

The development of the mollusc fauna in the Cenomanian of the stratigraphic sequence of Visogliano (Karst of Trieste, Italy)

Favnistični razvoj mehkužcev v cenomanijskem stratigrafskem zaporedju pri Vižovljah (Tržaški Kras, Italija)

Mauro Caffau & Nevio Pugliese

Dipartimento di Scienze Geologiche Ambientali e Marine,
Università degli Studi di Trieste, Via Eduardo Weiss 2 CAP 34127 Trieste

Mario Pleničar

Katedra za geologijo in paleontologijo,
Univerza v Ljubljani, Aškerčeva 2, 1000 Ljubljana, Slovenija

Abstract

The stratigraphic sequence of Visogliano (Karst of Trieste) belongs to lower part of the Zolla Member of the still informal and provisional "Trieste Karst Limestone Formation" and has been attributed to Middle-Late Cenomanian. This sequence records an environmental evolution of more or less restricted settings, where a rich mollusc fauna is present.

Among the molluscs, six radiolitid species occur (*Radiolites carsicus* n. sp., *Radiolites peroni*, *Praeradiolites acutilamellosus* n. sp., *Praeradiolites* cf. *P. fleuriaus*, *Sauvagesia sharpei*, and *Durania acuticostata* n. sp.). Of these, three species are described as new (*Radiolites carsicus* n. sp., *Praeradiolites acutilamellosus* n. sp., and *Durania acuticostata* n. sp.). In addition, attention has been focussed on the link between radiolitids and environmental changes to refine the previously described environmental evolution. In this regard, a hierarchy of tolerability to environmental changes can be also suggested. The most tolerant radiolitids species are *Praeradiolites* cf. *P. fleuriaus* and *Sauvagesia sharpei*, meanwhile the least tolerant ones are *Radiolites carsicus* n. sp., *Radiolites peroni*, *Praeradiolites acutilamellosus* n. sp., and *Durania acuticostata*.

Kratka vsebina

Stratigrafsko zaporedje plasti pri Vižovljah (Tržaški Kras) pripada spodnjemu delu »člena Col« (Membro di Colla), še neformalne in začasno določene »apnenčeve formacije Tržaškega Krasa«, ki ga štejemo v srednji do zgornji del cenomanijske stopnje. To zaporedje kaže na razvoj okolja na bolj ali manj omejenih območjih z bogato favno moluskov.

Med moluski smo ugotovili šest radiolitidnih vrst (*Radiolites carsicus* n. sp., *Radiolites peroni*, *Praeradiolites acutilamellosus* n. sp., *Praeradiolites* cf. *P. fleuriaus*, *Sauvagesia sharpei* in *Durania acuticostata* n. sp. Od teh so bile tri vrste opisane kot nove (*Radiolites carsicus* n. sp., *Praeradiolites acutila-*

mellosus n. sp. in *Durania acuticostata* n. sp.). Razen tega smo posvetili pozornost na zvezo med radiolitidi in spremembami okolja. Radiolitidi imajo različno stopnjo prilagodljivosti na spremembe okolja. Najbolj prilagodljivi radiolitidni vrsti sta *Praeradiolites* cf. *P. fleuriausius* in *Sauvagesia sharpei*, medtem ko so najmanj prilagodljive vrste *Radiolites carsicus* n. sp., *Radiolites peroni*, *Praeradiolites acutilamellosus* n. sp. in *Durania acuticostata* n. sp.

Introduction

In agreement with Cucchi et al. (1987), the lithotypes outcropping in the Karst of Trieste pertain to the still informal and provisional Trieste Karst Limestones Formation which ranges from early Cretaceous to early Eocene. Within this formation, the lower part of the Zolla Member, which has been up to now attributed to Cenomanian-early Turonian, corresponds to the beginning of a clear development of the mollusc fauna and, particularly, of the radiolitids. Thus, the paleontological study concerning this member can be considered very useful to increase the knowledge of the stratigraphy and palaeoenvironmental evolution of the Karst of the Trieste.

This research focuses on the outcrops of Visogliano, near Sistiana (western Trieste Karst, F°40 III NE of the IGM; Fig. 1), where the geological survey highlights a thick sequence with very fossiliferous beds within the lower part of the Zolla Member. The fossils here found mainly consist of bivalves and, particularly, of radiolitids.

Purposes of this work are 1) the chronological and palaeoenvironmental study of the stratigraphic sequence of Visogliano, and 2) the identification of the mollusc fauna and, particularly, of the radiolitids here found in order to refine the interpretation of the environmental evolution.

Historical setting

Cucchi et al. (1987) include the Zolla Member between the underlying dolomitic Rupin-grande Member (Albian p.p.-Cenomanian p.p.) and the overlying Borgo Grotta Gigante Member (early Turonian p.p.-Senonian p.p.). They subdivide it into two parts: the lower part, which is mainly characterized by blackish limestones, sometimes with a very rich radiolitid fauna and, at the basis, interbedded dolostones; the upper part, which is characterized by grey limestones, with rudist fragments and *Pithonella* specimens. The fossils of the lower part consist of radiolitids, such as *Sauvagesia nicaisei* and *Sauvagesia sharpei*, and microfossils, such as Nubeculariidae, Miliolidae, and ostracods. Because of these radiolitids, and of the lack of the microfossils, which are significant from the chronological point of view, these authors attribute the lower part of this member to an undefined time-span from Cenomanian to early Turonian. Besides, they attribute the upper part of this member to early Turonian for the finding of the *Pithonella* specimens, in agreement with Polšak (1979).

Other papers concerning the outcrops of the Zolla Member are due to Cucchi et al. (1986) and Colizza et al. (1987), who studied the stratigraphy of localities of the Karst of Trieste, such as Zolla-Monrupino and San Pelagio, respectively. These papers confirmed the stratigraphic data already presented in the above cited studies.

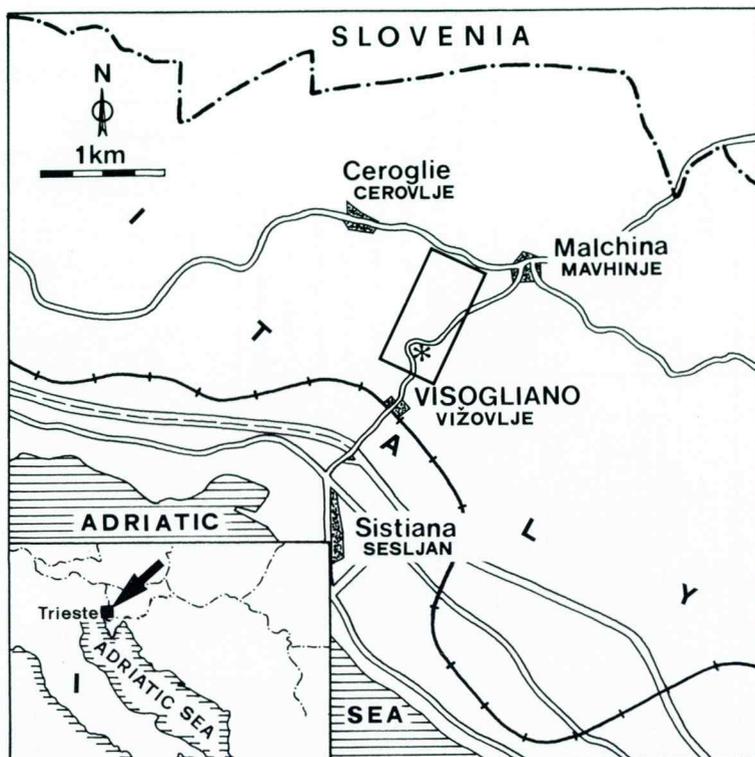


Fig. 1. Location map; the studied area is delimited by a rectangle. The asterisk shows the location of interval 6 of the Visogliano stratigraphic sequence, where all the studied mollusc species were represented. Visogliano

Sl. 1. Situacijska karta; raziskano območje je omejeno s pravokotnikom. Zvezdica kaže lego šestega intervala stratigrafskega zaporedja pri Vižovljah, iz katerega so vse predstavljene vrste moluskov. Vižovlje

