The shelf region of North Adria had still, in spite of its considerable pollution, exceptionally high bioproduction and thus also considerably varied and at the same time constant composition of those ecosystems which are comparable with fossil bio- or thanatocenoses (this was the case in the time of our investigations in the years 1964–1974). The richness and diversity in this region was caused e.g. at the western coast of Istria not only by the Adriatic current system which supported at the time of our investigations the contribution of typical mediterranean fauna and flora from south, but favourable conditions were created also by the

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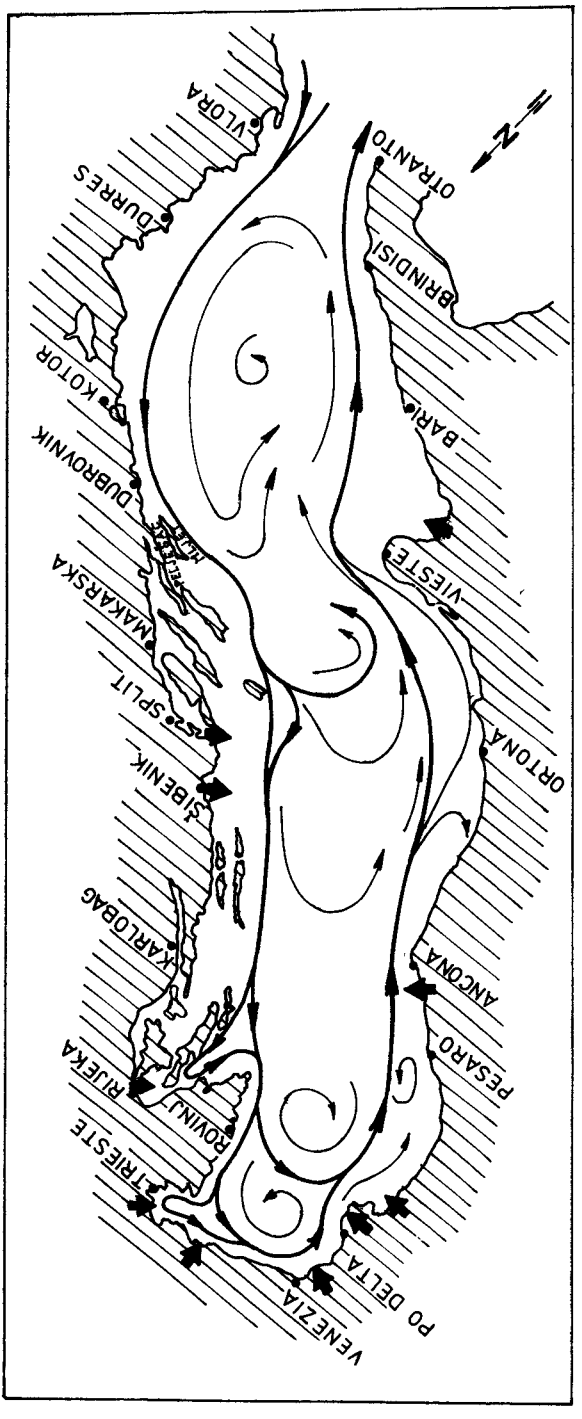

Fig. 1. Map of the Adriatic Sea showing its circulation and major pollution sources. (After Stirn et al., 1974).

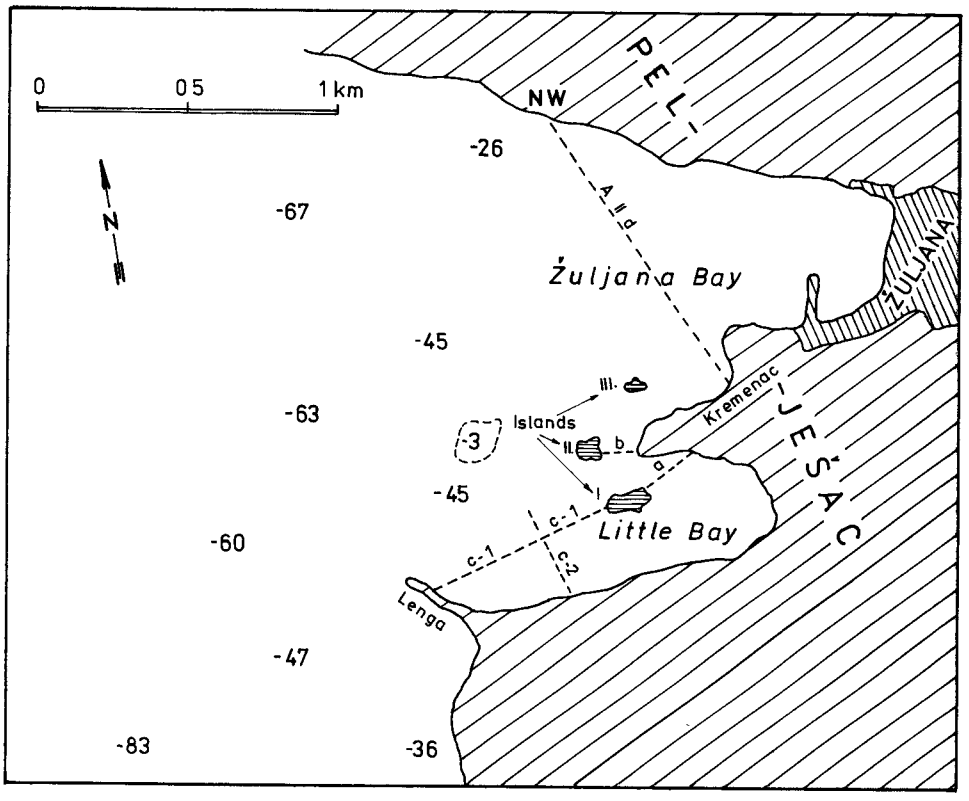

Fig. 2. Direction and numbers of sea-floor profiles A-II-a, b, c-1, c-2 and d in the Žuljana Bay (Pelješac).

shallowness of the environment (in average −38 m), great differences between winter and summer temperatures as well as seasonal variability of the in average very high salinity.

The differences in the ecosystems of the South Adriatic region and the previously studied ones were caused probably by three factors. The first one is certainly the closer connection with the Mediterranean itself through the Ionian Sea. The second one is undoubtedly the more unpolluted environment which is a precondition for mass occurrence of some organisms sensitive to organic, industrial or biocidic pollution. The third factor, except for a lower temperature variability, is probably the considerably higher transparency of the studied environment compared with the region of Istria. This could be caused by a lower density of phytoplankton in spring and autumn and, of course, by the considerably lower pollution. The high transparency of course allows considerably deeper occurrences of biocenoses with photophyllic organisms. From our viewpoint it is the case above all of calcareaous green and rock-forming red algae.

Our studies concentrated above all on the peninsula Pelješac (Seneš, 1988a), on the region of Drača Bay in the SE part of the Neretva Channel (region A-I) and the SW part of the Pelješac shelf in the broader region of the wide, open Žuljana-Trsteník Bay (region A-II). The 9200 m long profile was located between the islands Pelješac and Mljet (Profile P-M). I would like to point out that samples from quadrants and stations on this profile were

collected by the scuba-diving method only to a depth of −67 m, deeper parts of the shelf (max. −88 m) were sampled by a core-borer from a boat. Shorter profiles were studied also in infra- and circalittoral regions of the Zagorie submarine slope along the SE coast of Pelješac (Z-1, Z-2) and in the Vrhovnjac insular area on an island from the Vlašnik group (coord. 42° 46′ N; 17° 07′ E), 16 km E of the island Lastovo. The latter profiles were studied above all from the viewpoint of rocky supra- and mediolittoral ecosystems.

In this contribution I shall present the characteristics of ecosystems from profiles of the region A-II, i.e. the profiles a, c-1, d, as well as the profile P-M, more precisely the section PMx leading from the Kupinova Bay on Pelješac towards the island Mljet, and the second flank of the profile PMy leading from the vertical wall of Kobrava on Mljet towards Pelješac (location see in Senеš, 1988a). I have selected these profiles because of the optimal possibilities of their application in the reconstruction of the origin of fossil sediments.

As far as the chemical-physical parameters of this region of the South Adriatic Shelf are concerned, our data are the values measured in summer. Salinity increases gradually with depth (from −2 to −50 m) from 37.3 to 38.5 ‰. Temperature decreases in summer in horizons between −8−12 and −18−21 m by exceptionally large leaps. To −8 m it varies usually around 22−24 °C, in depths down to −18 m is the temperature as a rule only 17−18 °C and below this boundary it decreases gradually, down to −50 m, to 12−14 °C. The content of oxygen is in shallower horizons about 5.5, in deeper ones below −40 m it is usually by a few tenths lower, but it never falls under 5.1 ml/l. The pH value is usually constant about 8.1. Transparency in the region of Žuljana profiles reaches down to 20 m, on Zagorie and Mljet infracoralligene wall it exceeds 25 m and in the surroundings of the Vrhovnjaci islands it is as high as 30 m.

