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Biostratigraphy of Turonian to (?)Coniacian Platform Carbonates: A Case Study from the Island of Cres (Northern Adriatic, Croatia)

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Key words: Adriatic Carbonate Platform, Turonian, Coniacian, Rudists, Benthic foraminifera, Island of Cres, Croatia.

Abstract

The shallow marine carbonate deposits on the island of Cres, overlying deeper-water Cenomanian–Turonian limestones, are characterized by an assemblage of rudists, benthic foraminifera, and associated microfossils. The paucispecific character of the fossil association suggests deposition in shallow areas of a carbonate platform, with low current-energies and restricted circulation. Similar assemblages indicating similar palaeoenvironments, are common in the Upper Cretaceous deposits of the Adriatic Carbonate Platform and adjacent areas.

The assemblage of rudists (hippuritids) and microfossils indicate the Turonian to (?)Coniacian age of the investigated carbonate succession. The biostratigraphic importance of the so-called "primitive" hippuritids within the micropalaeontologically poorly defined biostratigraphy of deposits of this age, is accentuated.

1. INTRODUCTION

The Croatian island of Cres is situated in the northern part of the Adriatic Sea (Fig. 1). It is built up of predominantly Cretaceous carbonates, although there are some minor scattered outcrops of Palaeogene deposits (POLŠAK, 1967a; MAGAŠ, 1968; MAMUŽIĆ, 1968; ŠIKIĆ et al., 1969). A succession of Lower Cretaceous carbonates, approximately 800 m thick, ranges in age from the early Neocomian to the latest Albian, and is characterized by shallow-marine deposits sporadically interrupted by minor emersion horizons (FUČEK et al., 1995). Major facies differentiation took place during the Cenomanian (HUSINEC et al., 2000; KORBAR et al., 2001), as shown by lateral changes from peritidal restricted facies with radiolitid bouquets, via marginal coarse-grained bioclastic facies predominantly with recumbent rudists (ichthyosarcolitids and caprinids) to deeper-water calcisphaerulid facies.

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From the fossil association studied by them, previous authors (POLŠAK, 1967a; MAGAŠ, 1968; MAMUŽIĆ, 1968; ŠIKIĆ et al., 1969; MAMUŽIĆ et al., 1982) considered the youngest Cretaceous deposits on the island of Cres to be of Cenomanian–Lower Turonian age. However, that association is now considered to be restricted to the Cenomanian (GUŠIĆ & JELASKA, 1990). Later, JELASKA et al. (1994) proposed that sedimentation was interrupted close to the Cenomanian–Turonian boundary and that the gap lasted until the Eocene (Lutetian) transgression.

In contrast to the NE part of the island, where the youngest strata below the regional K–T emersion horizon are of Cenomanian age, deposition continued in the SW part into the post-Cenomanian (KORBAR, 1999; KORBAR et al., 2001; KORBAR & HUSINEC, 2002).

The aim of this paper is to describe the fossil assemblage in the youngest Cretaceous carbonate deposits on the island of Cres, as well as to interpret the age and depositional palaeoenvironment of the investigated strata. The boundary between these and the underlying Cenomanian–Turonian deeper-water limestones is marked by a fault. Nevertheless, field investigations indicated that no significant relative vertical displacement has occurred between these two limestone packages.

An approximately 70 m thick succession situated west of the village of Martinšćica was sampled and analysed (Fig. 2), and its palaeoenvironments and fossil assemblages are described here. The succession defines a lithostratigraphic unit of post-Cenomanian deposits occupying exclusively the southwestern part of the island (see location map, Fig. 1). Several samples containing embedded hippuritids were also collected from deposits belonging to the unit (sampling points CI, CL and CN; Fig. 1). On the basis of detailed geological mapping of the area and micropalaeontological analyses of the samples, the deposits represent laterally equivalent strata of the same age and depositional environment as those analysed at the Martinšćica section.

The morphotype nomenclature and terminology for rudist bivalves, e.g. "elevator", "recumbent", "bouquet", "cluster", is used according to the scheme of SKELTON & GILI (1991), summarised by ROSS &