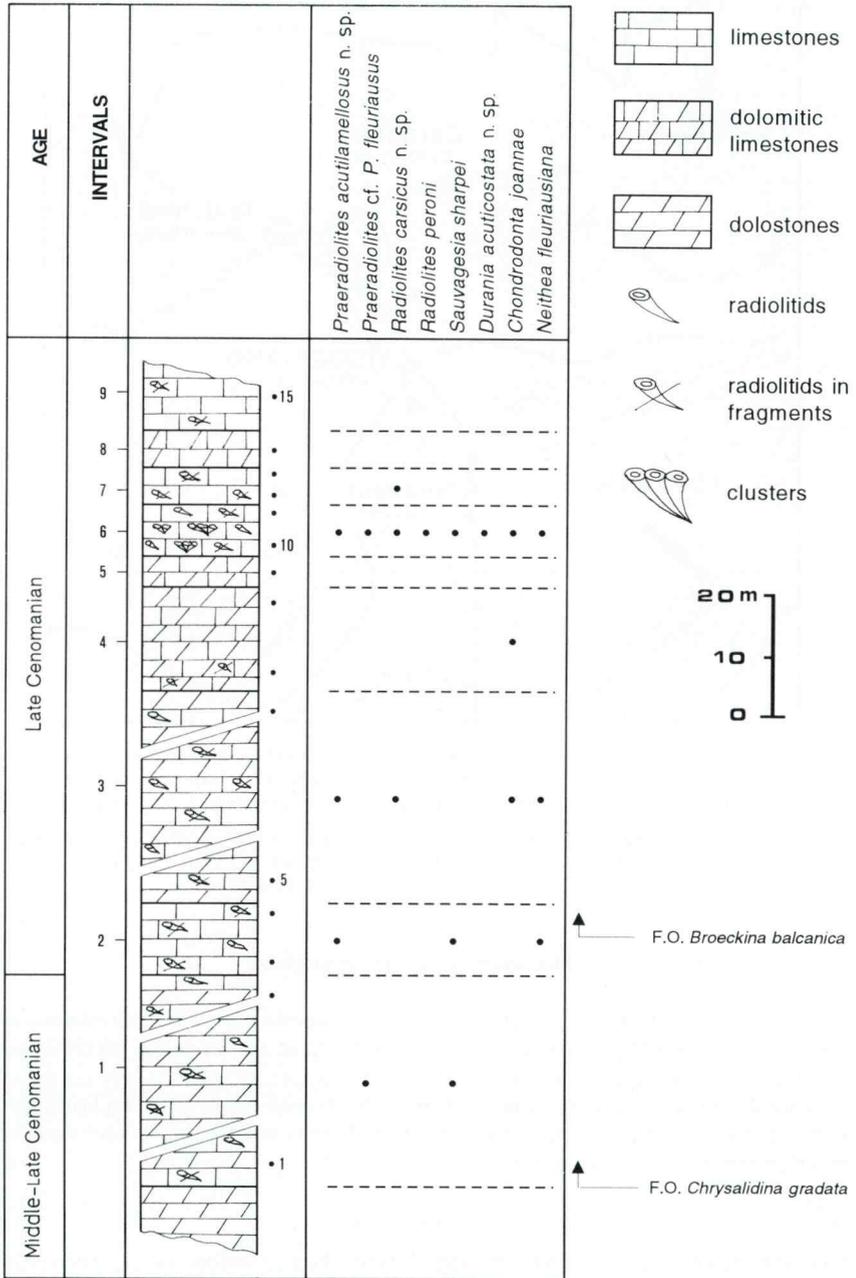
The stratigraphic sequence

In the Visogliano area the lithotypes of the Zolla Member show a monoclinial asset with WNW-ESE main axial direction and southward main dip of 22° . In detail, on the basis of the mollusc fauna and the microfacies analyses, the stratigraphic sequence here recognized can be subdivided into nine intervals (Fig. 2). For each interval, data regarding lithology, palaeontology, microfacies, thickness, and palaeoenvironment are reported. The nine intervals are described below, from bottom to top.

Interval 1

This interval consists of foetid very fossiliferous black limestones and interbedded dark greyish dolostones, both with bedding of decimetric period.

In the limestones, the fossils mainly consist of radiolites (*Praeradiolites* cf. *P. fleuriaus* and *Sauwagesia sharpei*), which are present in lenses of isooriented displaced shells.



These lenses are bordered by isolated specimens, which seem to be *in situ*. On the contrary, the dolostones are devoid of fossils, save for some rare gastropod ghosts.

The limestones are characterized by microfacies such as bioclastic (rudist) wackestones and packstones with very common Nubeculariidae, Miliolidae, and subordinate algae (*Thaumatoporella parvovesiculifera*, *Cayeuxia* sp.), Textulariidae, *Chrysalidina gradata*, *Cuneolina* sp., *Nezzazata simplex*, and ostracods. The dolostones show a subeuhedral dolomitic mosaic with gastropod ghosts only.

This interval overlies the dolostones of the Rupingrande Member and is 71 m thick. From the palaeoenvironmental point of view, it testifies very restricted settings, sometimes characterized by local biostromes (lenses of displaced radiolitids) and the first isolated radiolite specimens. The latter are probably able to colonize such restricted settings taking advantage of temporary permissive conditions for benthic life. These conditions degrade in correspondence with very restricted environment, as testified by the almost unfossiliferous dolostones.

Interval 2

This interval is characterized by dark-grey fossiliferous limestones, with bedding of decimetric period. The fossils consist of rare fragmented radiolite specimens pertaining to *Praeradiolites* cf. *P. fleuriaus* and *Sauwagesia sharpei*, together with *Neithea fleuriausiana*.

The corresponding microfacies are represented by wackestones and packstones with bioclasts (radiolitids) and very common Nubeculariidae, Miliolidae, and subordinate algae (*Thaumatoporella parvovesiculifera*, *Cayeuxia* sp.), *Chrysalidina gradata*, *Broeckina balcanica*, *Cuneolina* sp., *Nezzazata simplex*, and ostracods. This interval is 12 m thick. It indicates episodes of an increased bottom energy in a restricted environment, as demonstrated by the presence of very abundant radiolite fragments.

Interval 3

This interval is characterized by interbeddings of grey dolostones and blackish fossiliferous limestones, with bedding of decimetric period. The dolostones are devoid of fossils, meanwhile the limestones include fossils such as *Chondrodonta joannae*, *Neithea fleuriausiana*, and scattered fragments of *Praeradiolites acutilamellosus* n. sp. and *Radiolites carsicus* n. sp.

The corresponding microfacies are respectively represented by euhedral/subeuhedral dolomitic mosaic, with gastropod ghosts, and bioclastic mudstones or wackestones with rare intraclasts and pellets; the microfossils are represented by very common Nubeculariidae

Fig. 2. The stratigraphic sequence of Visogliano within the Zolla Member, showing the age, lithology, sampling-stations of the 9 intervals. The real thickness of intervals 1 and 3 is reported in the text. The interval 1 overlies the dolostones of the Rupingrande Member. In addition, the mollusc fauna and the microfossils, significant from the chronostratigraphic point of view, are reported. For the latter the first occurrence (F. O.) is indicated. The numbers 1–15 indicate the sampling-stations

Sl. 2. Stratigrafsko zaporedje pri Vižovljah, ki predstavlja »člen Col« (»Zolla Member«). Na stolpcu vidimo geološko starost, litologijo in lego vzetih vzorcev iz devetih intervalov. Resnična debelina prvega in tretjega intervala je navedena v besedilu. Prvi interval leži na dolomitu »člena Veliki Repen« (»Rupingrande Member«). Razen tega je podana favna moluskov in mikrofosilov, pomembnih za kronostratigrafijo. Slednji so bili najdeni prvič. Številke 1–15 označujejo lego vzetih vzorcev

and Miliolidae, and subordinate *Thaumatoporella parvovesiculifera*, *Cuneolina* sp., *Broeckina balcanica*, *Chrysalidina gradata*, *Pseudorhapydionina dubia*, Textulariidae, *Nezzazata conica*, and ostracods.

This interval, which is 65m thick, indicates very restricted settings (dolostones) with a moderately increased bottom energy (bioclastic limestones), where lamellar shells of *Chondrodonta joannae* colonize the substrate, also in correspondence with a low rate of sedimentation.

Interval 4

This interval is constituted by grey, sometimes dolomitic, limestones, with a fossiliferous level (in the basal part), which is from 1.80 to 3m thick and characterized by shells of *Chondrodonta joannae* and rare fragments of radiolitids.

The corresponding microfacies are represented both by bioclastic floatstones and boundstones (in the lower part), and wackestones or packstones (in the mid-upper part) with very common Miliolidae, and, subordinately, *Aeolisaccus kotori*, *Thaumatoporella parvovesiculifera*, *Broeckina balcanica*, *Chrysalidina gradata*, Textulariidae, Nubeculariidae, and thin carapaces of ostracods.

This interval is 18m thick. In the lower part, it records the colonization of the substrate due to the specimens of *Chondrodonta joannae*. Because of the lamellar morphology of the shell of *Chondrodonta joannae*, this colonization probably occurs in correspondence with episodes of moderate-high bottom energy and low sedimentation rate. In the mid-upper part of the interval, the mollusc fauna is substituted by a large number of microorganisms, probably in relation to environmental conditions showing a decreased bottom energy and an increasing sedimentation rate.

Interval 5

This interval is characterized by brown dolomitic limestones with not evident bedding.

The corresponding microfacies are characterized by very abundant euhedral dolomitic crystals included in a carbonatic mud, with rare Miliolidae and fragments of *Chrysalidina gradata*.

The thickness of this interval is 5m. It testifies very restricted settings, which become adverse for the benthic life.