Profile A-II-d, Kremenac-Žuljana NW (Pelješac, Žuljana Bay), 1050 m (Fig. 3)

The profile was sampled in July 1966 and August 1977. Since the environment dynamism is in this bay relatively calm and the observed biotops occur without changes in considerable distances even to the sides of the profile, no controlling samples had to be collected later on. Regardless of the seasonal vertical circulation, stronger S-N current has been determined only in the deeper infralittoral of the northern Žuljana shore zone. Even though the profile goes through a relatively shallow part of the bay (max. −24 m), it has a few interesting features. In supra- and mediolittoral horizons on the Kremenac flank it represents a fine-gravelled coarse- to fine-sandy beach development which we could not study e.g. in the Rovinj area. An important phenomenon for our interpretations is also the occurrence of a dasycladacean biocenose on this profile, which was not observed on our profiles on the North Adriatic Shelf, as well as the presence of an extensive *Posidonia* growth important for the determination of its variable biocenologic composition.

On supralittoral there is a prevalence of coarser, in places also fine, mostly sorted sand. To the sides of the profile it fills also broader spaces between rocks. From fossilizable forms only *Truncatella subcylindrica* has been found alive to a distance of 3 m from the edge of a flat beach, but the necrocenosis reflects the influence of an extensive infralittoral with *Miniacina miniacea,* the presence of the geni *Rissoa, Alvania, Bittium, Cerithium,* with fragmets of various decapods as well as terrestrial molluscs.

Mediolittoral is absolutely inconspicious.

The inclination is very slight along the whole profile. Already in a distance of 20 m from the shore of Kremenac, in a depth of −4 m, there is a biocenosis consisting of a thick growth of *Dasycladus clavaeformis* (I-3b) accompanied above all by *Murex trunculus, M. brandaris,*

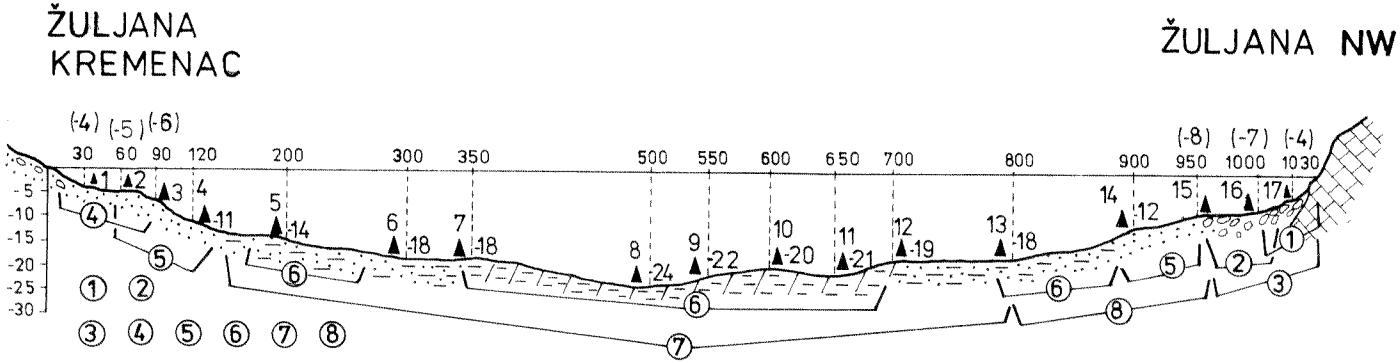

Fig. 3. Profile A-II-d, Kremenac–Žuljana NW (Pelješac, Žuljana Bay).

1. *Acetabularia mediterranea* + *Padina pavonia* (I-1a, b); 2. Infracoralligene (incl. *Amphiroa* + *Halimeda*, I-1e+I-2); 3. *Cystoseira* (I-1c); 4. *Dasycladus clavaeformis* (I-xx); 5. *Posidonia oceanica* (I-7c); 6. *Posidonia oceanica* + *Melobesia farinosa* (I-7d); 7. *Udotea petiolata* (I-yy); 8. *Lithophyllum racemus* (I-5c).

Alvania costata, Actaeon tornatilis and *Loripes lactaeus*. The substrate is fine-sandy, partly organodetrital, bound by algae or extinct roots of *Posidonia*. *Dasycladus clavaeformis* forms a more or less continuous cover.

In a distance of about 60 m from the shore, on a fine-grained substrate, a field with *Posidonia oceanica* (I-7a) with a very rare growth of *Zostera marina* on its margins occurs already in a depth of −6 m. This *Posidonia* growth becomes thicker towards the bay and it covers the sandy-biogenic-muddy bottom. It crosses the deepest point of the profile and reaches far to its other flank. Even though this growth does not reach in this bay as deep as on some other profiles in this region (as deep as −35, −40 m), its area is large enough to justify a more detailed study of this important, especially on the South Adriatic Shelf overall occurring biotop and its various biocenoses. It provides always several types of biocenoses, to a great extent differing from each other. Perhaps we could with right consider the *Posidonia* phytal to be an individual ecosystem. The composition of benthos on the lighted upper sides of stems differs from that on the lower shadowed side. Quite different is the biocenosis bound to the relatively large and resistant *Posidonia* roots. Different is also the association of organisms on extinct and usually to shallower horizons of the sea floor transported and here accumulated sea-grass stems. Special is the character of biocenoses in the very dense, by light almost impenetrable growth or in greater depths. At last there is still the biocenosis of the sediment itself on which the *Posidonia* meadows grow, above all coarse or fine sand frequently with considerable organodetrital muddy admixture. From the viewpoint of their application in geology, since we shall deal with thanatocenoses originating on the same location but from various biocenoses of the *Posidonia* environment, I distinguish only three types:

A. Thanatocenosis originating on the lighted sides of stems and in the case of less dense growth living also on the sedimentary substrate. It consists mostly of photophyllic organisms. The range of this thanatocenosis varies usually in a zone to −10, −15 m.

B. Thanatocenosis composed of mostly sciaphyllic species living either on the in the sediment partly burried *Posidonia* roots, or on the very dense growth of stems and thus also on the shadowed sedimentary substrate. Thanatocenoses more or less of this character occur on sediments in depths below −25, −30 m.

C. The substrate consisting either of extinct roots or accumulated extinct stems of *Posidonia* is characterized predominantly by thanatocenoses of photophyllic algae and other organisms of shallower infralittoral.

It is natural that also in fossil thanatocenoses there are numerous variants of all these three types, most frequent is nevertheless a mixture of thanatocenoses *A* and *B*. Since both on the stems themselves as well as on the substrate there is characteristic vagile as well as sessile benthos (not to speak of the endobiotic forms of the substrate), there shall also be a thanatocenosis frequently consisting of mixed herbivorous and carnivorous species.

Thanatocenosis *A* originating on the stems of the growth consists above all of sessile, smaller species of *Phaeophyta*, from *Rhodophyta* the most frequent is *Melobesia farinosa*, from foraminifers *Miniacina miniacea, Rosalina bradyi, Webbinella crassa, Iridia serialis*. *Silicispongiae* are abundant. Abundant are also the Polychaeta *Spirorbis pagenstecheri*, vagile molluscs *Gibbula varia, G. ardens, Alvania cimex, A. lineata, Rissoa variabilis, Rissoa ventricosa, Rissoina bruguieri, Phasianella pulla, Ph.speciosa, Bittium reticulatum, Marginella miliaris, Retusa truncatula*, further sessile *Modiolus barbatus, Propeamussium hyalinum*. Small bryozoans are also frequent, above all *Electra pilosa, E.posidoniae, Membranipora membranacea, Tubulipora flabellaris, Lichenopora radiata* and *Microporella johannae*. A majority of these bryozoans nevertheless prefers the solid roots of *Posidonia*, where except some microgastropods there are infrequent occurrences of small clusters of *Cladocora*

cespitosa and calcareous algae *Lithothamnium lenormandi, L.philippi, Peyssonnelia squamaria* and *P.polymorpha.* On the less covered, mostly sandy substrate the prevailing alga is *Udotea petiolata,* from molluscs *Cantharidus exasperatus, Columbella rustica, Mitrella scripta, Cerithium vulgatum, Phasianella pulla, Ph.speciosa, Gibbula ardens, Pinna nobilis, Modiolus barbatus, Propeamussium hyalinum, Chlamys varius, Lima inflata* and *Venus verrucosa.* From echinoderms abundant are in places *Ophiura albida, Amphiura chiajei, Ophiotrix fragilis, Psammechinus microtuberculatus.*

