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Ladinian–Lower Carnian echinoderms from the biohermal Raming Limestone at Liptovská Osada (Western Carpathians)

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Abstract

The Ladinian–Lower Carnian biohermal Raming Limestone exposed in the vicinity of the village Liptovská Osada (Western Carpathians, Slovakia) is well known by its rich content of fossil invertebrates. Although echinoderms are also very abundant in this lithofacies, they have never been studied in detail. From the small cavern and fissure fillings in the biohermal limestone a number of echinoderm ossicles have been collected. They belong to six echinoid and one crinoid species. Because echinoids are preserved mostly as isolate spines, they are treated parataxonomically. Finally, taphonomy and paleoecology of recognized fauna is also discussed.

Key words: echinoids, crinoids, biohermal Raming Limestone, Ladinian–Lower Carnian, Western Carpathians

Introduction

At the end of the Permian, echinoderms, a highly diversified group of marine invertebrates in the Paleozoic era became almost extinct. Only very few species of crinoids, echinoids and other members of the echinoderm groups survived this mass extinction event at the end of Permian. Consequently, during the Early Triassic, echinoderms were poorly diversified and inhabited certain environments only. However, during the Middle and Late Triassic the echinoderms became widespread and highly diversified again.

In the Triassic deposits of Europe and Asia, echinoderms are commonly preserved as intact fossils. A very good example is represented by the Muschelkalk of the Central Europe (Hagdorn, 1999, and literature cited therein) with the beautifully preserved crinoids and other echinoderms. In the Triassic deposits of the Western Carpathians echinoderms are also very common. Unfortunately, in most cases they are preserved as fragments or isolated ossicles only. This unfavourable preservation and low stratigraphic potential was probably the reason why Triassic echinoderms were omitted from the most paleontological studies concerning Triassic macrobenthic fauna from the Western Carpathians. Only few works have dealt with echinoderm taxonomy and paleoecology in detail. One of the first studies was carried out by Lefeld (1953) who described beautifully preserved crowns of *Dadocrinus grundeyi* Langenhan from the Middle Triassic deposits of the Polish Tatra Mts. Additionally, Kotański (1959) during his stratigraphical research on the Middle Triassic deposits of the Tatra Mts. considered *Dadocrinus* as an indicator of the Anisian. Two Middle Triassic (Anisian) crinoids *Dadocrinus gracilis* (Buch) and *Encrinus liliiformis* Lamarck were also reported from the Hainburg Hills in the northeast Austria (Kristan-Tollmann and Spendlingwimmer, 1975). More recently, Niedźwiedzki and Salamon (2006) described isolated columnals of five crinoid species recognized in the Middle Triassic carbonate deposits of three tectonic units (Tatricum, Fatricum and Hronicum). Finally, Ledvák (2010) described stem fragments of pseudoplanktonic crinoid *Traumatocrinus* from the Upper Ladinian Reifling Limestone and Carnian black shales of Svarín Formation in the Nízke Tatry Mts.

In many works, echinoderms are commonly mentioned in the lithological or microfacies analyses of carbonate rocks but without any taxonomical description or illustration. This is also the case of the Raming Limestone at Liptovská Osada (Fig. 1) from which Jablonský (1973) and Bujnovský et al. (1975) mentioned echinoid spines of *Cidaris dorsata* Braun, *Cidaris hausmanni* Wissmann and crinoid columnals of *Encrinus cassianus* Laube. Present study tries to fill this gap and enlarge the knowledge of the Triassic echinoderms coming from the Western Carpathian orogen.

Geographical and geological settings

The studied locality represents an abandoned quarry situated about 500 meters south from the Liptovská Osada village at the boundary of the Nízke Tatry and Veľká Fatra Mts. (Fig. 2). In the small quarry, Middle and Upper Triassic carbonate sequence of the Hronicum is exposed. The lower part of the sequence represents the light grey biohermal Raming Limestone. Because ammonites and conodonts are very rare in this formation and have not