Interval 6

This interval consists of grey-brown very fossiliferous limestones with bedding of decimetric period. The fossils are represented by requienids, and very common specimens of thickshelled radiolitids (*Radiolites carsicus* n. sp., *Radiolites peroni*, *Praeradiolites acutilamellosus* n. sp., *Praeradiolites* cf. *P. fleuriausius*, *Sauvagesia sharpei*, and *Durania acuticostata* n. sp.), very and *Chondrodonta joannae*; in addition, rare specimens of *Neitheia fleuriausiana* are also present. Among the molluscs, the radiolitids are often present in clusters consisting of from 2 to 10 specimens *in situ*.

The main microfacies are represented by boundstones (clusters of radiolitids) and bioclastic wackestones, with abundant microfossils. These latter consist of very common *Chrysalidina gradata*, Nubeculariidae, Miliolidae, and subordinate specimens of *Bacinella irregularis*, *Cayeuxia* sp., *Thaumatoporella parvovesiculifera*, *Cuneolina* sp. Textulariidae, *Broeckina balcanica*, and *Nezzazata simplex*.

This interval is 8.5m thick. It records restricted settings characterized by favourable environmental conditions for the benthic life, for both the growth of the build-ups and the

increased specific diversity of the microfossils. This episode can correspond to a decreased bottom energy and an increased sedimentation rate.

Interval 7

This interval is characterized by grey limestones with bedding of decimetric period. The fossils are rare and consist of fragments of radiolitids, such as *Radiolites carsicus* n. sp.

The main microfacies are represented by bioclastic wackestones with *Chrysalidina gradata*, and rare Textulariidae, *Broeckina balcanica*, Miliolidae, *Nezzazata simplex*, and thick carapaces of ostracods.

This interval is 6m thick. It shows a decreased specific diversity for both the radiolitids and the microfossils. The radiolitids are represented by rare small specimens and, over all, by fragments. The latter also testify episodes of high bottom energy in a restricted setting.

Interval 8

This interval consists of from light grey to grey-brown dolomitic limestones, with bedding of decimetric period.

The corresponding microfacies are characterized by very abundant euhedral dolomitic crystals included in a carbonatic mud, with rare Miliolidae.

This interval is 6m thick and indicates very restricted settings, which are adverse for the benthic life.

Interval 9

This interval is characterized by from dark-grey to blackish foetid limestones, with rare fragments of radiolitids and bedding of centimetric period.

The corresponding microfacies are represented by muddy plane-parallel laminations including rare microfossils, such as *Thaumatoporella parvovesiculifera*, *Chrysalidina gradata*, *Cuneolina* sp., Nubeculariidae, Miliolidae, *Nezzazata* sp., and ostracods.

This interval tops the sequence studied and it has been analysed in the first meters only. It indicates restricted settings affected by episodes of increased bottom energy, probably linked to tractive currents, as demonstrated by the plane-parallel laminations.

The mollusc fauna

Mauro Caffau and Mario Pleničar

The Visogliano sequence shows the occurrence of a rich mollusc fauna, characterized by *Chondrodonta joannae*, *Neithea fleuriausiana*, requienids (*Requienia* sp.), and, over all, radiolitids. The radiolitid fauna consist of six species: *Praeradiolites acutilamellosus* n. sp., *Praeradiolites* cf. *P. fleuriaus*, *Radiolites carsicus* n. sp., *Radiolites peroni*, *Sauwagesia sharpei*, *Durania acuticostata* n. sp.

Chondrodonta joannae, *Neithea fleuriausiana*, and requienids have been already signalled in the Karst of Trieste by several Authors in beds which are Cenomanian and/or Turonian in age, as reported by Forti and Masoli (1969). Recently, *Chondrodonta joannae* and *Neithea fleuriausiana* are reported as *Chondrodonta* and *Neithea*, respectively, and occur in the limestones of Borgo Grotta Gigante Member (Cucchi et al., 1987), meanwhile requienids have been signalled by Masoli and Ulcigrai (1969) and Cucchi et al. (1987) in black limestones of Aptian-Albian age.

Among the radiolitids, *Praeradiolites acutilamellosus*, *Radiolites carsicus*, and *Durania acuticostata* are considered new. Thus, these species have been signalled for the first time in the Karst of Trieste, meanwhile *Radiolites peroni* and *Sauvagesia sharpei* had already been signalled in the Turonian beds by Parona (1932) and in the Zolla Member by Cucchi et al. (1987), respectively. In addition, *Praeradiolites* cf. *P. fleuriausius* and *Radiolites carsicus* are also present in the Cenomanian of the Archi locality (Karst of Gorizia) by Caffau and Pleničar (1991).

All the radiolitid species are described in the following sections, where data concerning their morphology, stratigraphic distribution, and geographical diffusion are reported. Basic source for the stratigraphic and geographic data is Sánchez' catalogue (1981).

Family Radiolitidae Gray, 1848
 Subfamily Radiolitinae Gray, 1848
 Genus *Praeradiolites* Douvillé, 1902

Praeradiolites acutilamellosus n. sp.
 Pl. 1, figs. 1, 2, 3, 4; Pl. 2, figs. 1, 2, 3; Pl. 7, fig. 1

Derivation of name: The specific name *acutilamellosus* is due to large and strongly dissociated lamellae.

Type-series: Holotype, MCV 104 (Pl. 1, fig. 1). Paratype, MCV 105 (Pl. 1, fig. 2), deposited in the rudist collection of the Institute of Geology and Paleontology, University of Trieste.

Examined material: Lower valves of 15 specimens from MCV 104 to MCV 118, deposited in the rudist collection of the Institute of Geology and Paleontology, University of Trieste.

Type-locality: Visogliano (Vižovlje) near Sistiana (Sesljan).

Diagnosis: The right valve shows strong external lamellae turned towards the commissure and projecting outwards in correspondence of the cardinal zone (Pl. 2, fig. 2). A considerable variability characterizes the siphonal ridges which are protruding, flat (Pl. 1, figs. 1, 2) or rounded (Pl. 1, fig. 4; Pl. 2, fig. 1). The ridge "E" is wider than ridge "S". The interband is slightly concave; in its middle part it shows a weak rib, which does not appear in all the specimens. Where present, the rib is differently pronounced, mostly in the lower part of the valve. (Pl. 1, fig. 2; Pl. 2, fig. 2). The ligament ridge is thin. The valve layer is considerably broader in the cardinal zone than in the siphonal one.

Description: The valves are from 25 to 90 mm long, with a commissural diameter of 30–60 mm. The structure of the layer is characterized by parallel rows of rectangular prisms along the entire valve periphery, save for the siphonal zone where the rows of prisms bend and form a syncline-like arrangement (Pl. 7, fig. 1). External lamellae are both almost horizontal in correspondence of the cardinal side, and erected in the siphonal one.

Similarities and differences: *Praeradiolites acutilamellosus* resembles the species *Praeradiolites fleuriausius* (d'Orbigny), but it differs from the latter for the lack of foot fold "V".

Praeradiolites cf. *P. fleuriausius* (d'Orbigny, 1842)
 Pl. 4, fig. 4; Pl. 7, fig. 2

Examined material: Lower valves of 6 specimens; from MCV 120 to 125, deposited in the rudist collection of the Institute of Geology and Paleontology, University of Trieste.

Description: The lower valves are cylindrical-conical, from 40 to 70mm long, with commissural diameter of 30–39mm. The lower valve has strong and protruding lamellae. In the lower part of the valve, in correspondence with the foot fold “V”, the lamellae are pronouncedly inverted (Pl. 4, fig. 4). The siphonal zone is not entirely preserved in each valve examined. This part is damaged in all the specimens, and as a consequence, the species could not be exactly determined. Because of this, a dubitative taxonomic attribution is to be preferred. The celluloprismatic structure of the layer is very evident in cross section (Pl. 7, fig. 2). The layer is 1–2mm thick in the siphonal side, and 3–4mm in the cardinal one.

Stratigraphic distribution and geographic diffusion: Even if this species is dubitatively determined, we recall that *Praeradiolites fleuriaus* (d’Orbigny) is characteristic of Cenomanian. It may be found in Italy, Istria (Croatia), France and Romania.

Genus *Radiolites* Lamarck, 1801

Radiolites carsicus n. sp.

Pl. 3, figs. 1, 2, 3; Pl. 4, figs. 1, 2; Pl. 8, figs. 1, 2, 3

Derivation of name: The specific name *carsicus* is due to Karst of Trieste.

Type-series: Holotype, MCV 126 (Pl. 3, fig. 2). Paratype MCV 127 (Pl. 4, fig. 1); MCV 128 (Pl. 4, fig. 2), deposited in the rudist collection of the Institute of Geology and Paleontology, University of Trieste.

Examined material: Lower valves of 20 specimens; from MCV 126 to MCV 145, deposited in the rudist collection of the Institute of Geology and Paleontology, University of Trieste.

Type-locality: Visogliano (Vižovlje) near Sistiana (Sesljan).