Thanatocenosis *B* differs from the previous one by vanishing of photophyllic species and representatives of vagile benthos. The prevailing elements are sciaphyllic, predominantly sessile or endobiotic ones. This means e.g. also a decrease in the number of important phytal indicators, like microgastropods. However, there are more frequent occurrences of the algae *Halimeda tuna, Mesophyllum lichenoides,* all three species of the genus *Peyssonnelia, Sphaerococcus coronopifolis* and sporadically even *Pseudolithophyllum expansum.* Leading forms are nevertheles still *Melobesia farinosa* and *M.lejolisii.* The abundancy of porifers and corals increases, especially that of *Cladocora cespitosa* and *Parazoanthus axinellae.* Some molluscs are still numerous – *Phasianella pulla, Alvania cimex, A.lineata, Turbonilla lactaea* – but the representatives of the geni *Rissoa, Rissoina* and *Bittium* become less frequent. Benthos, above all that of sandy substrate, is characterized by *Gibbula magus, G.ardens, Columbella rustica, Mitrella scripta, Cerithium vulgatum, Dentalium div.*sp., *Arca lactaea, Modiolus adriaticus, Propeamussium hyalinum, Venus verrucosa, Lima lescombei, L.elliptica.* The leaves of *Posidonia* still carry the representatives of the genus *Electra,* in its roots, especially in dense and deeper lying growth, there are *Aetea truncata, Lichenopora radiata, Scrupocellaria reptans, Microporella malusii,* less frequently *Porella cervicornis, Cellopora pumicosa* and *Lichenopora radiata.* Echinoderms prevailing on more free areas are *Psammechinus microtuberculatus, Echinocardium cordatum, Antedon mediterranea* and to a lesser extent also specimens of ophiuroids.

From the viewpoint of our interpretation in the study of fossil sediments we shall thus deal in both cases with mixed thanatocenoses containing even elements of aphytal environments. Thus, whether we shall study clayi, marly or sandy sediments, the presence of phytal environment can be indicated mostly only by increased quantity of microgastropods and some species of bryozoans. (This is of course true also for facies displaying the presence of other marine angiospermal growths, i.e. above all *Cymodocea* and *Zostera* fields, as well as extensive meadows with *Thalassia* in tropical regions. The presence of herbivorous benthos in a coarse, unsorted sandy environment or in more clastic sediments indicates with greatest probability algal phytal, above all dense growths of *Cystoseira* or *Sargassum* character.)

The third variety of *Posidonia* environment denoted by the symbol *C* (accumulated extinct stems and roots) occurs in most cases only from the biomass of the living growth itself towards the coast. It is settled as a rule on shallower sandy infralitoral and since it does not contain herbivorous elements characteristic for phytal environment, its components (above all as far as fossilizable species are concerned) are the same as in the substrate, i.e. aphytal coarse- and fine-grained or organodetrital sea-floor. Clusters of this extinct phytal in fossil state could be indicated only by the presence of sessile benthos, above all greater amount of small bryozoans, or also dispersed remnants of some fossilizable red algae.

The on the profile continuous, 850 m long *Posidonia* meadow is on places with less dense growth made more varied by the abundant green alga *Udotea petiolata.* It covers exceptionally densely the fine- to muddy-sandy bottom on clearances between the stations No. 6 and 7 and Nos. 13–14 (−17 to −19 m). From other phytal we can see growths of *Acetabularia mediterranea* (I-1a) and *Padina pavonia* (I-1b) only on the northern flank of the profile, on

bouldery sea-floor together with coastal infracoralligene (I-2+I-1e). and to a distance of about 100 m and a depth of −8 m there is a less dense *Cystoseira* growth (I-1c) with its typical accompanying fauna (for more details see Seneš, 1988c).

The facies I-5c is on this profile worth of notice. It is represented by organodetrital sand and not very dense occurrences of *Lithophyllum racemus* accompanied above all by *Arca noae* and *Dosinia exoleta*. It is the only place in the Pelješac region where we could notice the occurrence of this on the North Adriatic Shelf clasically developed biocenosis. (It is nevertheless necessary to point out that the current, even according to repeated measurements, was on this profile by far not so strong as on classical occurrences of this facies between the islands Valmascim-Sturago-S.Giovanni.)

Profile A-II-a, Žuljana SW – Island I. (Žuljana, Little Bay), 290 m (Fig. 4)

Field work on this short and shallow profile was done in the year 1966. Control sampling in 1975 and 1982 revealed human ifluences which lead to an almost total disappearance of more attractive mollusc and bryozoan fauna. The following description and Fig. 4 correspond to the original state in the year 1966.

The whole central part of the profile between the stations No. 3 and 7 is covered by *Posidonias*. An exception is the middle part, where the growth is sparse and between −14 and −19 m, on organodetrital sandy sea-floor, a typical biocenosis with *Pecten jacobaeus* and *Glycymeris glycymeris* was formed. (I would like to mention that this facies was even on the North Adriatic Shelf not named for a quantitative prevalence of *Pecten jacobaeus*, but more because of its prominency and greatest concentration of individuals in this zone.) A speciality of the *Posidonia* ecosystem was on this profile the very dense occurrence of large specimens of *Pinna nobilis* (between the stations 4 and 5 in average 1 large specimen on a square meter). The rest of benthos is equal to the profile A-II-d with types *A* and *B*. Less prominent are the occurrences of *Melobesia* and *Electra*, in contrast to the in comparison with the previous profile more frequent finds of *Nassa incrassata* and *Arca lactaea*. Infracoralligene (I-2a) together with the biocenosis with *Lithothamnium lenormandi-Halimeda tuna-Amphiroa rigida* (I-1e) can be found only on a short, rather steep slope of the Island I., especially on boulders from the limestone debris between the stations No. 8 and 9. A special feature of this development was in the year 1966 on lower sides of boulders still predominant dense occurrence of the bryozoans *Retepora beaniana* and *Myriozoum truncatum*, in relatively low depths.

Profile A-II-c-1, Rt. Lenga – Island I. (Pelješac, Little Bay), 740 m (Fig. 5)

The profile was studied and documented in the year 1967, its southern section near Lenga was controlled and sampled anew in 1971 and 1982. Especially the southern flank of the profile falls steeply into a relatively flat infra- and circalittoral plain with an exceptionaly interesting development. It crosses the profile c-2 (see later). Infralittoral slope on the other flank of the profile (Island I) falls less steeply and corresponds, as far as its biocenoses are concerned, to the already known succession of rocky and sandy infralittoral, above all with the facies I-1a,b, I-1e, I-2, I-7c,d, and the environment I-5a.

The profile reaches the depth −35 m in the direction from Lenga already in a distance of 100 m from the shore, then it falls more moderately to −45 m in a distance of 250 m and later on it continues in the form of a flat plain to the submarine slope of the Island I. The limestone

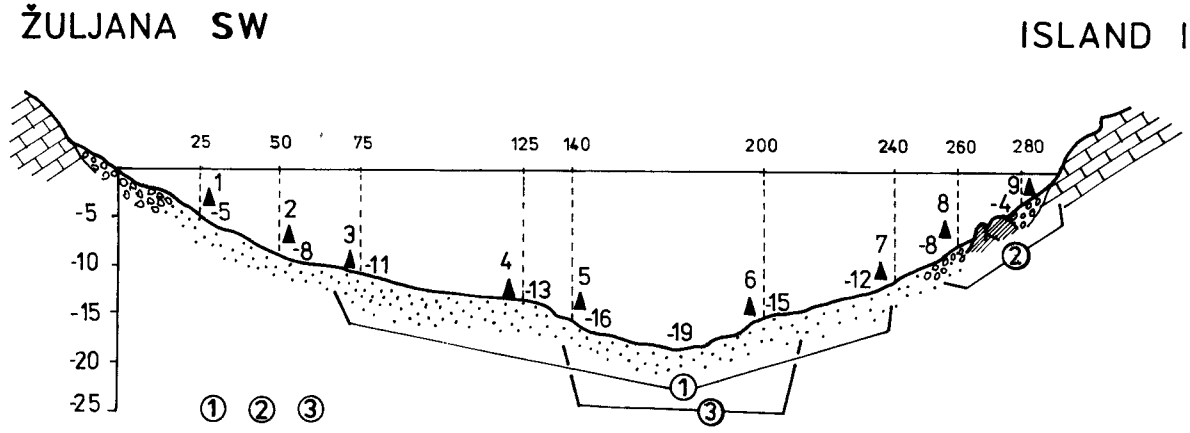

Fig. 4. Profile A-II-a, Žuljana SW–Island I. (Pelješac, Žuljana, Little Bay).
1. *Posidonia oceanica + Pinna nobilisa* (I-7c); 2. *Cystoseira* (I-1c); 3. *Pecten jacobaeus + Glycymeris* (I-5a).