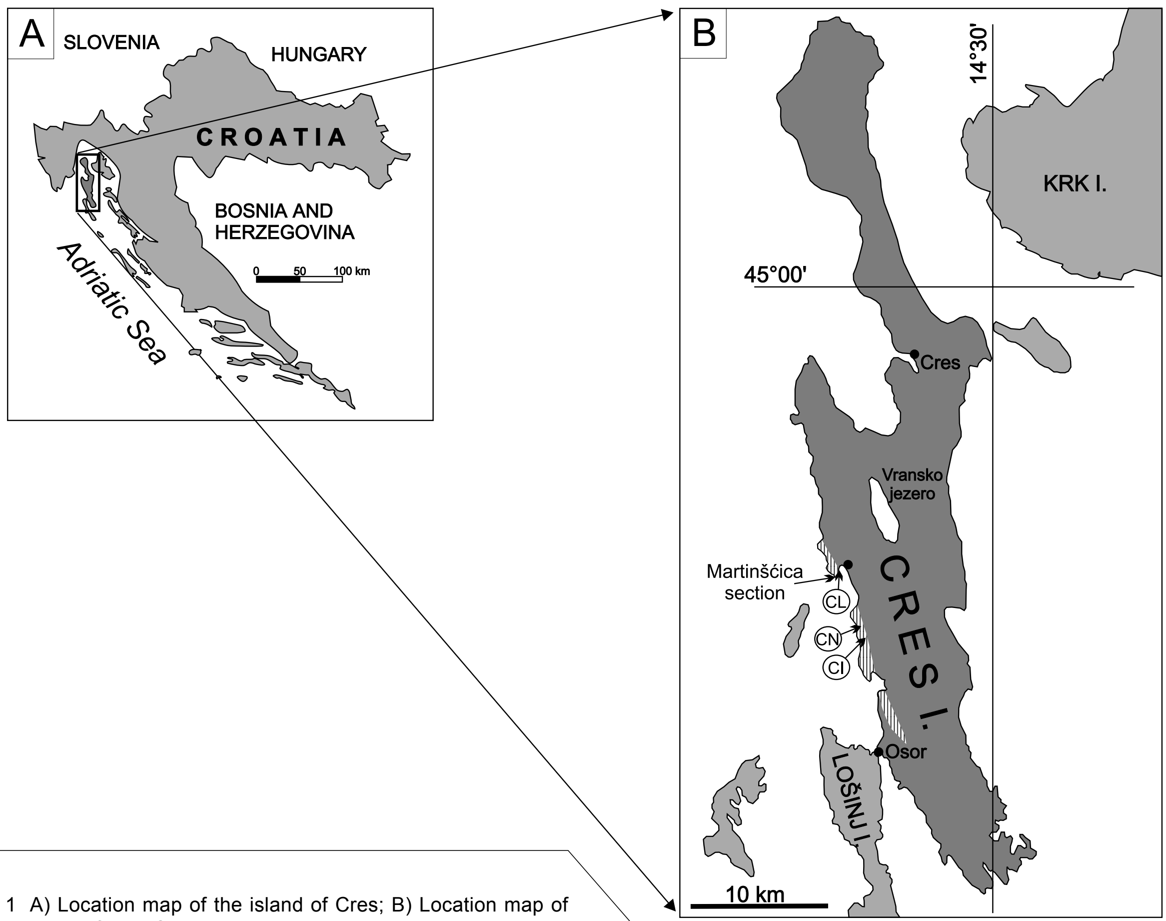

Fig. 1 A) Location map of the island of Cres; B) Location map of the area of post-Cenomanian deposits outcrops (hatched), the sampling points and the Martinšćica section (arrows).

SKELTON (1993). Since radiolitids are poorly preserved and of minor biostratigraphic value, only several hippuritid specimens were analysed.

2. PALAEOENVIRONMENTS

The strata investigated are characterized by predominantly mud-rich limestones with numerous specimens of *Aeolisaccus* and *Thaumatoporella* (Pl. II, Figs. 5, 6). The paucispecific character of the fossil association suggests deposition in shallow areas of the carbonate platform, with low current-energies and restricted circulation. Contrary to the older mid-Cretaceous shallow-water limestones that yield several important cosmopolitan foraminiferal index taxa of the family Orbitolinidae (HUSINEC et al., 2000; HUSINEC, 2001), the post-Cenomanian strata contain a low-diversity association. However, the association implies that following the deposition of the deeper-water limestones that characterize the underlying succession, the environment again became favourable for population by larger foraminifera and, sporadically, rudists.

Rudist bivalves are the most frequent macrofossils within the strata investigated. Radiolitids (Radiolitidae) have been found both in autochthonous (*in situ* bouquets, clusters and small lenticular thickets) or para-autochthonous position (displaced locally in the vicinity of their habitats). Rare hippuritids (Hippuritidae) have been found in bouquets characterized by three to four conjoined specimens. In the vicinity of the village of Martinšćica (Martinšćica section, Fig. 2), thick-bedded peritidal limestones (Pl. I, Fig. 1) contain some radiolitid clusters and thickets (biostromes) sporadically including hippuritids. Radiolitids commonly occur in the uppermost part of some beds (Pl. I, Fig. 4). Minor subaerial exposure surfaces are also common at the tops of some beds. Solitary hippuritids (elevators) or small hippuritid bouquets (sample CN–864d contains an embedded bouquet of 4 hippuritid specimens – Pl. I, Fig. 7) were found within subtidal mud-rich limestones.