Diagnosis: The lower valve is from 41 to 110mm long, abruptly narrowing towards the basis, ornamented with fine longitudinal ribs. The external lamellae are numerous and well expressed. They also pass through the siphonal region. The latter consists of two protruding siphonal ridges. In some specimens, the ridge “E” is slightly stronger than ridge “S”. The intersiphonal area is characterized by two different types of ornamentation. The most frequent ornamentation is constituted by three longitudinal ribs, which run along the shell, or by V-shaped protruding lamellae.

Description: Twenty lower valves have been studied. They are 40 to 112mm long, with a commissural diameter of 25–50mm. The shell is traversed by rounded and well expressed ribs interrupted by well developed neighbouring megacycles. The “E” siphonal band is rounded, protruding and similar to the “S” band. The interband consists of both three ribs, very similar to the others of the shell (Pl. 3, fig. 2) and by “V”-shaped lamellae (Pl. 4, figs. 1, 2). In a transversal section of the lower valve the siphonal zone shows a structure of pseudopillars. The “E” siphonal zone shows two small different-sized lobes, meanwhile the “S” zone presents only one prominent lobe (Pl. 8, figs. 1, 2). In cross section the cellular structure of the shell is evident (Pl. 8, figs. 1, 2, 3) The ligament ridge is triangular.

Similarities and differences: *Radiolites carsicus* n. sp. differs from *Radiolites lusitanicus* (Bayle) and *Radiolites trigeri* (Coquand) because of the siphonal area morphology. “E–S” bands are very protruding and rounded in *Radiolites carsicus* n. sp., while in the other mentioned species these bands are slightly pronounced and flattened.

Radiolites peroni (Choffat, 1886)

Pl. 4, fig. 3

1981 *Radiolites peroni* (Choffat) – Sánchez, p. 182 cum syn.

Examined material: Lower valves of 3 specimens, from MCV 29 to MCV 31, deposited in the rudist collection of the Geology and Paleontology Institute of Trieste university.

Description: The lower valves examined are from 30 to 45 mm long with a conical shape. The outer part of the shell consists of a series of protruding and neighbouring megacycles. The lamellae are traversed by wide longitudinal ribs which determine an undulating outline. The “E–S” bands are flattened, slightly protruding, and have similar sizes. The interband is concave and traversed by a pleat which vanishes towards the basis of the shell. The ligament ridge is small and triangular. The inner part of the layer shows a polygonal structure, which is sometimes seen as a quadrangular network. This effect should be due to oblique sections as reported by Alencaster and Pons (1992).

Stratigraphic distribution and geographic diffusion: *Radiolites peroni* (Choffat) is characteristic of Cenomanian. It may be found in Italy, Istria (Croatia), Portugal, France, Greece, Romania, Albania, Liban and Iran.

Subfamily Sauvagesiinae Douvillé, 1908

Genus *Sauvagesia* Bayle, 1887*Sauvagesia sharpei* (Bayle, 1857)

Pl. 5, fig. 1; Pl. 9, fig. 1.

1981 *Sauvagesia sharpei* (Bayle) – Sánchez, p. 202 cum syn.

Examined material: Lower valves of 6 specimens, from MCV 20 to MCV 25, deposited in the rudist collection of the Institute of Geology and Paleontology, University of Trieste.

Description: The lower valves are cylindrical-conical and slightly curved, crossed by thin longitudinal ribs. The valves are from 45 to 100 mm long with a commissural diameter of 25–50 mm. The “E” siphonal band is three times wider than the “S” one. Along the “E” band there are 17 thin ribs, and other 7 can be seen in the “S” band. The interband is concave. The triangular ligament ridge is wellpronounced. The shell structure is prismatic, consisting of hexagonal prisms (Pl. 9, fig. 1).

Stratigraphic distribution and geographic diffusion: *Sauvagesia sharpei* (Bayle) is characteristic of late Cenomanian-early Turonian. It may be found in Italy, Croatia, Portugal, Spain, France and Algeria.

Genus *Durania* Douvillé, 1908*Durania acuticostata* n. sp.

Pl. 5, figs. 2, 3; Pl. 6, figs. 1, 2; Pl. 9, fig. 2

Derivation of name: The specific name *acuticostata* is due to its ornamentation, characterized by strong and longitudinal costae.

Type-series: Holotype, MCV 4 (Pl. 6, figs. 1, 2). Paratype, MCV 5. (Pl. 5, fig. 3), deposited in the rudist collection of the Institute of Geology and Paleontology, University of Trieste.

Examined material: Lower valves of 15 specimens from MCV 1 to MCV 15, deposited in the rudist collection of the Institute of Geology and Paleontology, University of Trieste.

Type-locality: Visogliano (Vižovlje) near Sistiana (Sesljan).

Diagnosis: The lower valve is conical-cylindrical and characterized by a commissural diameter which is 0.5–1 times longer than the shell. 13–16 triangular and well pronounced costae run longitudinally along the thick shell. The “E” siphonal band area is flattened and traversed by 9–11 thin ribs while the “S” area shows 5–7 ones. A concave interband, as wide as the “S” band, is traversed by a protruding thin rib.

Description: These specimens are characterized by graceless lower valves, with a development in length once or twice the commissural diameter. In the correspondence with the commissure, the thickness of the layer varies from 6 to 10 mm, in the dorsal zone, and from 1 to 2.5 mm, in the ventral one (Pl. 9, fig. 2). The “E” and “S” siphonal band areas are flattened, slightly protruding, and located in the thinner part of the shell (ventral zone). The “E” band is three times wider than the “S” band. Both are separated by a concave 1.8 mm deep and 4 mm wide interband, traversed by a thin 0.4 mm wide and 0.6 mm high rib (Pl. 6, figs. 1–2). Thin sections of lower valves show the celluloprismatic structure of the shell. In addition, a great difference in thickness between the dorsal and ventral areas is evident. The former is thicker than the latter. The shell ornamentation consists of triangular and well pronounced ribs, with wide basis and acute apex. The distance between the ribs corresponds to the width of each rib.

Similarities and differences: *Durania acuticostata* n. sp. presents significant differences with respect to all the species of this genus so far described in literature, mainly for the morphology of siphonal area (presence of a concave interband) and the shell ornamentation (strong and longitudinal costae).

Discussion

Save for the interval 1, which should be generically attributed to middle-late Cenomanian for the presence of *Chrysalidina gradata* (Pl. 10, fig. 1), in agreement with De Castro (in Schroeder & Neumann, 1985), the Visogliano sequence can be entirely attributed to late Cenomanian p.p. This chronological attribution is due to *Broeckina balcanica* (Pl. 10, figs. 2, and 3), which is present in all the Visogliano sequence, and over all to *Chondrodonta joannae* and *Neithea fleuriausiana*. Really, the foraminiferal species is considered as middle-late Cenomanian in age by Cherchi and Schroeder (in Schroeder & Neumann, 1985), meanwhile the molluscs are considered as late Cenomanian in age by Dhondt and Dieni (1993). In agreement with the above described data, it is possible to refine the previous chronological attribution of the majority of the lower part of the Zolla Member by dating back it from Cenomanian-Turonian to late Cenomanian p.p.

Thus, the previously described environmental evolution mainly occurs during the late Cenomanian p.p. Within a frame of an evolution of restricted settings, it is possible to record a very important biological event: the development of the mollusc fauna and, particularly, of the radiolitids. Really, after a first very brief appearance of requienids within the Aptian-Albian limestones of the Monte Coste Member, the molluscs found in the Visogliano sequence are able to colonize the substrates.

In the Visogliano sequence, the development of the mollusc fauna begins with the occurrence of two radiolite species, such as *Praeradiolites* cf. *P. fleuriaus* and *Sauwagesia sharpei*, in the interval 1. This colonization is interrupted several times, as recorded in the dolostones of the interval 1, the bioclastic high bottom energy limestones of the interval 2, and in the dolostones and bioclastic limestones of the interval 3. Thus, the above cited radiolite species are able to colonize the substrate in the scattered way, only in correspon-

dence with the favourable environmental conditions, probably linked to restricted rather than very restricted settings. In the intervals 3 and 4, the specimens of *Chondrodonta joannae* begin colonizing the substrate with their lamellar shells. The succession of several generations of shells of *Chondrodonta joannae* is recorded in the thick build-up of the interval 4 and testifies their builders' activity. This action is again interrupted in the interval 5, in correspondence with the dolomitic limestones of very restricted environment. In the interval 6, several radiolitid species (*Radiolites carsicus* n. sp., *Radiolites peroni*, *Praeradiolites acutilamellosus* n. sp., *Praeradiolites* cf. *P. fleuriausius*, *Sauvagesia sharpei*, and *Durania acuticostata* n. sp.), *Chondrodonta joannae*, and rare specimens of *Neithea fleuriausiana* occur probably in relation to a change from very restricted to restricted environment. Such molluscs take advantage of this situation and begin again colonizing the substrate with specimens of *Chondrodonta joannae* and radiolitid elevators (Pl. 11, fig. 1; sensu Skelton, 1978, 1985). As soon as these forms have prepared a sufficiently coherent substrate, successive radiolitids, i.e. the encrusters (Pl. 11, fig. 2; sensu Skelton, 1978, 1985), appear and settle on the previous shells.