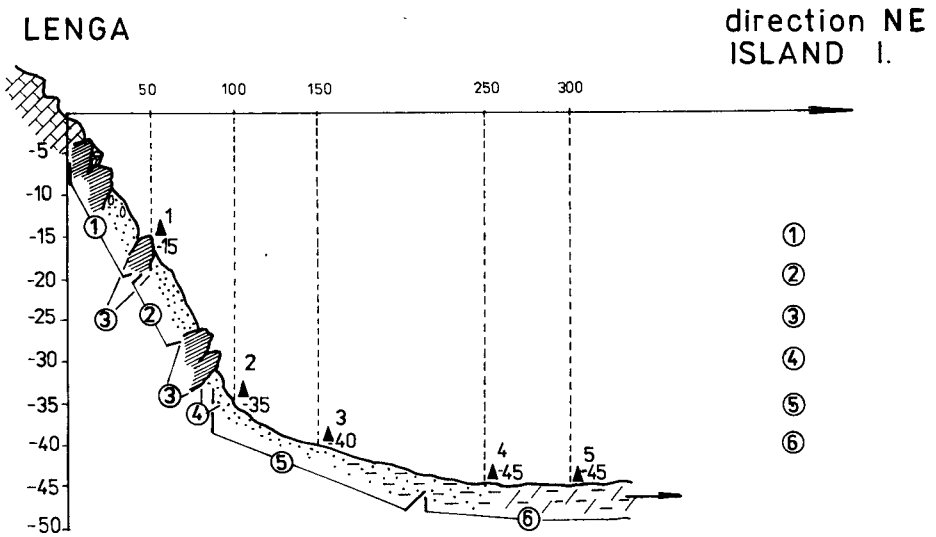

Fig. 5. Profile A-II-c-1, Rt. Lenga–Island I. (Pelješac, Žuljana, Little Bay).

1. Infracoralligene + *Cystoseira* (I-2+I-1c); 2. *Posidonia oceanica* + *Pinna nobilis* (I-7d); 3. Infracoralligene (I-2); 4. *Axinella verrucosa* zone (I-zz); 5. *Pecten jacobaeus* + *Glycymeris* (I-5a); 6. *Sabella pavonina-Venus casina* (C-2c).

slope debris, often with large boulders but also sandy flats, is covered by for South Adriatic infralittoral typical biocenoses with *Acetabularia mediterranea* (I-1c), *Halimeda tuna-Lithothamnium lenormandi-Amphiroa rigida* (I-1e). The typical macrophytal with *Cystoseira* (I-1c) is also not absent, making the previously mentioned biocenoses more varied by its marked islets occurring especially on sandy enclaves between the debris and boulders. The composition of its biocenoses has already been described in previous publications (Seneš, 1988b, c, 1989), however, it is necessary to mention that in contrast to the North Adriatic Shelf, *Ceramium rubrum* and *Nassa incrassata* are here predominant. Infralittoral covered in the upper section by large boulders can be partly classed with infracoralligene, however, only with its shallower and not quite typical development (I-2). The more lighted parts are except *Serpula vermicularis* and *Chiton corallinus* mostly without macroorganisms, the shadowed, overhanging or northwards oriented parts of boulders are covered by *Lithothamnium philippi, Lithothamnium lenormandi, Silicispongia* div. sp., *Spirorbis pagenstecheri* and bryozoans.

Large boulders of the slope in depths of −15 and between 27 and −32 m represent already the classical infracoralligene development with numerous representatives of rhodophytes, including *Pseudolithophyllum expansum* and sciaphyllic silicispongias (I-2b). Exept *Parazoanthus axinellae* abundant anthozoans are *Caryophyllia clavus* and *Alcyonum palmatum*. The prevailing bryozoans are *Scrupocellaria reptans, Cellaria fistulosa, Retepora beaniana, Myriozoum truncatum* and *Porella cervicornis*. The coarse-sandy floor of the slope is between stations No. 1 and 2 from −15 to −35 m covered by a thick growth of *Posidonia oceanica* with all varieties of its biocenoses. Below the lower boundary of this growth there is a zone with abundant occurrences of *Axinella verrucosa* and some other silicispongias *(Chondrosia reniformis, Geodia cydonium, Calyx micaeensis, Caccospongia scalaris)*. It lies on organodetrital substrate with a prevalence of *Glycymeris glycymeris* over *Pecten jacobaeus*

(I-5a). This prevalence is conspicious especially in depths from −35 to −40 m. *Lithothamnium* cf. *calcarsatum* (or *solutum?*) occurs also on this sediment, as well as more abundant *Cardium tuberculatum* and *Venus fasciata.* In deeper, muddy horizons of this zone occur also the representatives of the geni *Natica, Leda, Tellina* as well as extinct forms of the near circalittoral from the facies with *Venus casina-Tapes geographicus.* The station No. 4 (−45 m) displays towards the circalittoral plain, on muddy-sandy substrate, a biocenosis with prevailing *Cypraea lurida, Nucula nitida, Lima hians, Venus casina, Kellya suborbicularis, Tapes geographicus* and sporadically also *Dolium galea* (C-2b). The 50 m further lying station No. 5 (in the same depth of −45 m) is situated already in the middle of an extensive area densely settled by *Sabella pavonina* (I-2c). This biocenosis predominant in this bay on an area of about 200×70 m passes on all sides in similar depths into the biocenosis with *Venus casina − Tapes geographicus.* Samples taken from the bottom of this polychaeta zone to a depth of 30 cm indicate its organogenic origin, predominantly from the tubes of extinct *Sabella. Rhodophytes* occur only sporadically − *Peyssonnelia polymorpha, P. rubra, Wrangelia penicillata,* molluscs are represented by a relativelly little number of specimens − by *Lima hians, Kellya suborbicularia, Venus casina* and *Arcopagia balaustina.*

Profile A-II-c-2, Žuljana SE − direction NW (Pelješac, Žuljana, Little Bay), 520 m (Fig. 6)

This profile is crossing the section A-II-c-1 in a distance of 300 m from the shore. It was studied in the year 1967, its deeper section with the stations Nos. 6, 7 and 8 was controlled and sampled also in 1982. We did not observe any more important changes in biotops or currents.

This profile is in comparison with the previously described one more varied especially as far as the following features are concerned: Infracoralligene of the steep rocky slope is exceptionally densely covered by *Amphiroa rigida,* especially in depths from −6 to −10 m and about −13 to −15 m. The facies with *Glycymeris* reaches from the station. No. 1 to the station No. 4. i.e. from −17 to −41 m. It is possible to distinguish on this section a lower horizon richer in *Pecten jacobaeus* located in depths from −24 to −41 m. Classical eucoralligene (C-4), is developed as well on this profile it is composed above all of *Pseudolithophyllum expansum, Mesophyllum lichenoides, Neogonionlithon mamillosum* with very abundant *Peyssonnelia polymorpha* and *P. rubra* as well as dense growth of *Silicispongiae* and bryozoans. A part of from each other isolated bioherms (−41 to −44 m) displays sections decomposed due to biological erosion. Lithothamnion sand formed as a result of this degradation is distributed towards the shore in an as much as 60−80 m wide section in a depth of −44, −45 m, to a lesser extent in the direction to the open part of the bay. It forms an individual biocenosis (C-4s), where the prevailing elements, except the lithothamnion organogenic sand, are *Lima hians, Tapes geographicus, Arcopagia balaustina* and *Moerella donacina.* This representation of benthos is very similar to the biocenosis C-2b. The stations No. 7 and 8 in a depth of −45 m are a part of the already described biocenosis with *Sabella pavonina-Venus casina.*

Profile PM, Pelješac (Kupinova) − Mljet (Kobrava), 9200 m (Fig. 7)

This profile, leading through the Mljet Channel from the Kupinova Bay on the coast of Zagorje (peninsula Pelješac) to the vertical wall of Kobrava on the oposite island Mljet was studied in the years 1967 and 1971. Direct sampling of quadrants and stations coud be done