Depositional environments were similar to those characterized by the Turonian to Upper Santonian limestones of neighbouring southern Istria (MORO, 1997; VLAHOVIĆ et al., 2002). Thus, the carbonate platform regime was re-established in the area during the Middle Turonian, following the Cenomanian/Turo-

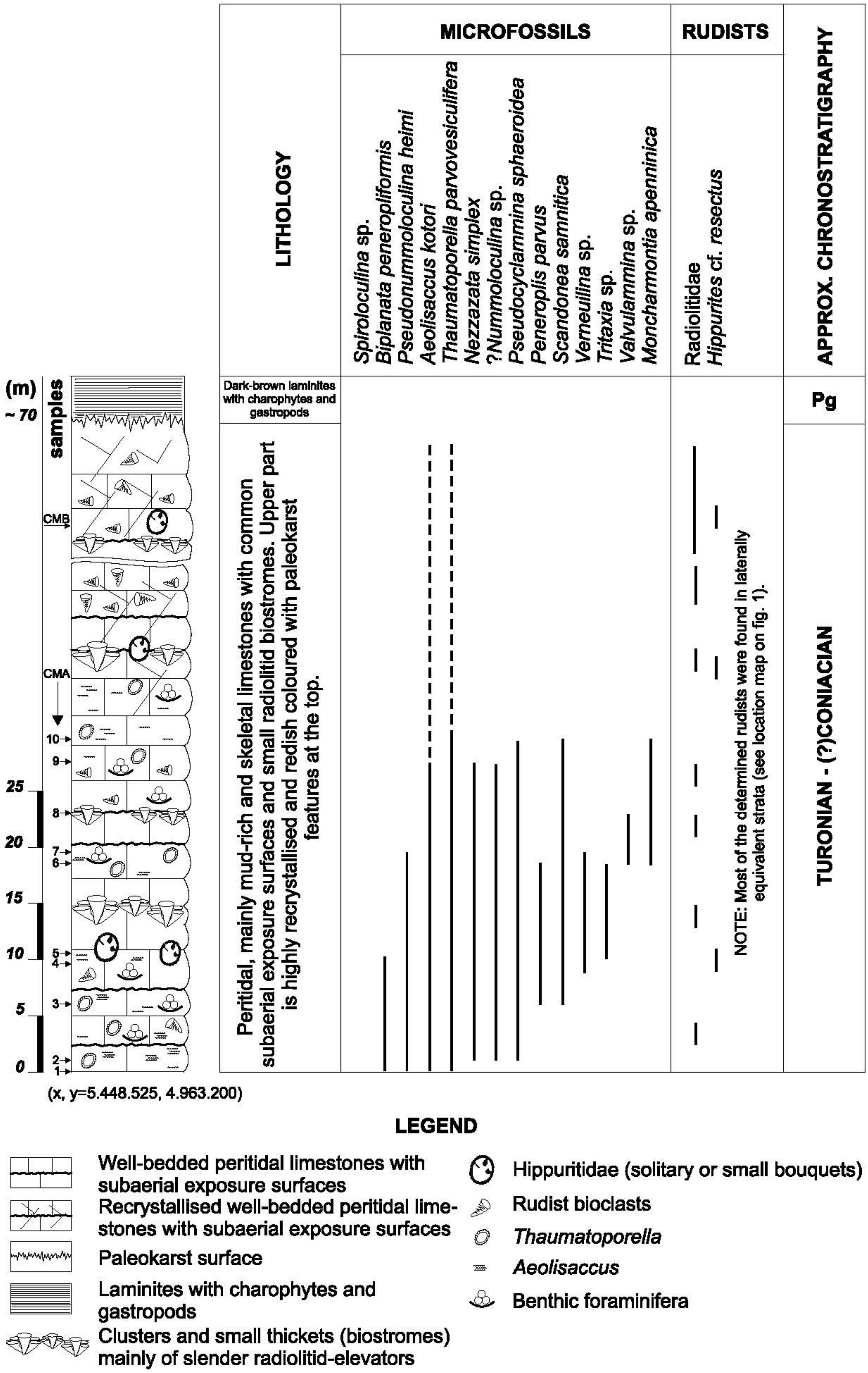

Fig. 2 Stratigraphic distribution of microfossils and rudists within the Martinšćica section (modified after KORBAR, 1999).

nian drowning of the platform (GUŠIĆ & JELASKA, 1990, 1993; JENKYNS, 1991; DAVEY & JENKYNS, 1999; VLAHOVIĆ et al., 2002).

Similar associations, and consequently depositional environments, are common in the Upper Cretaceous of the Adriatic Carbonate Platform and adjacent areas. The investigated sequence of strata on the island of Cres can be correlated with the lower part of the Gornji Humac Formation, (above the Gračišće Member) of (?)Late Turonian–Early Campanian age, and was originally described from the island of Brač, (GLOVACKI JERNEJ & JELASKA, 1986; GUŠIĆ et al., 1988; GUŠIĆ & JELASKA, 1990). Similar deposits of (?)Late Turonian–Early Santonian age, are known from the island of Dugi Otok (FUČEK et al., 1990), and from the islands of Ist and Olib (MORO & JELASKA, 1994). On the Trieste–Komen plateau it corresponds to the lower part of the Sežana Formation, which is of Late Turonian–Early Campanian age (JURKOVŠEK et al., 1996).