Among the radiolitids, the elevators are more frequent with respect to the encrusters. The elevators are able to aggregate in monospecific clusters mainly consisting of *Radiolites carsicus* n. sp. or *Praeradiolites acutilamellosus* n. sp. These clusters consist of up to 10 specimens, which present thick, well ornamented, cylindrical-conical, straight, more or less equal in size shells, with neighbouring megacycles. This shell morphology corresponds to an increased sedimentation and a decreased bottom energy. Other elevators present an individual development; they are characterized by very flattened ornamentations, such the megacycles in *Praeradiolites acutilamellosus* n. sp., or by conical shapes with broad basis in correspondence with the commissure, as present in *Sauvagesia sharpei*. These ornamentations and shapes represent adaptive strategies to avoid the burial. The encrusters always show an individual development and are represented by small specimens from 29 to 40 mm in size.

The following intervals show a probably local decline of the radiolitid fauna, probably due to an increased bottom energy (limestones of the intervals 7, and 9), with an interbedded period of very restricted conditions (dolomitic limestones of the interval 8).

In conclusion, the molluscs found in the Visogliano sequence are represented by a number of species, which is the highest of all the outcrops hitherto examined within the Zolla Member. Among them, three radiolitid species are described as new (*Praeradiolites acutilamellosus*, *Radiolites carsicus*, and *Durania acuticostata*).

It is also possible to underline the role of both *Chondrodonta joannae* and the elevators in preparing the substrate for the life of successive molluscs and for their builders' activity. In addition, among the radiolitids, it is also possible to consider *Praeradiolites* cf. *P. fleuriausius* and *Sauvagesia sharpei*, which are able to tolerate a continuous shifting from restricted to very restricted environment (interval 1), as pionier species in colonizing the environment. Thus, they can be considered as opportunistic species. Other radiolitids species (*Radiolites carsicus* n. sp., *Radiolites peroni*, *Praeradiolites acutilamellosus* n. sp., and *Durania acuticostata* n. sp.) appear successively and probably indicate stabler environmental conditions with respect to the previous ones. With respect to the tolerance of environmental changes, this can suggest a possible hierarchy of radiolitids from the most tolerant (*Praeradiolites* cf. *P. fleuriausius* and *Sauvagesia sharpei*) to the least tolerant (*Radiolites carsicus* n. sp., *Radiolites peroni*, *Praeradiolites acutilamellosus* n. sp., and *Durania acuticostata*). This hierarchy will have to be tested and, if verified, enlarged in further studies on rudist communities of the Karst area.

Acknowledgements

We gratefully acknowledge geom. Marino Caffau for finding the fossiliferous area. We also thank Marjan Grm for the photographic job and Dr. Maria Ines Gutierrez and Dr. Simon Pirč for helping with the translation of the text. Research is supported by 40 % and 60 % MURST Programs (1992), directed by G. Longo Salvador and N. Pugliese, respectively, and with the grant of the Ministry for Science and Technology of the Rep. Slovenia and of the Slovene Academy of Sciences and Arts.

References

- Alencaster, G. & Pons, J. M. 1992: New observation on the Upper Cretaceous rudist of Chiapas. – Comparison between american and european fauna and taxonomic implications 28, 327–339, 1 fig., 2 pls., Roma.
- Caffau, M. & Pleničar, M. 1991: Rudistid fauna from Turonian deposits of the locality Archi/Moščenice in the surroundings of Duino (Karst of Trieste). – *Razprave SAZU* 4. razreda 32 (8), 259–315, 4 figs., 16 pls., Ljubljana.
- Colizza, E., Costa, R., Cucchi, F., Knezaurek, G., Pirini Radrizzani, C., Pugliese, N., Ulcigrai, F. & Zucchi Stofa, M. L. 1987: The geology of the San Pelagio area (Karst of Trieste, Italy). – *Mem. Soc. Geol. It.* 40, 45–51, 6 figs., Trieste.
- Cucchi, F., Melis, R., Pallini, M., Pirini Radrizzani, C., Pugliese, N. & Ulcigrai, F. 1986: Il passaggio Cenomaniano-Turoniano nell'area di Monrupino (Carso Triestino). – *Quad. Mus. Geol. Paleont. Monfalcone, num. spec.* 13–24, 11 figs., Monfalcone.
- Cucchi, F., Pirini Radrizzani, C. & Pugliese, N. 1987: The carbonate stratigraphic sequence of the Karst of Trieste (Italy). – *Mem. Soc. Geol. It.* 40, 35–44, 1 fig., 2 tabs., Trieste.
- Dhondt, A. V. & Dieni, I. 1993: Non-rudistid bivalves from late Cretaceous rudist limestones of NE Italy (Col dei Schiosi and Lago di S. Croce areas). – *Mem. Sc. geol.* 45, 165–241, 18 text-figs., 20 pls., 1 tab., Padova.
- Forti, F. & Masoli, M. 1969: Comparazioni cronostatigrafiche delle formazioni carbonatiche del Carso Triestino. – *Boll. Bibl. e dei Mus. Civ. e delle Biennali d'arte antica*, 1–23, Udine.
- Masoli, M. & Ulcigrai, F. 1969: Termini Albiani della serie stratigrafica del Carso Triestino. – *St. Trent. Sc. Nat., Sez. A* 46, 65–91, Trento.
- Parona, C. F. 1932: Fauna cretacea di Aurisina (Trieste). – *Giornale di Geologia*, ser. 2, vol. 7, 405–421, Bologna.
- Polšak, A. 1979: Upper Cretaceous beds of the Northwestern part of Outer Dinarides (Lika, Croatian littoral and Istria). – 16th *Europ. Micropaleont. Coll.*, 101–106, Ljubljana.
- Schroeder, R. & Neumann, M. 1985: Les grands foraminifères du Crétacé moyen de la région méditerranéenne. – *Geobios, Mém.* 7 spécial, 1–161, 68 pls., Lyon.
- Sánchez, M. V. 1981: Hippuritidae y Radiolitidae (Bivalvia). – *Catalogo de especies.* – Univ. aut. Barcelona, pub. de geologia 15, 1–228, Barcelona.
- Skelton, P. W. 1978: The evolution of functional design in rudist (Hippuritacea) and its taxonomic implication. – *Phil. Trans. R. Soc. London.* 284a, 305–318, 1 pl., 8 figs., London.
- Skelton, P. W. 1985: Preadaptation and evolutionary innovation in rudist bivalves. – *Spec. Pap. Paleont.* 33, 159–173, 2 pls., 3 figs., London.

Plate 1 - Tabla 1*1, 2 Praeradiolites acutilamellosus* n. sp.

Ventral side view of holotype (fig. 1) and paratype (fig. 2). The straight and protruding E-S siphonal bands can be seen ($\times 1$). Visogliano. Samples MCV 104 (holotype) and MCV 105 (paratype)

Pogled na ventralno stran holotipa (sl. 1) in paratipa (sl. 2). Vidimo ravni in štrleči sifonalni progi E-S ($\times 1$). Vižovlje. Primerka MCV 104 (holotip) in MCV 105 (paratip)

3 Praeradiolites acutilamellosus n. sp.

Lateral view ($\times 1$). Visogliano. Sample MCV 111
Pogled od strani ($\times 1$). Vižovlje. Primerek MCV 111

4 Praeradiolites acutilamellosus n. sp.

Ventral side view. The E-S siphonal bands are rounded and protruding ($\times 1$). Visogliano. Sample MCV 112
Ventralna stran. Sifonalni progi E-S sta zaobljeni in štrleči ($\times 1$). Vižovlje. Primerek MCV 112