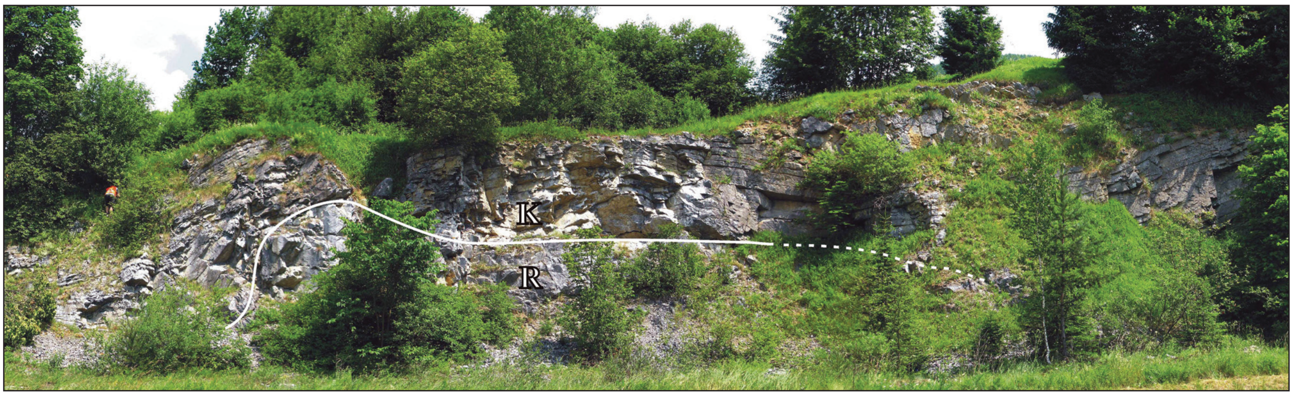

Fig. 1. The abandoned quarry near the village Liptovská Osada, frontal panoramatic view. The line marks the boundary between Raming (R) and Korytnica (K) Limestone. Photo was taken during summer 2010.

been described so far, the exact stratigraphical range of the Raming Formation is still unclear. Based on *Sphinctozoa* Jablonský (1971) considered the Raming Limestone to be of Ladinian age. Additionally, from the uppermost part of the Raming Limestone Bujnovský et al. (1975) described poorly diversified echinoderm and brachiopod fauna which indicates Ladinian–Cordevolian age.

In the upper part of the exposed sequence, the Raming Limestone is overlain by the grey to black thick-bedded organodetrital limestone with small bodies