Furthermore, in terms of facies and biostratigraphy, the studied sequence can be correlated with the lower part of the Borgo Grotta Gigante Member from the Trieste Karst (CUCCHI et al., 1989), and the lower part of the Calcari di Aurisina ("Calcari a Rudiste") from the Isontino Karst (TENTOR et al., 1994). In the central Apennines, the Upper Turonian–Lower Campanian carbonate deposits are also characterized by predominantly mud-rich lithologies, sporadically containing numerous fragments of radiolitids and hippuritids, and with microfossil associations that become richer and more diversified upwards in the section (CHIOCCHINI et al., 1994).

In general, this distribution represented by radiolitids dominating hippuritids in more internal peritidal cycles, seems to be typical of the central/southern Tethyan carbonate platforms (CARANNANTE et al., 2000; STÖSSEL & BERNOULLI, 2000; MORO et al., 2002; KORBAR, 2003).

3. SYSTEMATIC PALAEONTOLOGY

3.1. Rudists

Analysed rudists are referred to the family Hippuritidae according to the diagnoses of DECHASEAUX & COOGAN (1969), SKELTON (1978) and SKELTON & SMITH (2000). Rudist determinations were made according to descriptions of European rudist fauna (DOUVILLÉ, 1890–94; TOUCAS, 1903–04) and descriptions of rudist fauna collected in the neighbouring areas (POLŠAK, 1967b).

Order **HIPPURITOIDA** NEWEL, 1965

Superfamily **Hippuritoidea** GRAY, 1848

Family **Hippuritidae** GRAY, 1848

Genus ***Hippurites*** LAMARCK, 1801

Hippurites sp., cf. *H. resectus* DEFRANCE, 1821
(Pl. I, Figs. 2, 3, 5–8)

1903 *Hippurites* (*Orbignya*) *requieni* MATHERON; TOUCAS, text-fig. 23–29.

1903 *Hippurites* (*Orbignya*) *requieni* var. *resecta* DEFRANCE; TOUCAS, text-fig. 30, 31.

1903 *Hippurites* (*Orbignya*) *requieni* var. *subpolygonia* TOUCAS, text-fig. 32.

1967 *Hippurites* (*Hippuritella*) *incisus* DOUVILLÉ; POLŠAK, p. 109, text-fig. 33.

1997 *Hippurites requieni*; MORO, pl. 9, fig. 3.

1999 *Hippurites requieni* MATHERON; CAFFAU, pl. 2, fig. 1.

2002 *Hippurites* cf. *requieni*/*incisus;* VLAHOVIĆ et al., p. 126, text-fig. 5.

Material: Ten limestone samples containing embedded rudists were collected within the Martinšćica section (Figs. 1, 2) – CMB (1 specimen), and within laterally equivalent strata occupying the investigated area (location map of the sampling points CI, CL and CN on Fig. 1): CI–861 (1 specimen), CL–1195 (2 specimens), CN–864 (1 specimen), CN–864a (3 specimens), CN–864c (1 specimen with broken ligamental pillar), CN–864d (1 specimen as a part of a bouquet of four hippuritid specimens), CN–952 (1 specimen), CN–953 (1 specimen) and one unlabelled sample (1 specimen). All of these 13 specimens are transverse sections of right valves embedded in slightly recrystallized limestones. The samples are stored at the repository of the Institute of Geology in Zagreb (Croatia).

Description: The valves are 12–30 mm in diameter. Anterior (ligamental) pillars are triangular with wide bases and truncated apical parts. Central pillars are slightly wider and shorter than the more protruding posterior one. Central and posterior pillars are characterized by rounded heads. Some specimens are characterized by central and posterior pillars that are as long as the anterior ones, while the posterior pillars have a slightly narrower bases than the central ones. The angles between anterior and posterior pillars ranged between 80 and 110 degrees.

Stratigraphic distribution: Turonian (TOUCAS, 1903–04; MAMUŽIĆ et al., 1976; SÁNCHEZ, 1981; PHILIP, 1998; VLAHOVIĆ et al., 2002), Upper Turonian (POLŠAK, 1967b; SLIŠKOVIĆ, 1968; POLŠAK & MAMUŽIĆ, 1969; POLŠAK et al., 1982; CAFFAU, 1999), Upper Turonian–?Coniacian (STEUBER, 1999a) or Middle–Upper Turonian (PHILIP in HARDENBOL et al., 1998; PLATEL, 1998; SIMONPIÉTRI, 1999).

Remarks: There are a few transverse sections of right valves of *Hippurites requieni* MATHERON shown in TOUCAS (1903–04) that are characterized by a wide range of the angles between the anterior (ligamental) pillar and the second pillar. It is not clear what the reason is for such a strict value as 120° for a determination of the species as established by TOUCAS (1903–04) in the text. Moreover, these angles vary in relation to the departure of the right valve transverse section from circularity, which in turn depends on the available space during growth (STEUBER, 1999a). That is why we are of the opinion that all specimens described in this paper are consistent with the description of the morphologically variable species *Hippurites resectus* DEFRANCE revised by SIMONPIÉTRI (1999). According to the same author *Hippurites requieni* MATHERON represents a synonym of *H. resectus* DEFRANCE. Complete synonymy lists of all synonyms, including references, are given in SÁNCHEZ (1981) and STEUBER (1999c). The small number and poor preservation of collected specimens did not allow morphometric analysis. Therefore, specimens are referred to the species by comparison of the internal morphological characters of their right valves (i.e., resemblance of morphology of the pillars and their distribution along the shell interior). We are aware that determination based only on pillar morphology can be difficult and is not always reliable (STEUBER, 1999a). Consequently, our determinations are tentative, but can be used for the purpose of this paper (i.e., to prove post-Cenomanian carbonate deposition on the island of Cres).