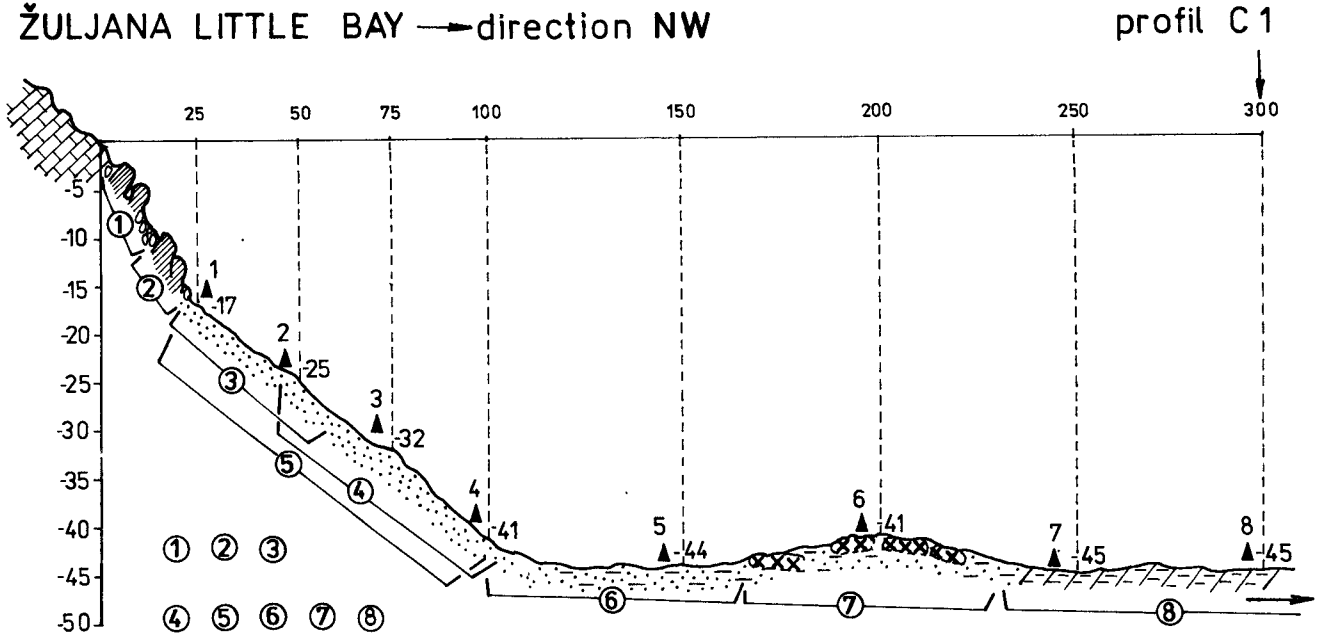

Fig. 6. Profile A-II-c-2, Žuljana SE – direction NW (Pelješac, Žuljana, Litte Bay).
1. *Cystoseira* + Infracoralligene + *Amphiroa* (I-1c+I-2); 2. Infracoralligene (1-2); 3. *Posidonia oceanica* (I-7c, d); 4. *Pecten jacobaeus* (I-5a); 5. *Glycymeris* (I-5ax); 6. *Lima-Tapes-Tellina* (I-6ax); 7. Eucoralligene (C-4); 8. *Sabella pavonia* + *Lima-Tapes-Tellina-Venus casina* (C-2c).

because of technical reasons only to a depth of −68 m on both flanks of the profile. Below this depth, where the bottom of the Mljet Channel lies between −75 and −88 m, the samples were obtained only by a core-borer with a diameter of 11.5 cm and a length of 1.30 m, with a back-folding check seal.

Both flanks of the profile, denoted as PMx and PMy, have been evaluated in great detail and they provided valuable information on the development of infra− and circalittoral. Their more detailed description is presented in the following. Except this profile we have studied two further sections from Pelješac towards the Mljet Channel, beginning from the Zagorje shore (near Sapovica) to a distance of 260 and 380 m from the shore, to depths of −52 and −56 m (denoted as profiles Z-1 and Z-2). Since even in these depths they did not reach the flat bottom of the channel and they do not differ very much as far as the composition of their ecosystems is concerned from the profile PMx, I shall refrain from their detailed description.

A slight current has been observed on both flanks of the profile PM below the depth −50 m, with a direction to NW.

Deep parts of the Mljet Channel are formed on the profile PM by a flat bottom, beginning on the Pelješac side as far as 1 km from the shore in −80 m and on the Mljet side approx. in a depth of −75 m already 120 m from the vertical wall of Kobrava. Samples obtained from points 1 to 6 are little-sandy, but partly strongly organodetrital, grayish or brownish, in places also variegated clays with very variable $CaCO_3$ contents. I do not exclude that due to a stronger current on many places there is no recent sedimentation of anorganic material and that the obtained samples could be of Pleistocene age. Fragments of benthonic organisms obtained by a core-borer are by far not sufficient for a serious characterization of biocenoses or ecosystems of the channel bottom, even less for further application in the study of fossil sediments. The collected material (frequently only fragmets or particles of organisms) indicated the presence of a shelf plain (C-5), denoted by Perès and Picard (1964) as "Fonds détritiques du Large". On this shelf a little shallower sandy-muddy-detrital facies, above all C-2a,b and areas covered by destructed eucoralligene (C-4s) gradually pass into this facies "large". On one section of such a passing, in a depth of −73 m (due to decompression a depth inaccessible for us as far as direct sampling is concerned), we have found on the lithothamnion sand *Fusus rostratus, Pinna pectinata* and *Propeamussium* cf. *hyalinum.*

Samples obtained by a core borer from the sampling sites Nos. 3 to 7 contained the alga *Halopteris* cf. *felicina,* the foraminifers *Quinqueloculina seminula, Q.elegans, Spiroculina excavata, S.canaliculata, S.depressa, Sigmoilina costata, Bolivina difformis, Asterigerinata mamilla, Sphaerogypsina globula, Globigerinoides* sp. *Globigerina bulloides, Cibicides lobatulus* and several species from the genus *Elphidium.* We have determined the poriphers *Myxilla rosacea, Ircinia muscarum,* from anthozoans *Caryophyllia clavus, Alcyonum palmatum, Funiculina* sp.?, *Pennatula phosphorea.* I do not exclude that a part of the determined species was washed to this environment from eucoralligene. From ostracods we have determined *Conchoecia spinirostria, Bosquetina pectinata, Pterygocythereis jonesi, Carinocythereis antiquata.* Molluscs are represented in the samples only by fragments of *Calliostoma* sp. *(conulus?), Scala communis, Fusus* sp., *Entalina quinquangularis, Dentalium* sp., *Cadulus subfusiformis, Leda* div.sp., *Amussium* sp. (?), *Tellinidae* div.sp., *Cardium echinatum, Abra alba.* Fragments of bryozoans indicate the presence of *Cellaria fistulosa, Porella* sp., *Frondipora verrucosa.* We have determined the presence of echinoderms *Antedon mediterranea, Echinus melo, Astropecten aurantiacus* (?), *Amphiura chiajei* and also a fragment of the tunicate *Ascidia* sp. (?).

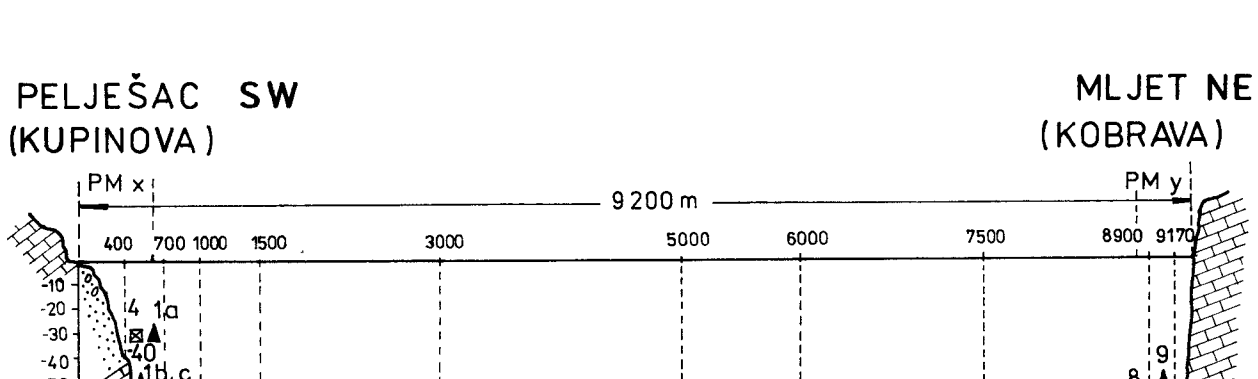

Fig. 7. Scheme of the profile PM, Pelješac SW (Kupinova) – Mljet NE (Kobrava) (length 9200 m, depth −88 m).