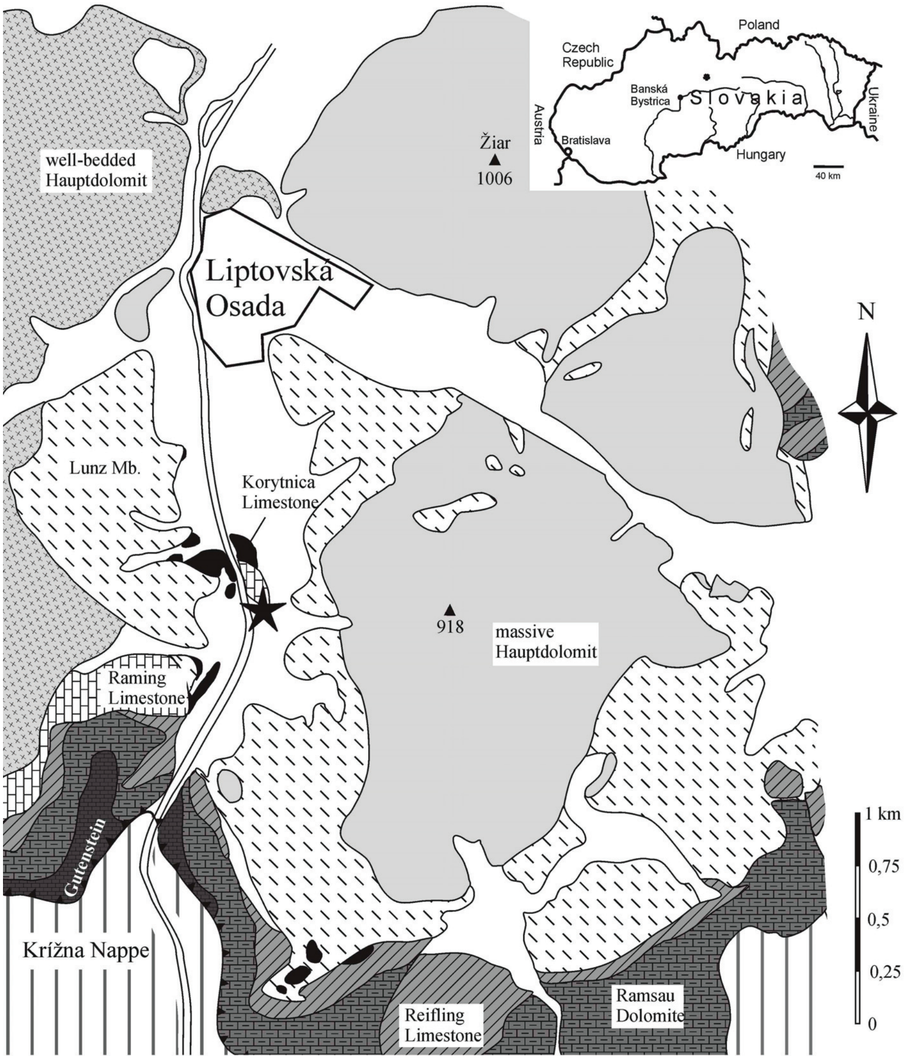

Fig. 2. Geological map of the Choč nappe in the vicinity of the village Liptovská Osada (Bujnovský and Kochanová, 1973, modified).

of biohermal limestone (patch-reef bodies). This part of the sequence was introduced as a new lithostratigraphical unit – Korytnica Limestone, and placed into Julian on the basis of the brachiopod and bivalve fauna by Bujnovský et al. (l. c.). Jablonský (1973) previously suggested for the organodetrital limestone Julian or Cordevolian age. More precise dating of this unit was given by Gaździcki et al. (1978), who described rich assemblage of foraminifers, conodonts, holothurian sclerites and sponge spicules. On the basis of holothurian sclerites Gaździcki et al. (l. c.) assigned the Korytnica Limestone into Cordevolian, *Theelia koeveskalensis* Zone in the sense of Mostler (1972).

Material and methods

Studied material was taken from the light grey biohermal limestone exposed at the left margin of the abandoned quarry. Because of the massive nature of the limestone, the macrofossils were sampled almost exclusively from the weathered rock surface. The best preserved material consisting of the crinoid and echinoid ossicles, was obtained from the small fissures and caverns filled by the muddy sediment. Since this sediment is weakly lithified, echinoderm ossicles could be easily extracted using chisel and brush. To remove remaining mud, some specimens were treated with the alcohol-detergent Rewoquad. Specimens prepared for SEM photographing were additionally cleaned with ultrasound.

Figured echinoderm ossicles are deposited in the Slovak National Museum, Bratislava, under SNM Z 36943 – Z 36957. All remaining material is stored in the personal collection of the first author.

Systematic description

Because isolated spines cannot be attributed to certain echinoid test fragments and thus to any formal species, their systematics is based on parataxa. Echinoid species (parataxa) based solely on the spine morphology are classically assigned to *"Cidaris"*.

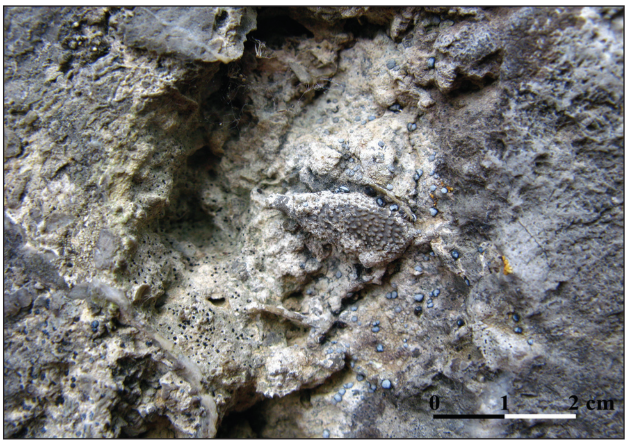

Fig. 3. Close up view on weathered surface of a small cavern in biohermal limestone. Well preserved spine of *"Cidaris" trigona* is exposed in the centre.