3.2. Microfossils

Ten samples were obtained from the Martinšćica section (see Fig. 2) and were examined in thin sections. The following microfossil taxa have been determined: *Aeolisaccus kotori* RADOIČIĆ, *Biplanata peneropliformis* HAMAOUI & SAINT-MARC, *Moncharmontia apenninica* (DE CASTRO), *Nezzazata simplex* OMARA, ?*Nummoloculina* sp., *Peneroplis parvus* DE CASTRO, *Pseudocyclammina sphaeroidea* GENDROT, *Pseudonummoloculina heimi* (BONET), *Scandonea samnitica* DE CASTRO, *Spiroloculina* sp., *Thaumatoporella parvovesiculifera* (RAINERI), *Tritaxia* sp., *Valvulammina* sp. and *Verneuilina* sp. Other foraminifera found in the area investigated belong to the families Miliolidae, Nezzazatidae, Charentiidae, Coskinolinidae, Spiroloculinidae, Hauerinidae, Verneulinidae, Tritaxidae, and Valvulinidae (according to LOEBLICH & TAPPAN, 1988). They are not important in terms of biostratigraphy because of their relatively long stratigraphic ranges. The morphologic characteristics of the biostratigraphically and palaeoecologically most important species are briefly discussed, while their stratigraphic ranges are discussed in the following chapter.

Order **FORAMINIFERIDA** EICHWALD, 1830

Suborder **TEXTULARIINA** DELAGE & HÉROUARD, 1896

Superfamily **Biokovinacea** GUŠIĆ, 1977

Family **Charentiide** LOEBLICH & TAPPAN, 1985

Genus ***Moncharmontia*** DE CASTRO, 1966

Moncharmontia apenninica DE CASTRO, 1966
(Pl. II, Fig. 1)

1966 *Neoendothyra apenninica* DE CASTRO; DE CASTRO, p. 14–19, text-figs. 5, 6, pls. I–V

1988 *Moncharmontia apenninica* DE CASTRO; GUŠIĆ et al., pl. II, figs: 8, 10, 11

1990 *Moncharmontia apenninica* DE CASTRO; FUČEK et al., pl. II: fig. 8

1994 *Moncharmontia apenninica* DE CASTRO; MORO & JELASKA, pl. II: fig. 5

Material: A few specimens were observed in thin sections (samples CMA–6, CMA–7, CMA–8, and CMA–10; Fig. 2). The samples and thin sections are stored at the repository of the Institute of Geology in Zagreb (Croatia).

Description: Test planispirally enrolled, involute, without uncoiled stage. Wall finely agglutinated, outer wall seemingly perforated, inner visibly smooth. Aperture cribrated with pores.

Remarks: Despite the lack of appropriate sections and small number of specimens studied, they are attributed to *Moncharmontia apenninica* due to their characteristic overall morphology.

Stratigraphic distribution: Turonian–Campanian (DE CASTRO, 1966).

Superfamily **Loftusiacea** BRADY, 1884

Family **Cyclamminidae** MARIE, 1941

Subfamily **Choffatellinae** MAYNC, 1958

Genus ***Pseudocyclammina*** YABE & HANZAWA, 1926

Pseudocyclammina sphaeroidea GENDROT, 1968
(Pl. II, Fig. 2)

1968 *Pseudocyclammina sphaeroidea* GENDROT, p. 674–675, pl. IV: figs. 1–5

1990 *Pseudocyclammina sphaeroidea* GENDROT; FUČEK et al., pl. II: fig. 7

1991 *Pseudocyclammina sphaeroidea* GENDROT; FUČEK et al., pl. II: fig. 6

Material: Several specimens were observed in thin sections (samples CMA–5, CMA–6, CMA–7, and CMA–8; Fig. 2). The samples and thin sections are stored at the repository of the Institute of Geology in Zagreb (Croatia).

Description: Test involutely enrolled, outer form inflated, almost sphaerical. Final coil with clear sutures slightly depressed. Endoskeleton with labyrinthic septa. Wall agglutinated. Cribrate aperture.

Remarks: The specimens were observed in equatorial and oblique sections.

Stratigraphic distribution: Turonian–Senonian (see text – section 4).