Table 1
Textural and mineralogical composition (Fejdiová, 1972)

Composition			Sample					
			profile PELJEŠAC — MLJET (P-M)					
			Kv-1	Kv-2	Kv-3	Kv-4	Kv-5	Kv-6
Mean		M	0.2	8.6	8.1	8.0	7.5	7.6
Sorting		δ_I	2.0	3.5	1.4	1.6	1.6	1.7
Asymetry		SK_I	0.20	−0,25	−0.8	−0.5	0.12	−0.5
Kurtosis		K_G	1.1	1.9	1.0	0.8	0.7	0.7
$CaCO_3$		%	97.5	74.6	19.8	32.9	7.3	22.5
Mineral composition	chlorite							
	biotite		+	+	+	+	+	+
	muscovite		+	+	+	+		+
	garnet		+	+	+	+	+	+
	rutile		+	+	+	+	+	+
	epidot			+	+	+		
	amphibole			+	+	+	+	+
	pyroxene		−	+	+	+	+	+
	glauconite			+		+		+
	illmenite		+	+	+		+	+
	leucoxene			+	+	−	+	+
	apatite				+			+
	chromite		+			+	+	+
	cinnabarite				+	+		
	bauxite							
	zircon				+			+
	corundum							+
	tourmaline				+			+
	magnetite							+
	mocryt. quartz							
	carbonates							
Resulting sediment			coarse -sand	fine- -sand	clay	clay	clay	clay

Profile section PMx, Kupinova (Pelješac), 600 m (Fig. 8)

Work on this section was done in the year 1964, it was controlled and sampled once more in 1971 and 1980.

Supralittoral is gravelly with fragments and remnants of extinct washed benthos. Mediolittoral is also gravelly, not very marked. Infralittoral begins with coarse fragmental sediments, gravel and boulders which reach to a distance of about 50 m from the shore. They are covered by *Acetabularia mediterranea* (I-1a), the biocenosis of which contains except the leading form also abundant *Padina pavonia, Amphiroa rigida* and *Gibbula varia.* To this distance reaches on the southern side of the bay also the growth with *Cystoseira* (I-1c) enriched especially by specimens from the geni *Alvania, Rissoa, Rissoina* div.sp.. In places, more on the NW margin of the bay, the occurrences of *Padina pavonia* is more dense (I-1b), with more abundant representation of rhodophytes and serpulides than in earlier described facies. It is characterized especially by the presence of a considerable number of *Gibbula divaricata, Cerithium rupestre* and *Pusia tricolor.* A large number of bryozoans is also not absent in this as well as in the cystoseira biocenosis, above all *Aetea truncata, Membranipora membranacea* and *Schizoporella sanguinea.* Less important is the occurrence of *Elphidia* and a few ostracods, on the other hand, an important role is that of infralittoral echinoderms known from previous profiles. On this section there is also a shallow infracoralligene on boulders (mixed facies I-1e+I-2a) with *Halimeda tuna, Lithothamnium philippi, L.lenormandi, Amphiroa rigida, Peyssonnelia squamaria, Serpula vermicularis, Spirorbis pagenstecheri, Retepora beaniana, Myriozoum truncatum* and numerous desmospongias.

Coarse- to fine-sandy, in places organodetrital substrate with *Posidonia oceanica* reaches through quadrant No. 1 to a distance of 100 m and a depth of −23 m. The growth contains all on the profile A-II-d described varieties of biocenoses. Infracoralligene occurring in the middle of this section enriches the sorrounding thanatocenoses even by a greater amount of extinct fragments of red algae and silicispongia spicules.

Quadrant No. 2 is located on a sandy substrate in a distance of 200 m (−27 m) in the middle of a deeper infracoralligene (I-2b). (I do not exclude that the infracoralligene substrate is here formed by from the sea-floor protruding limestone basement and not by isolated boulders). Sand collected from the quadrant is of organogenic origin and it is composed of extinct elements of the biocenosis I-2b. The infracoralligene itself, even though we classify it already with its deeper development, does not contain *Pseudolithophyllum expansum* in leading quantity, but above all a growth of *Mesophyllum lichenoides, Neogoniolithon mamillosum, Peyssonnelia polymorpha,* from green algae especially *Halimeda tuna,* a large amount of partly already sciaphyllic *Spongiae,* 6 anthozoan species, especially *Parazoanthus axinellae* on the exposed parts of the substrate, further from this biocenosis already described sessile and vagile molluscs, bryozoans and tunicates (Seneš, 1988b,c).

Organodetrital sand reaches to a distance of 400 m (−40), above all in the development of *Pecten jacobaeus* and *Glycymeris glycymeris* (I-5a). This section of the sea-floor is made more varied by the lower horizon of the *Posidonia* facies (I-7d) with a rich rhodophytal, sponge and bryozoan growth as well as a very typical, strongly destructed eucoralligene bioherm (C-4). Approximately between the lower edge of the *Posidonia* meadow and eucoralligene we can observes the facies I-5a containig an unusual amount of *Pinna nobilis* (in a depth of −34 to −37 m). In particles of calcareaous algae and bryozoans rich "lithothamnion sand" (C-4s) predominates in a range of several tens of meters around eucoralligene, containing a lesser number of large lamellibranchiates. On hard organogenic remnants of the sea-floor we can see, especially in the broader surroundings of the station No. 4, newly forming eucoralligene

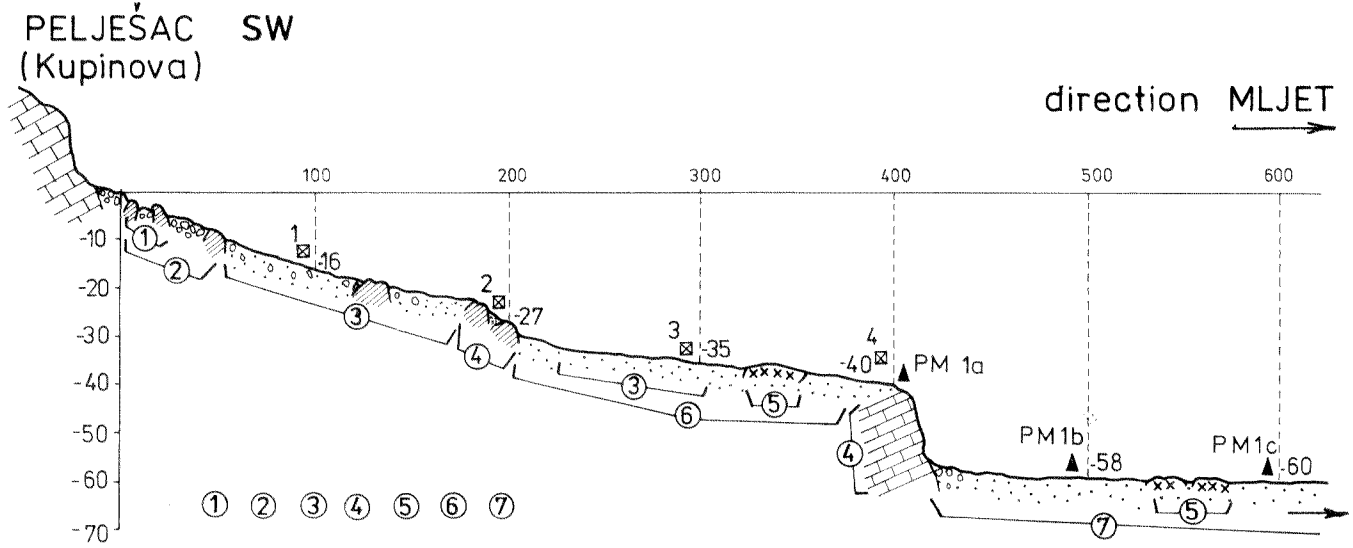

Fig. 8. Profile PMx, Pelješac SW (Kupinova).