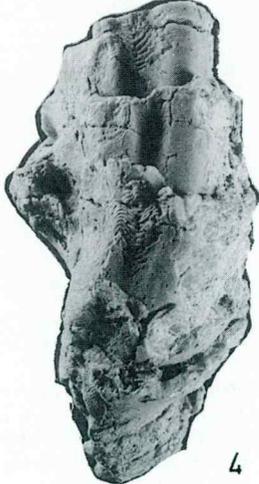


Plate 2 – Tabla 2

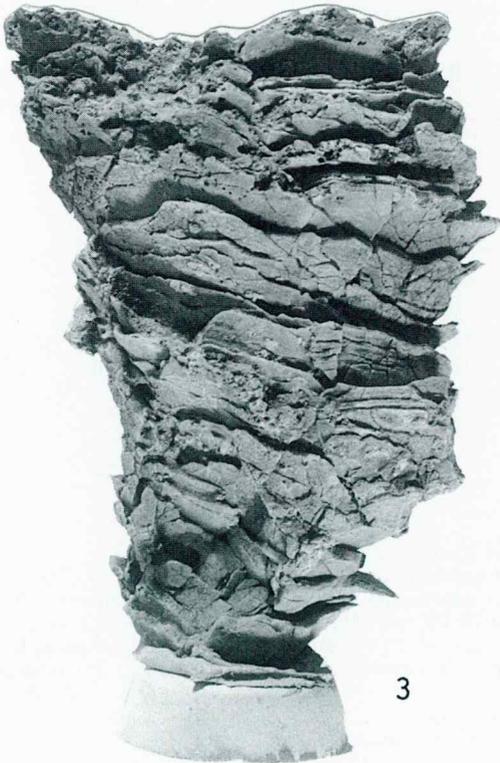
- 1 *Praeradiolites acutilamellosus* n. sp.
Ventral side view. The rounded E–S siphonal bands can be seen (× 1). Visogliano. Sample MCV 113
Ventralna stran. Vidni sta zaobljeni sifonalni progi E–S (× 1). Vižovlje. Primerek MCV 113
- 2 *Praeradiolites acutilamellosus* n. sp.
Protruding and flattened E–S siphonal bands (× 1). Visogliano. Sample MCV 114
Štrleči in sploščeni sifonalni progi E–S (× 1). Vižovlje. Primerek MCV 114
- 3 *Praeradiolites acutilamellosus* n. sp.
Lateral view. The neighbouring megacycles can be seen (× 1). Visogliano. Sample MCV 107
Pogled od strani. Vidijo se sosednji megacikli na lupini (× 1). Vižovlje. Primerek MCV 107



1



2



3

Plate 3 - Tabla 3*1, 2 Radiolites carsicus* n. sp.

Ventral side view of holotype (fig. 2) and paratype (fig. 1). The E-S siphonal bands are seen as rounded and protruding ribs. The interband is traversed by three ribs ($\times 1$). Visogliano. Samples MCV 127 and MCV 128

Ventralna stran holotipa (sl. 2) in paratipa (sl. 1). Sifonalni progi E-S sta zaobljeni štrleči rebri. V medsifonalni coni potekajo tri podolžna rebra ($\times 1$). Vižovlje. Primerka MCV 127 in MCV 128

3 Radiolites carsicus n. sp.

Ventral side view ($\times 1$). Visogliano. Sample MCV 131

Ventralna stran ($\times 1$). Vižovlje. Primerek MCV 131

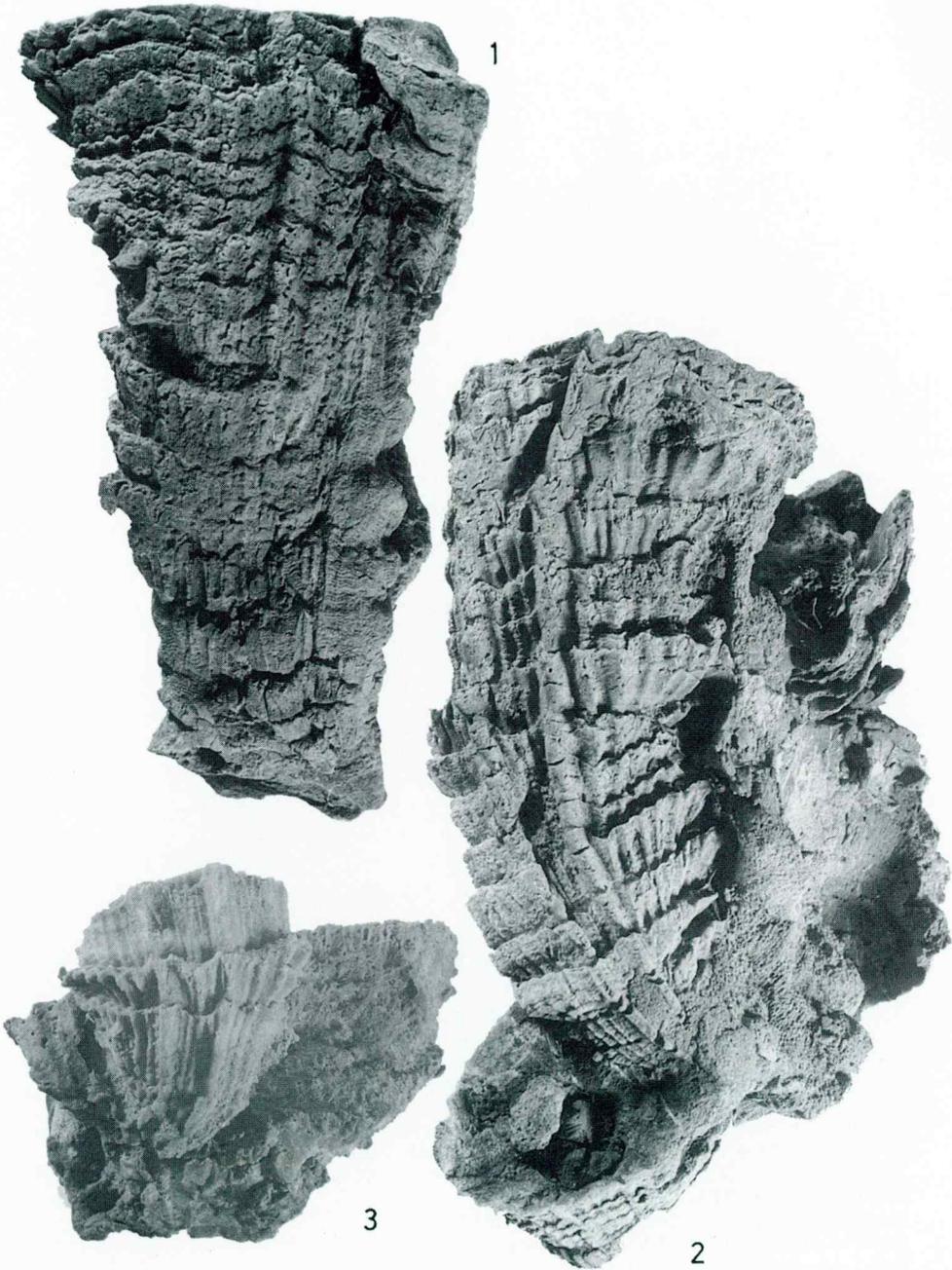


Plate 4 - Tabla 4**1, 2** *Radiolites carsicus* n. sp.

Ventral side view of two specimens. The protruding and rounded E-S siphonal bands, and the V - shaped interband can be seen ($\times 1$). Visogliano. Samples MCV 129 and MCV 130
Ventralna stran dveh vzorcev. Vidimo štrleči in zaobljeni sifonalni progji E-S in med-sifonalno cono v obliki črke V ($\times 1$). Vižovlje. Primerka MCV 129 in MCV 130

3 *Radiolites peroni* (Choffat)

Ventral side view. The E-S siphonal bands are flattened and protruding. The interband is traversed by a rib ($\times 1$). Visogliano. Sample MCV 24
Ventralna stran. Sifonalni progji sta sploščeni in štrleči. Na med-sifonalni coni je podolžno rebro ($\times 1$). Vižovlje. Primerka MCV 24

4 *Praeradiolites* cf. *P. fleuriaus* (d'Orbingny)

Lateral view of foot fold V ($\times 1$). Visogliano. Sample MCV 121
Lateralna stran z nožno gubo V ($\times 1$). Vižovlje. Primerka MCV 121



Plate 5 – Tabla 5

- 1 *Sauwagesia sharpei* (Bayle)
Ventral side view (× 1). Visogliano. Sample MCV 21
Ventralna stran (× 1). Vižovlje. Primerek MCV 21
- 2 *Durania acuticostata* n. sp.
Ventral side view. The E and S siphonal areas are wide, flattened and slightly protruding (× 1). Visogliano. Sample MCV 2
Ventralna stran. Sifonalni progi E in S sta široki, sploščeni in rahlo štrleči (× 1). Vižovlje. Primerek MCV 2
- 3 *Durania acuticostata* n. sp.
Lateral view. The ornamentation characterized by strong and triangular costae can be seen (× 1). Visogliano. Sample MCV 5
Lateralna stran. Značilna ornamentacija so močna trikotna rebra (× 1). Vižovlje. Primerek MCV 5