Suborder **MILIOLINA** DELAGE & HÉROUARD, 1896

Superfamily **Soritacea** EHRENBERG, 1839

Family **Soritidae** EHRENBERG, 1839

Subfamily **Praerhapydionininae** HAMAUI & FOURCADE, 1973

Genus ***Scandonea*** DE CASTRO, 1971

Scandonea samnitica DE CASTRO, 1971
(Pl. II, Figs. 3, 4)

1971 *Scandonea samnitica* DE CASTRO, p. 5–6, 16–65, text-figs. 1–10, 12–15, pls. I–XII, XV–XVII,

1988 *Scandonea samnitica* DE CASTRO; GUŠIĆ et al., pl. I: fig. 5

1990 *Scandonea samnitica* DE CASTRO; FUČEK et al., pl. II: figs. 3–6

Material: Several specimens were observed in thin sections (samples CMA–3, CMA–5, CMA–6, CMA–7, CMA–8, and CMA–10; Fig. 2). The samples and thin sections are stored at the repository of the Institute of Geology in Zagreb (Croatia).

Description: Test enrolled, initially in various planes, later planispiral and involute. Final stage may be uncoiled and rectilinear. Endoskeleton with basal layer and rudimentary(?) subepidermal partitions in the adult chambers and in the chambers of adult stage. Wall calcareous, imperforate, porcellaneous, outer wall very thick. Cribrate aperture.

Remarks: The specimens were observed in median and axial sections.

Stratigraphic distribution: Turonian–Senonian (see text – section 4).

4. DISCUSSION

The Hippuritid taxon *Hippurites resectus* DEFRANCE (including synonyms, see section 3.1.), that characterizes the investigated area, is well known from numerous localities on the Adriatic Carbonate Platform and adjacent areas. This taxon has been commonly attributed to the Upper Turonian (POLŠAK, 1965; SLIŠKOVIĆ, 1968; POLŠAK & MAMUŽIĆ, 1969; MAMUŽIĆ et al., 1976; POLŠAK et al., 1982; GUŠIĆ & JELASKA, 1990; FUČEK et al., 1990; CESTARI & SARTORIO, 1995; CAFFAU, 1999) or an even wider range, e.g. Upper Turonian–?Coniacian (STEUBER, 1999a) and Upper Turonian–Lower Santonian (MORO, 1997; MORO & JELASKA, 1994).

On the other hand, SIMONPIÉTRI (1999) revised the taxonomy and stratigraphy of a few "primitive" hippuritid species from Western Europe, including type specimens, and concluded that *H. resectus* is Middle–Late Turonian in age.

Furthermore, recent results based on strontium isotope stratigraphy and morphometric analyses of the Hippuritidae from Central and Eastern Europe, imply that *Vaccinites cornuvaccinum* and *V. inaequicostatus* (see CESTARI et al., 1996; STEUBER, 1999a), traditionally considered as Santonian–Early Campanian in age (SÁNCHEZ, 1981; POLŠAK et al., 1982; STEUBER, 1999a), are no younger than Coniacian (STEUBER, 1999b; STEUBER & HÖFLING, 1999; STEUBER, 2001). However, the revised chronostratigraphy of these taxa should be confirmed for the Adriatic Carbonate Platform domain analyzing the specimens from southern Istria (localities in POLŠAK, 1967b). Nevertheless, there is a need for biochronostratigraphic recalibration according to the new Cretaceous biochronostratigraphy (HARDENBOL et al., 1998).

Finally, the association of hippuritids described in this paper suggests the Middle–Late Turonian age of the strata investigated.

The microfossil association does not contain many stratigraphically relevant taxa. Moreover, the stratigraphic ranges of the only three "index" species are still disputed. The least debate surrounds the first appearance of *Moncharmontia apenninica* DE CASTRO, which is the Upper Turonian (e.g. DE CASTRO, 1966; GUŠIĆ & JELASKA, 1990; CHIOCCHINI et al., 1994). However, various authors have given very different data on the stratigraphic range of *Scandonea samnitica* DE CASTRO: Lower Senonian (CHIOCCHINI et al., 1994), Lower Santonian–Lower Campanian (HARDENBOL et al., 1998), Upper Santonian (BILOTTE, 1984, 1986), and Turonian–Santonian (DE CASTRO, 1971) – maybe even to Maastrichtian (FLEURY, 1980; GUŠIĆ & JELASKA, 1990). This is also the case with *Pseudocyclammina sphaeroidea* GENDROT: Turonian–Santonian (FLEURY, 1980), Coniacian–Santonian (BILOTTE, 1984; HARDENBOL et al., 1998), and Santonian (GENDROT, 1968). In central Croatia, the association of these three "index" species occurs in the Lower Senonian rudist limestones (VELIĆ, 1973; VELIĆ et al., 1980). FUČEK et al. (1991) reported on resedimented shallow-marine bioclastic material containing the aforementioned foraminifera, interbedded with deeper-water carbonates from Dugi otok Island. Undisturbed autochthonous layers of pelagic limestone contain planktonic foraminifera that clearly indicate the Middle to Late Turonian age of these deposits. However, there is one additional clue to narrow the stratigraphic range of the examined sequence, namely, that foraminifera which appear in the Santonian on the Adriatic Carbonate Platform (*Dicyclina schlumbergeri* MUNIER-CHALMAS, *Accordiella conica* FARINACCI, *Keramospherina tergestina* (STACHE), *Scandonea mediterranea* DE CASTRO, and *Nummofallotia apula* (LUPERTO SINNI) – e.g. GUŠIĆ et al., 1988; GUŠIĆ & JELASKA, 1990), were not found in the study area. Therefore, based on the microfossil association, and knowing that underlying deeper-water deposits are dated to the latest Cenomanian–earliest Turonian, the age of the investigated sequence on the island of Cres is likely to be (Middle) Turonian to (?)Coniacian.