1. *Acetabularia mediterranea* (I-1a); 2. *Cystoseira* + Infracoralligene (I-1c+I-2); 3. *Posidonia* + Infracoralligene (I-7c, d); 4. Infracoralligene (I-2); 5. Eucoralligene (C-4); 6. *Pecten jacobaeus* + *Glycymeris* + *Pinna nobilis* (I-5a); 7. *Lithothamnium fruticulosum-Tapes geographicus* (C-2a).

bioherms from the geni *Peyssonnelia* and *Neogoniolithon,* but above all *Pseudolithophyllum expansum.* They are also a dominant component of classical infracoralligene on a limestone wall on another section of the profile in depths between −42 and −56 m. The already described quadrant No. 4 located in the facies C-4s above this wall contains except the mentioned calcareous algae above all bryozoans, as well as more abundant *Balanophyllia italica, Cariophyllia clavus, Eunicella cavolinii, Serpula vermicularis, Pomatoceros triqueter, Chiton corallinus, Vermetus arenarius, Capulus hungaricus, Arca barbata, Tapes geographicus, Anomia ephippium, Cardita trapezia.*

Under the vertical infracoralligene wall there is towards the Mljet Channel plain only a very slightly sloping sandy-organodetrital, slightly muddy bottom which we have observed to a distance of 600 m (−60 m). The presence of the facies "large" at the station PM-1c in a depth of −60 m indicates an icreased muddiness of the sea-floor. The whole section (except for lesser, even in these relatively great depth by *Halimeda tuna* covered enclaves of eucoralligene) is characterized by the biocenosis *Lithothamnium fruticulosum-Tapes geographicus* (C-2a). Large nodules of this red alga are in places numerous, there are as much as 15−20 specimens on 1 sq.m. For this biocenosis are characteristic except a large number of sciaphyllic *Silicispongiae* also *Lima hians, Venus casina, Psammobia costulata* and *Arcopagia balaustina.* More frequent are also the algae *Palmophyllum crassum, Vidalia volubilis,* from foraminifers *Quiqueloculina seminula, Q. costata, Q. elegans, Triloculina trigonula, Discorbis globularis, Asterigerina planorbis, Ammonia beccari, Elphidium crispum, Planorbulina mediterranensis.* From anthozoans and polychaetes the prevailing are *Alcyonum palmatum* and *Serpula vermicularis.* Typical ostracods are *Aurila speyeri, Xestolebris dispar, Pontocythere elongata* and *Neocytheridis fascinata.* Molluscs are except the already mentioned ones represented more frequently also by the species *Diodora gibberula, Venus fasciata, V.ovata, Spisula subtruncata, Thracia distorta* and in lower, more muddy horizons by several specimens of *Leda, Nucula* and *Tellina* div.sp.. Bryozoans predominant especially on more pelitic sections are *Cellaria fistulosa, Myriozoum truncatum* and *Porella cervicornis,* from echinoderms are relatively frequent *Antedon mediterranea, Astropecten aurantiacus* and *Ophiura albida.*

From the tectono-morphological point of view it is worth of notice that the basement of the mentioned limestone wall in the middle of circalittoral of this profile corresponds in the depth of −56 m approximately to the vertical wall of Kobrava on the opposite side of the profile on the island Mljet.

Profile section PMy, Kobrava (Mljet), 120 m (Fig. 9)

The work was done in the year 1964 and 1980. The almost to 60 m under the sea reaching vertical, in places overhanging limestone wall of infralittoral provides unique possibilities for the study of all varieties of infracoralligene biocenoses (I-2a,b). The wall is in the depth −20 m interrupted by about 3−5 m wide terrace covered by detrital sand, rock fragments and algal growth. A smaller, very narrow terrace is in the depth −30 m, above it is a short cave with a several meters high portal. The walls of the cave itself are as usually densely covered above all by sciaphyllic rhodophyts, *Spongiae* and nearer to the entrance also by bryozoans and *Balanophyllia* and *Caryophyllia.* Another cave is near to the base of the wall in a depth of −55 m and it is probably a relic of an old, now inactive spring.

Regardless of the known biocenoses of caves (Riedl, 1966; Seneš, 1988c) we can divide the wall of this infracoralligene into three depth zones, above all depending on the with the depth decreasing light and only to a lesser extent on bathymetric relations of organisms.

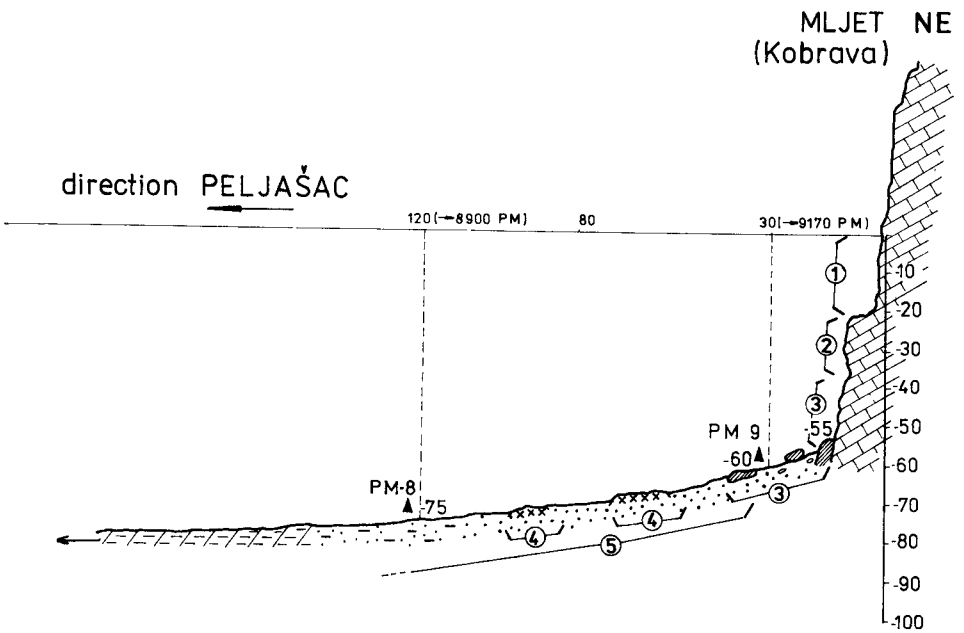

Fig. 9. Profile PMy, Mljet NE (Kobrava).
1. Infracoralligene *(Lithothamnium lenormandi + Lithophyllum incrustans + Halimeda tuna);* 2. Infracoralligene *(Lithothamnium philippi + Melobesia farinosa + Halimeda tuna);* 3. *Pseudolithophyllum expansum + Mesophyllum lichenoides + Peyssonnelia squamaria;* 4. Eucoralligene *(Pseudolithophyllum expansum, Neogoniolithon + Mesophyllum + Peyssonnelia + Scrupocellaria);* 5. *Lithothamnium fruticulosum-Tapes geographicus.*

The upper infracoralligene horizon reaching to a depth of about −20 m can be characterized by a prevalence of *Lithothamnium lenormandi, Lithophyllum incrustans* and *Halimeda tuna.* From red algae are more abundant also *Lithothamnium philippi, Corallina mediterranea, Jania rubens, Amphiroa rigida* and *Peyssonnelia squamaria.* The foraminifers occurring here are *Miniacina miniacea, Rosalina bradyi,* from polychaetes there are *Serpula vermicularis* and *Protula tubularia.* Abundant are porifers, especially on bare parts of the rock wall and on calcareous algae amid *Halimeda* growth. The most frequent anthozoan is *Parazoanthus axinellae,* from molluscs we can find mostly only *Acanthochiton communis, Chiton corallinus, Clanculus corallinus, Capulus hungaricus, Crepidula moulinsi* and *Modiolus barbatus.*

The middle infracoralligene horizon reaching to a depth of −35 to −40 m is characterized also by the occurrence of *Halimeda tuna,* but the prevailing rhodophyt is *Lithothamnium philippi* and on them and numerous bryozoans a mass of *Melobesia farinosa.* On the overhanging part of this section of the wall are not rare growths and covers of *Mesophyllum lichenoides, Peyssonnelia polymorpha, P.rubra,* in places *Pseudolithophyllum expansum.* The representatives of other organisms are more or less the same as on the upper horizon of the wall.

The predominant elements on the horizon between −40 and −60 m are *Pseudolithophyllum expansum, Neogoniolithon mamillosum, Mesophyllum lichenoides, Peyssonnelia*

polymorpha (rubra?), i.e. the same rock-forming species which are typical mostly also for eucoralligene. *Halimeda tuna* is almost completely missing. The same composition of organisms is displayed also on boulders on the foot of the rock wall. They are dispersed on the slight sandy slope which acquires gradually with depth the character of the biocenosis with *Lithothamnium fruticulosum*. The lower infracoralligene horizon on the Kobrava wall is however also characterized by the presence of *Palmophyllum crassum*, a large amount of little fossilizable rhodophyts like *Halymenia dichotoma, Rhodymenia corallicola, Lomentaria linearis*, further foraminifers, especially *Cibicides lobatulus, Discorbis globularis, Planorbulina mediterranensis, Hanzawaia boueana*, abundant *Silicispongiae* and anthozoans (more frequently *Eunicella cavolinii* and *Alcyonum palmatum*, very rarely *Paramuricea chamaeleon*, further molluscs *Astraea rugosa, Calyptraea chinensis, Arca barbata, Hinnites multistriatus*. The prevailing bryozoan is *Scrupocellaria reptans*. Similar is the composition of eucoralligene enclaves developed on mobile sandy slope towards the probe PM-8 (−75 m). The sandy bottom itself, except the fact that it is densely covered by nodules of *Lithothamnium fruticulosum*, is considerably organodetrital due above all to the influence of fallen and transported fragments of calcareous rhodophytes. Their benthonic thanatocenosis is almost identical with the lower part of the profile section PMx.