Class: ECHINOIDEA Leske, 1778
Subclass: Cidaroidea Smith, 1984

"Cidaris" dorsata Braun, 1841
(Figs. 4A – D)

1858 *Cidaris dorsata* Braun – Desor, p. 19, Pl. 2, Fig. 4
1865 *Cidaris dorsata* Braun – Laube, p. 283, Pl. 9, Fig. 12
1909 *"Cidaris" dorsata* – Bather, p. 178, Pl. 11, Figs. 334 – 339
1909 *"Cidaris" dorsata typica* – Bather, p. 179, Pl. 11, Figs. 310, 311, Pl. 14, Fig. 438
1909 *"Cidaris" dorsata marginata* mut. nov. – Bather, p. 180, Pl. 11, Figs. 312 – 333; Pl. 12, Fig. 439
1957 *Cidaris dorsata* (Bronn. mns.) Münster – Szörényi, p. 130, Pl. 5 (unnumbered figure)
1973 *Cidaris dorsata* Braun – Zardini, p. 17, Pl. 7, Figs. 29 – 34; Pl. 8, Figs. 1 – 19; Pl. 9, Fig. 10; Pl. 11, Fig. 48; Pl. 18, Figs. 39 – 41

Material: 10 spines with or without the base and numerous spine fragments.

Description: Spines are stout and clavate with the length ranging from few millimeters up to 2 cm. In the cross section spines are circular or slightly depressed. Maximal diameter lies in the upper half, but it can also be situated in the middle section. Shaft is covered by the dense and irregularly arranged pustules, which can be relatively long and uprising, or low. In some specimens pustules can be arranged in indistinct rows (Fig. 4A). Neck is short and smooth. Large or rarely small spines may have a ring of minute perforations in the uppermost part of the neck directly beneath the shaft (Fig. 4A, B, D). Base is relatively short and separated from the collar by the well developed milled ring. Margin of the acetabulum is non-crenulated.

Remarks: A large number of spine based "species" is known from the Triassic of Western Europe and Asia. Probably most of these parataxa were described from the Upper Ladinian–Lower Carnian dolomites of the famous St. Cassian. In the Cassian Formation *"Cidaris" dorsata* co-occur with the similar species *"Cidaris" hausmanni* and *"Cidaris" trigona*. The former species differ from *"C." dorsata* with its narrower and fusiform spines and with the shaft having pustules arranged in the distinct longitudinal rows. The latter species *"C." trigona* has also a shaft with the dense and irregularly arranged pustules, but its transverse profile is strongly depressed, not circular. All three mentioned parataxa are generally close in morphology and commonly co-occur in the fossil record. This may suggest that they were situated in the different regions of one type of echinoid test and thus could belong to one nominal species. Only new finds of the echinoid tests with associated spines can solve this problem.

Distribution: Clavate spines assigned to *"C." dorsata* are common in the dolomites of St. Cassian (Italy) and in the Ladinian–Carnian deposits of Bakony Mts. (Hungary).

In the biohermal Raming Limestone at Liptovská Osada these spines represent the most common echinoderm remains.

"Cidaris" trigona Münster, 1841
(Fig. 4E)

1865 *Cidaris trigona* Münster – Desor, p. 19, Pl. 2, Fig. 3
1909 *"Cidaris" trigona* Münster – Bather, p. 219, Pl. 13, Figs. 413 – 416
1973 *Cidaris trigona* Münster – Zardini, p. 16, Pl. 7, Figs. 11 – 20

Material: One complete spine.

Description: The spine is moderately large with the ovate and strongly depressed shaft covered by the irregularly arranged pustules. In the middle and upper part of the shaft pustules are relatively large and uniform, but they diminish towards the neck. They are directing outwards and slightly upwards. The neck is relatively short and smooth. It is well separated from the markedly sunken collar. Milled ring is poorly developed and the base moderately high. Margin of the acetabulum is non--crenulated.

Remarks: *"C." trigona* includes by the original designation two spine types: relative massive spines with more or less trigonal profile and the spines with strongly depressed shaft. Our material represents the second type. *"C." trigona* closely resembles spines of *"Cidaris" alata* which are also depressed in the profile and have shaft covered by the irregularly arranged pustules. The only character which separates these two species is the lateral keel present in *"C." alata*, but absent in *"C." trigona*. However, both parataxa show some variability in ornamentation which may cause confusions in determination.