Additional investigations and correlations with regional and global stratigraphic charts and sequence stratigraphy, as well as possible strontium isotope dating are required. Neither rudists nor microfossil benthic assemblages allow (at least not according to our present knowledge) greater stratigraphic resolution within carbonate platform domains of this age.

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PLATE I

Shallow-water carbonates and rudists from the island of Cres

1 Thick-bedded peritidal limestones. Lower part of the Martinšćica section. Turonian to (?)Coniacian.

2 *Hippurites* cf. *resectus* DEFRANCE, sample CMB. Upper part of the Martinšćica section. Turonian to (?)Coniacian.

3 *Hippurites* cf. *resectus* DEFRANCE, sample CN–864c. Turonian to (?)Coniacian.

4 Radiolitid thicket (biostrome) at the top of a thick bed of peritidal limestone. Central part of the Martinšćica section. Turonian to (?)Coniacian.

5 *Hippurites* cf. *resectus* DEFRANCE, sample CN–864. Turonian to (?)Coniacian.

6 *Hippurites* cf. *resectus* DEFRANCE, sample CN–953. Turonian to (?)Coniacian.

7 *Hippurites* cf. *resectus* DEFRANCE, sample CN–864d. Turonian to (?)Coniacian.

8 *Hippurites* cf. *resectus* DEFRANCE, sample CL–1195. Turonian to (?)Coniacian.

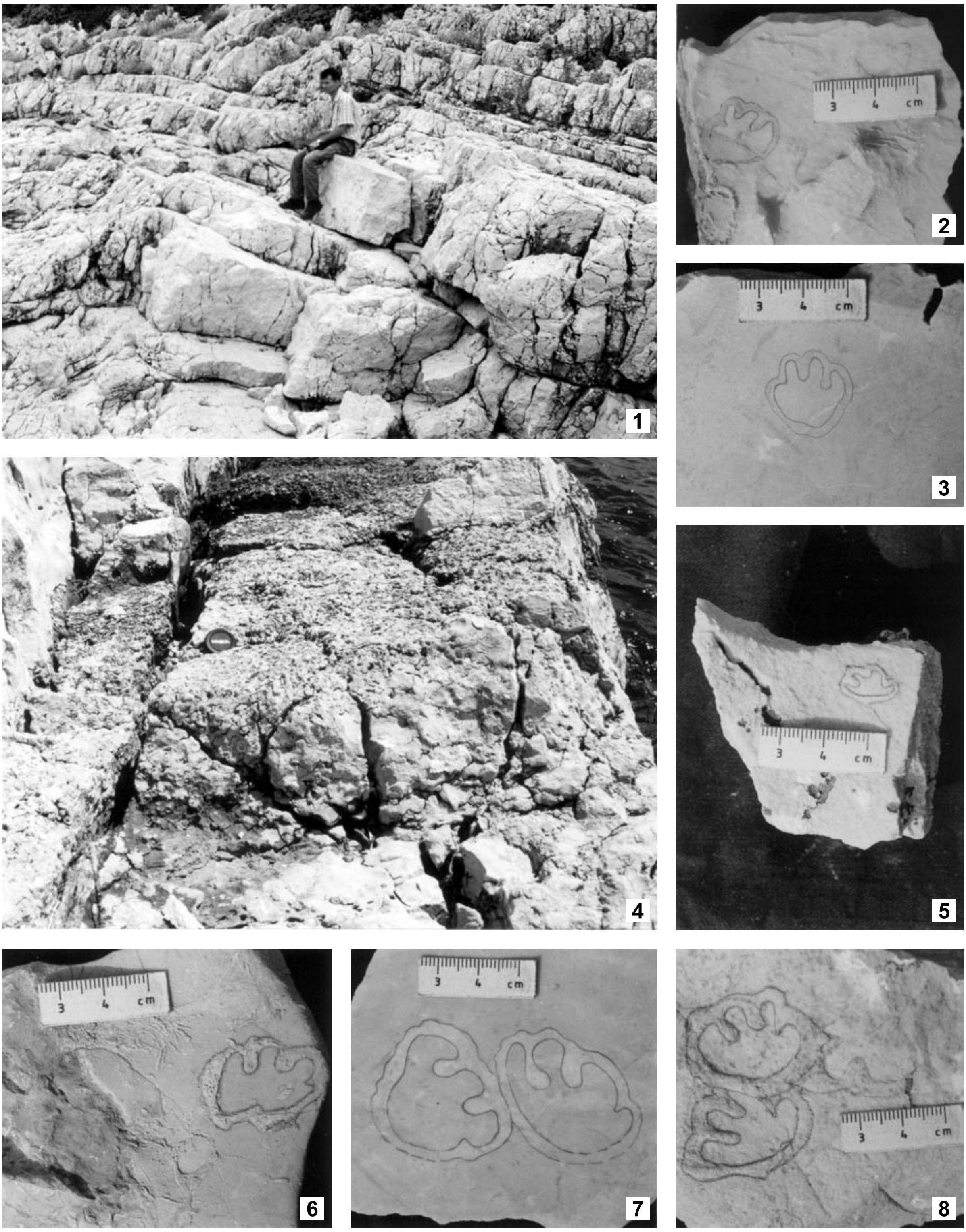
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PLATE II