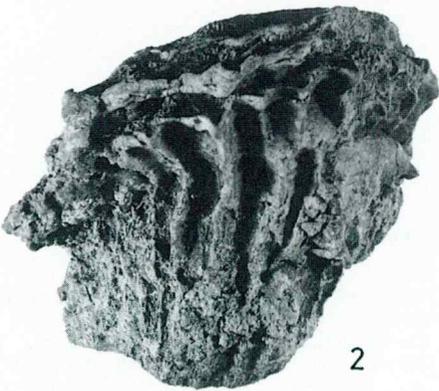
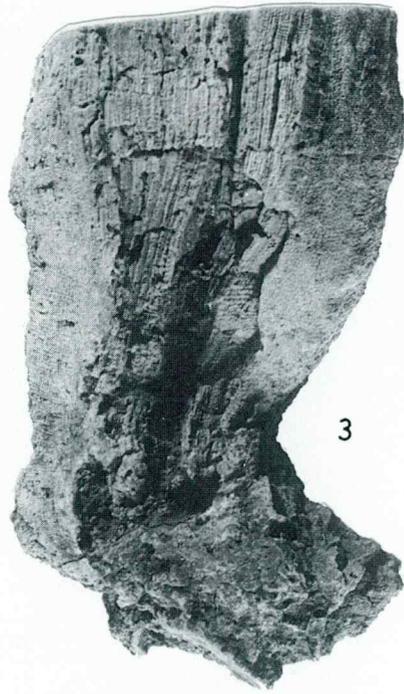
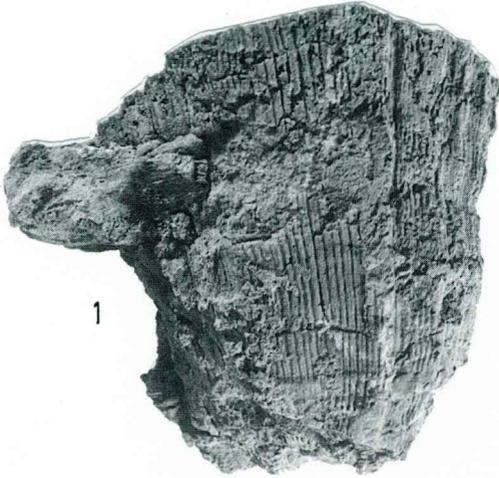


Plate 6 - Tabla 6*1, 2 Durania acuticostata* n. sp.

Holotype. Ventral (fig. 1) and dorsal view (fig. 2) of the same specimen. The E-S siphonal areas traversed by thin ribs, and the concave interband with a thin rib (fig. 1) and longitudinal costae (fig. 2) can be seen ($\times 1$). Visogliano. Sample MCV 12

Holotip. Ventralna (sl. 1) in dorzalna (sl. 2) stran istega primerka. Čez sifonalni progi E-S potekajo tenka rebra, vidimo pa tudi konkavno medsifonalno cono s tenkim rebrom (sl. 1) in še z več drobnimi rebri ($\times 1$). Vižovlje. Primerek MCV 12

3 Neithea fleuriausiana (d'Orbigny)

Left valve ($\times 1$). Visogliano. Sample MCV 22b

Leva lupina ($\times 1$). Vižovlje. Primerek MCV 22b

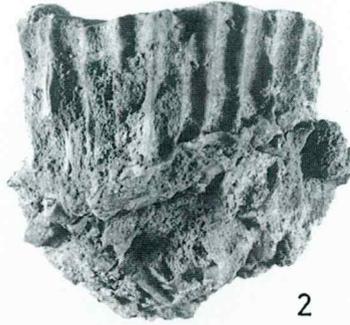
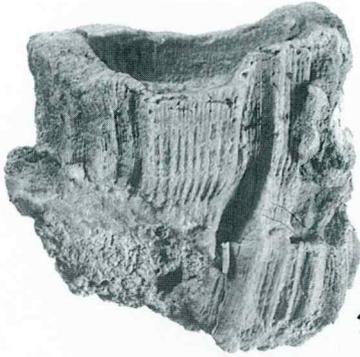


Plate 7 – Tabla 7**1** *Praeradiolites acutilamellosus* n. sp.

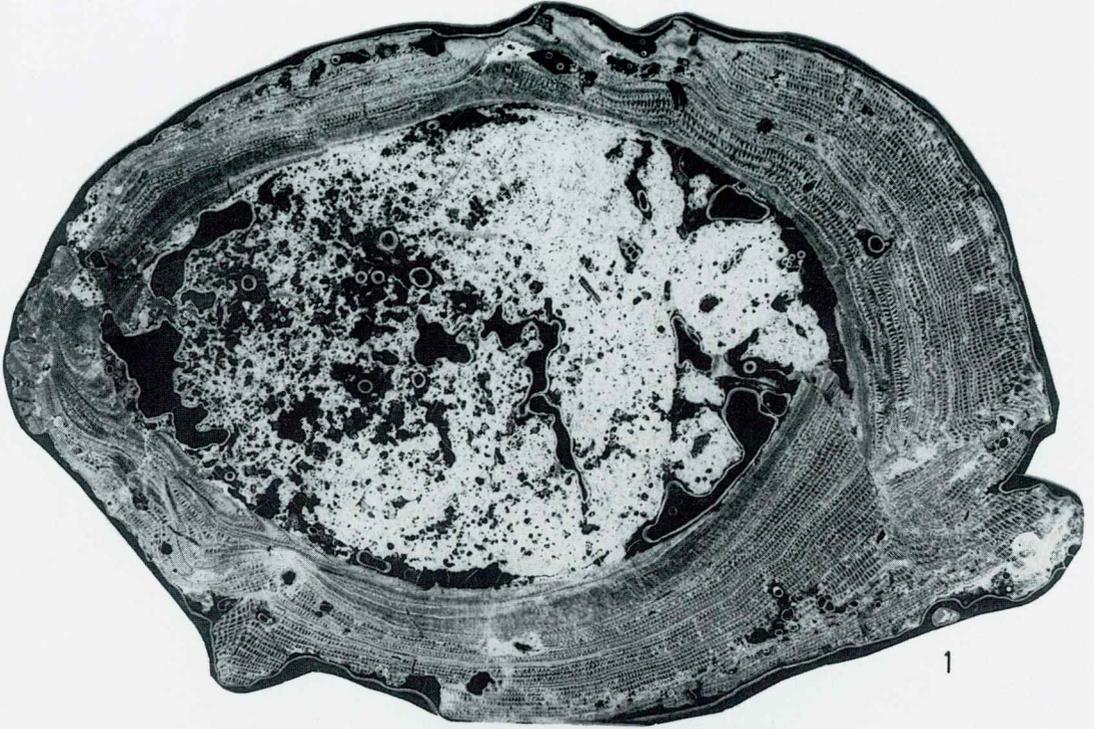
Transversal thin section showing the celluloprismatic structure. In the siphonal area, the prisms form a syncline-like arrangement. Visogliano. The length of the bar at the bottom of the table corresponds to 10mm

Prečni presek (zbrusek) kaže celulo-prizmatično strukturo lupine. V sifonalni coni so prizme razporejene v obliki sinklinale. Vižovlje. Dolžina črtice spodaj ustreza dolžini 10mm

2 *Praeradiolites* cf. *P. fleuriausius* (d'Orbigny)

Transversal thin section showing the celluloprismatic structure. Visogliano. The length of the bar at the bottom of the table corresponds to 10mm

Prečni presek (zbrusek) kaže celulo-prizmatično strukturo lupine. Vižovlje. Dolžina črtice spodaj ustreza dolžini 10mm



1



2

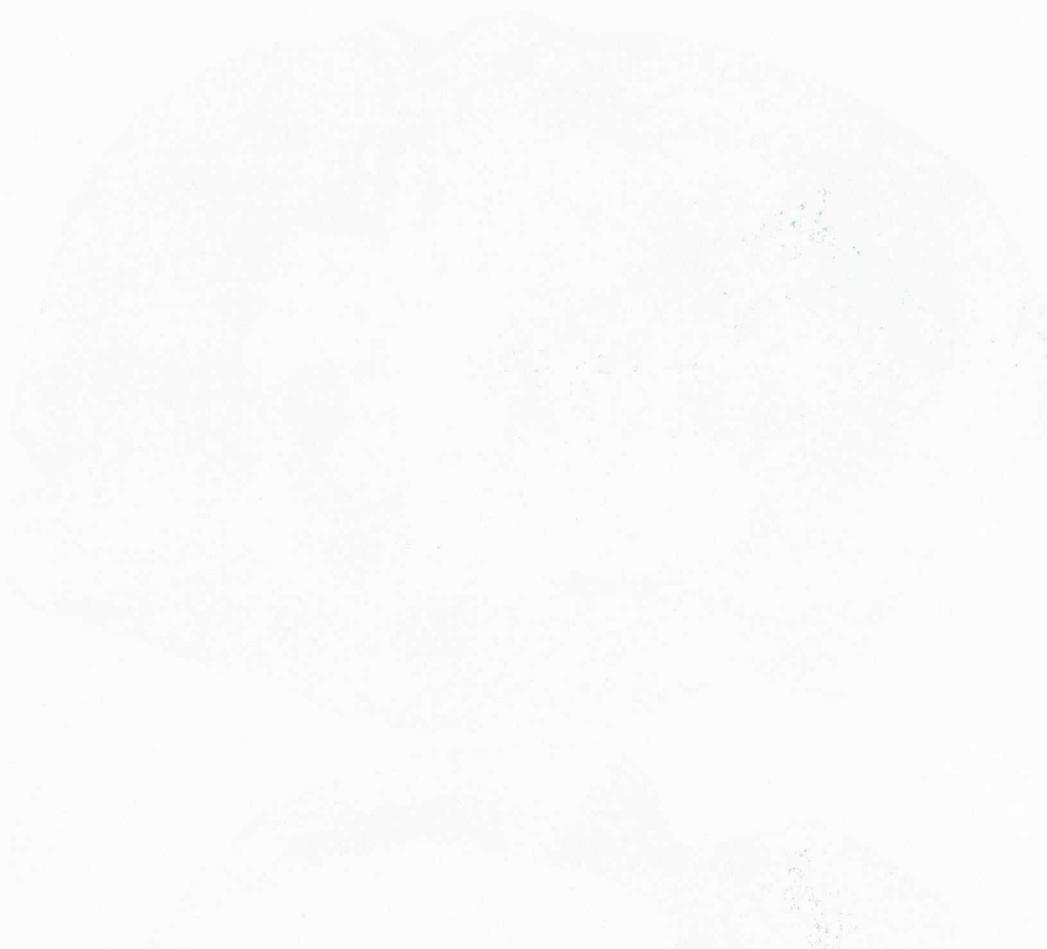


Plate 8 - Tabla 8

1, 2 Radiolites carsicus n. sp.