Supra- and Mediolittoral of Vlašnik islands

In relation to the field work on the South Adriatic Shelf I shall mention also the results of our study of supra- and mediolittoral on one of the islets in the group of Vlašnik (the location is mentioned in the introduction to this paper). The islands have a flat morphology and are considerably abraded along slightly inclined Mesozoic limestone beds. The karsted surface of the islands is free of vegetation.

In supralittoral (S-1) to a height of 2.2−2.9 m from the level of the bay (July 28. 1975) we have determined in two 300 m zones on the northern as well as southern side of the islet the cyanophytes *Entophysalis granulosa, Colotrix scopulorum, Rivularia mesenterica*, from rhodophytes extinct *Bangia fuscopurpurea*, belts of *Catanella opuntia* growth, from *Cirripedia Chthamalus stellatus, Cht.depressus*, from gastropods near the tide level *Patella lusitanica* and in the whole supralittoral range very abundant *Littorina neritoides*. The thanatocenosis in horizontal karst fissures of the supralittoral is formed by various accumulated, mostly fossilizable extinct organisms originating in medio- and partly also shallower infralittoral.

The life in rocky mediolittoral (M-1) is incomparably more rich, even though this ecosystem occurs here only in a narrow range approx. to 0.5 m and thus it can be hardly divided into individual zones of upper and lower mediolittoral. In the determination of the lower mediolittoral boundary I take into account the lowest line that remained in the time of our sampling after low tide at a calm water surface without humectancy.

From cyanophyts occurs here especially *Rivularia atra*, from chlorophytes we have found only on one location a few *Bryopsis balbisiana, Enteromorpha intestinalis, Cladophora dalmatica*, from rhodophyts relatively dense *Bangia fuscopurpurea*, on the upper boundary of this zone extinct *Nemalion helmintoides*. Typical are dense growths and coats of *Hildebrandtia prototypus, Lithothamnium lenormandi, Lithophyllum incrustans* (on the northern side of the island as well as in cracks in rocks frequently together with *Catanella opuntia*), further *Polysiphonia sertularoides*. We have determined from foraminifers only the presence of *Miniacina miniacea*, from *Cirripedia* in the higher horizon of this zone *Balanus tintinnabulum* and in groups also *Balanus perforatus*. From molluscs occur rarely *Middendorfia caprearum* and *Acanthochiton fascicularia*, considerably more abundant *Chiton olivaceus,*

Patella coerulea, P.lusitanica, Monodonta turbinata, on vertical surfaces of rocks colonies of *Brachyodontes minimus,* further endolithic *Lithophaga lithophaga* and on the lower boundary of low tide sporadically *Cardita calyculata.*

We classify with mediolittoral of course also the "trottoir" (M-2) and by incrustating calcareous algae covered, frequently even more than a meter to the sea protruding limestone beds that I denoted "pseudotrottoir" (M-2p). We have found real trottoir near the profile Z-2, psudotrottoir occurs on many locations on the Middle and South Adriatic Shelf. The site we have sampled was on medilittoral of the Zagorje region, between the profiles Z-1 and Z-2.

The principal components of red calcareous algae as well as sessile and vagile benthos are on both types basically the same. The decisive forming element are rhodophyts *Lithophyllum cristatum* (syn. *tortuosum*) and in most cases also *Lithothamnium lenormandi, Lithophyllum incrustans,* however, most frequently *Lithophyllum papillosum* and *Neogoniolithon notarisii.* Epifauna is usually poor in specimens, but we can consider *Chthamalus stellatus, Balanus tintinnabulum, Chiton ōlivaceus, Monodonta turbinata, Patella lusitanica* and *P.coerulea* to be also the inhabitants of trottoir on our localities.

Fig. 10. *Acetabularia mediterranea* LAMOUR in infralittoral of the profile PMx in the depth −2 m.

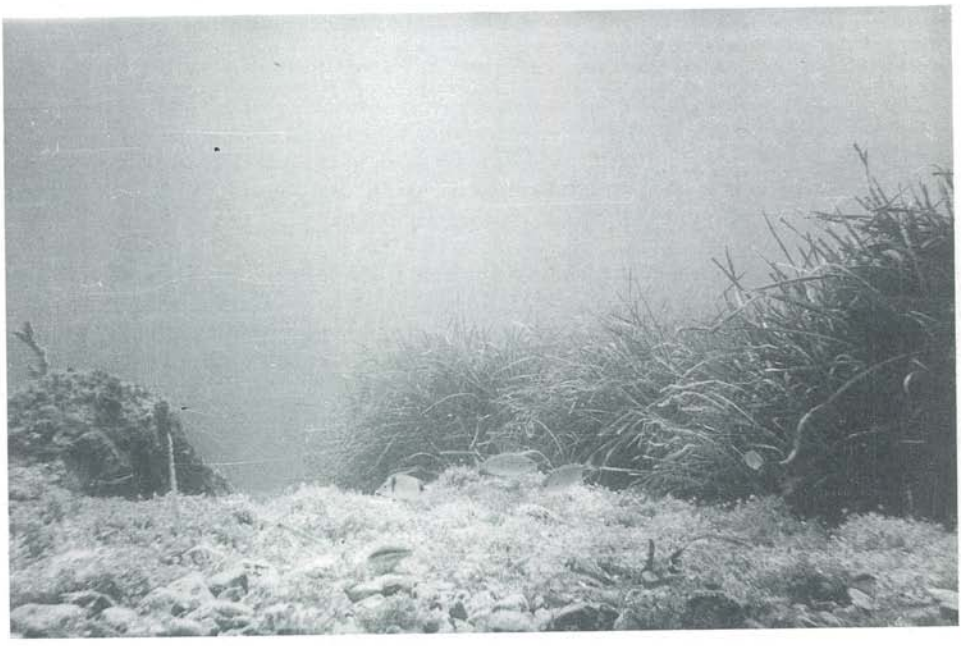

Fig. 11. Boundary of infralittoral biocenosis with *Acetabularia mediterranea* (I-1a) and the biocenosis with *Posidonia oceanica* (I-7c) on the profile PMx in the depth −6 m. On the left side there is a boundary representing the shallower infracoralligene facies (I-2a).

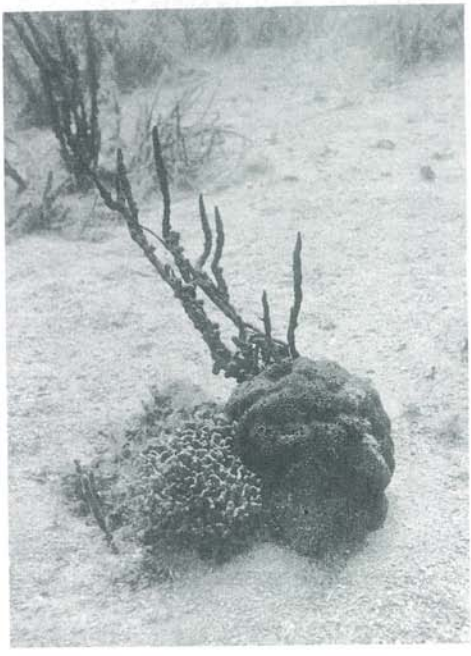

Fig. 12. Zone (enclave) with *Axinella verrucosa* SCHMIDT on the sandy bottom of the profile A-II-c-1 in the depth −37 m near the station No. 2, with *Posidonia oceanica* (I-7d, in the background). In the center of the picture and on the left side back is *Axinella verrucosa,* in front of it *Geodia cydonium,* to the left *Caccospongia scalaris.*

Fig. 13. The facies *Sabella pavonina-Venus casina* on the profile A-II-c-1, in the depth −45 m near the station No. 5. (Facies C-2c).

Fig. 14. The biocenosis *Posidonia oceanica* (I-7c) in the variety *A*, with dense settlement of stems by the red alga *Melobesia farinosa* and with bryozoans from the geni *Aetea* and *Electra*. In the middle of the picture we can see *Amphiroa rigida*. South of the island Lirica (in Žuljana Bay) in the depth −16 m.

Fig. 15. Facies I-5a *(Pecten jacobaeus-Glycymeris glycymeris)* enriched by dense occurrence of large specimens of *Pinna nobilis* L. on the profile PMx, in the depth −36 m.

Fig. 16. Karst relief of abraded islands in the Vlašnik group on the South Adriatic Shelf. A view at low tide with exposed mediolittoral.

Fig. 17. A boulder transported by waves from upper mediolittoral to the edge of supralittoral, with traces of burrows made by *Lithophaga lithophaga*. Photographed on one of the Vlašnik islands in the Vrhovnjac Archipelago on the South Adriatic Shelf.

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The listed references concern hydrographic conditions in all Adria as well as every in this paper mentioned profile. Not wanting to interrupt unnecessarily the text, I have not cited the references in the description of each profile.

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