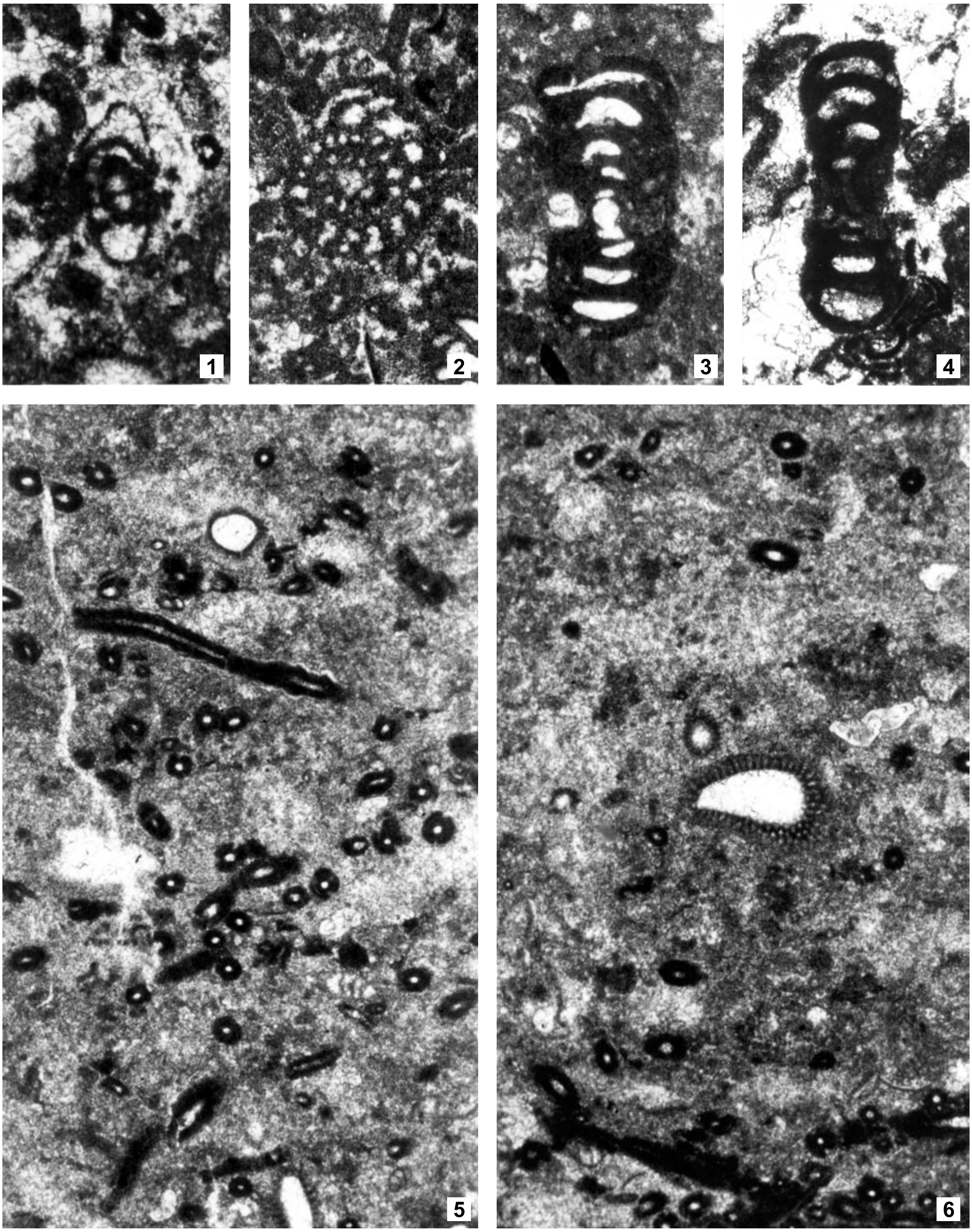
Microfossils from the Martinšćica section (see Fig. 2).

1 *Moncharmontia apenninica* DE CASTRO, sample CMA–7, 70x. Turonian to (?)Coniacian.

2 *Pseudocyclammina sphaeroidea* GENDROT, sample CMA–5, 55x. Turonian to (?)Coniacian.

3, 4 *Scandonea samnitica* DE CASTRO, samples CMA–5 (3) and CMA–3 (4), 55x. Turonian to (?)Coniacian.

5, 6 *Aeolisaccus kotori* RADOIČIĆ – *Thaumatoporella parvovesiculifera* (RAINERI) wackestone, sample CMA–9, 55x. Turonian to (?)Coniacian.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