Transversal thin section of three specimens showing the celluloprismatic structure. The siphonal structure E is seen as a double radial band and S structure as one radial band (magnification of fig. 1 - $\times 2,5$, and fig. 2 - $\times 3,5$). Visogliano

Prečni preseki (zbruski) treh primerkov kažejo celulo-prizmatično strukturo. Struktura lupine v sifonalni coni E je podobna dvojni radialni progji, v sifonalni coni S pa enojni radialni progji (povečava sl. 1 - $\times 2,5$ in sl. 2 - $\times 3,5$). Vižovlje

3 Radiolites carsicus n. sp.

Transversal thin section showing a celluloprismatic structure. The structures of E-S siphonal bands differs from those of figs. 1, 2 because the section is not perfectly transversal to the development of the specimen. Visogliano. The length of the bar at the bottom corresponds to 10mm

Prečni presek (zbrusek) spodnje lupine kaže celulo-prizmatično strukturo. Strukturi sifonalnih prog E-S se ločita od struktur na slikah 1, 2, ker presek na sliki 3 ni popolnoma pravokoten na glavno os primerka. Vižovlje. Dolžina črtice spodaj ustreza dolžini 10mm

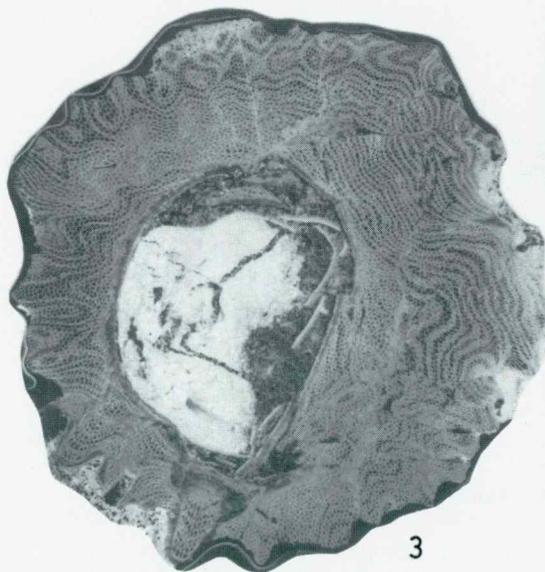




Plate 9 – Tabla 9

1 Sawagesia sharpei (Bayle)

Transversal thin section showing the celluloprismatic structure ($\times 2$). Visogliano
Prečni presek (zbrusek) spodnje lupine kaže celulo prizmatično strukturo ($\times 2$). Vižovlje

2 Durania acuticostata n. sp.

Transversal thin section the lower valve showing the celluloprismatic structure ($\times 2$). Visogliano
Prečni presek (zbrusek) spodnje lupine kaže celulo prizmatično strukturo ($\times 2$). Vižovlje

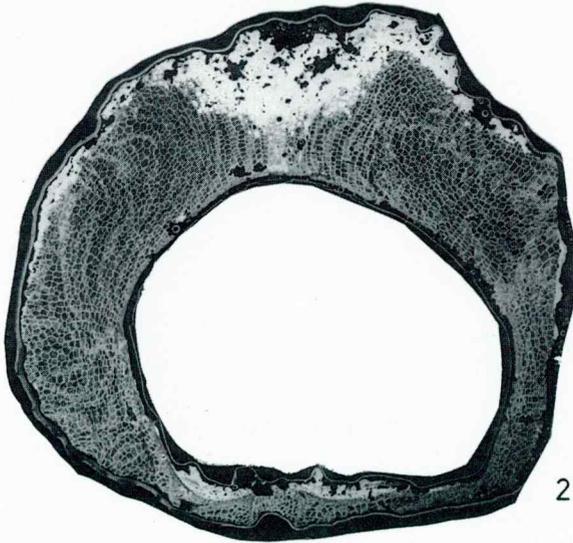
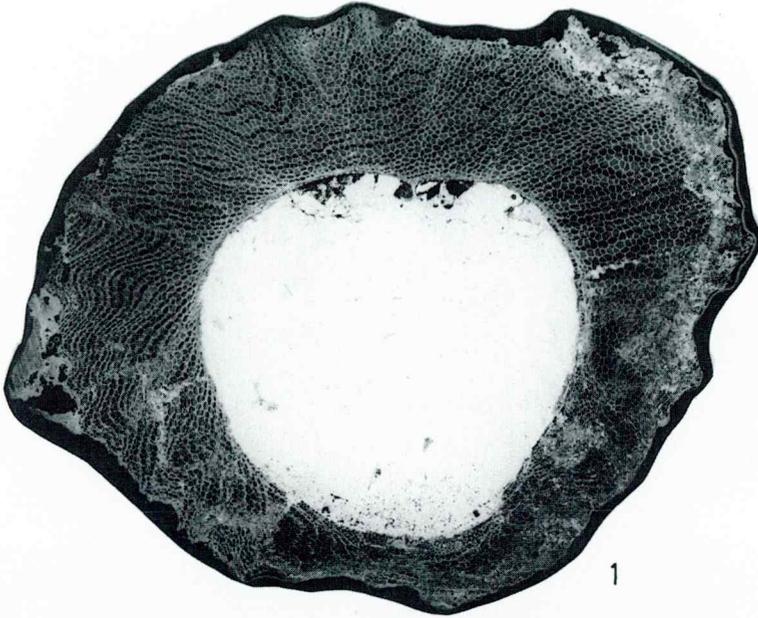
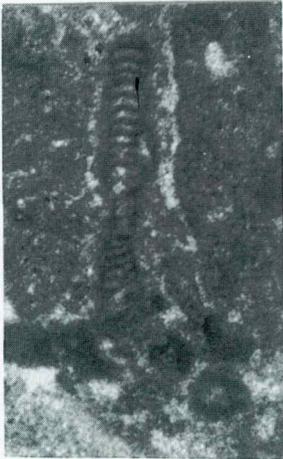


Plate 10 - Tabla 10

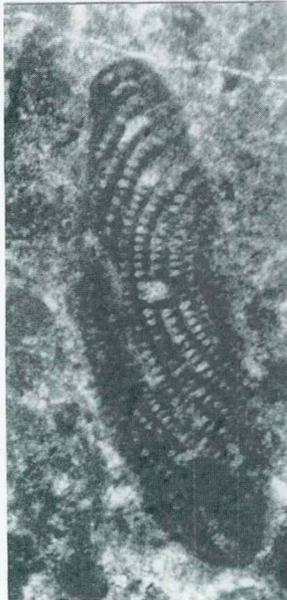
- 1 *Chrysalidina gradata* (× 38)
Interval 6 of the Visogliano sequence
Interval 6 stratigrafskega zaporedja pri Vižovljah
- 2, 3 Some sections of *Broeckina balcanica* (× 58)
Interval 6 of the Visogliano sequence
Nekaj presekov vrste *Broeckina balcanica* (× 58)
Interval 6 stratigrafskega zaporedja pri Vižovljah



1



2



3

Plate 11 – Tabla 11

- 1 Monospecific cluster of *Praeradiolites acutilamellosus* n. sp. consisting of specimens developed as elevators (× 1). Visogliano
Monospecifični skupek rudistov vrste *Praeradiolites acutilamellosus* n. sp., razvit kot elevator (× 1). Vižovlje
- 2 Specimens of *Praeradiolites acutilamellosus* n. sp. (signed by the arrow) encrusted on the shell of a shell of *Radiolites carsicus* n. sp. (× 1). Visogliano
Primerki vrste *Praeradiolites acutilamellosus* n. sp. (označeni s puščico), prirasli (inkrustirani) na lupini vrste *Radiolites carsicus* n. sp. (× 1). Vižovlje