Distribution: Similar as for *"C." dorsata*.

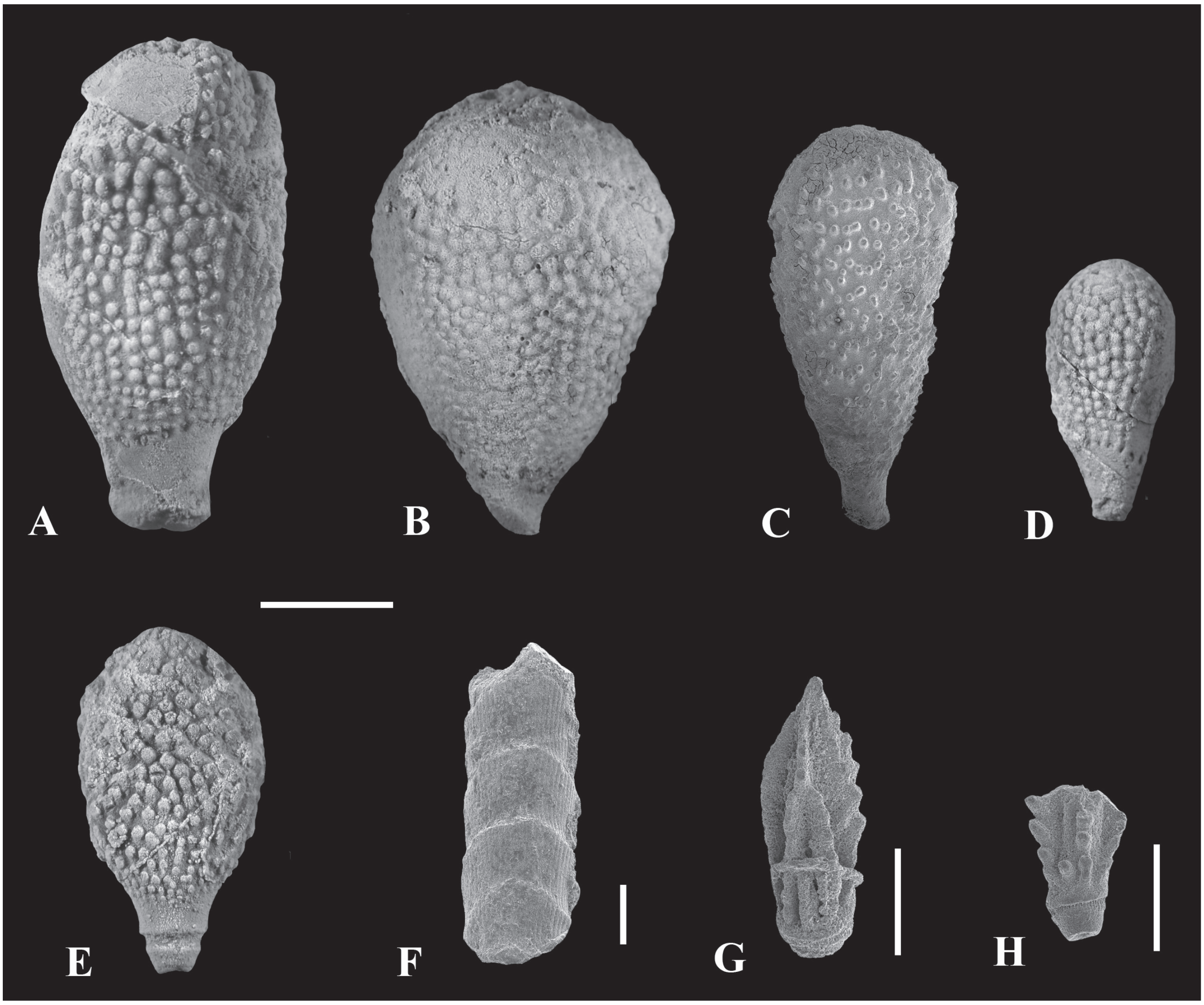

Fig. 4. Echinoid spines from biohermal Raming Limestone. A – D – *"Cidaris" dorsata* Braun, 1841, SNM Z 36943-36946; E – *"Cidaris" trigona* Münster, 1841, SNM Z 36947; F – *"Cidaris" flexuosa* Münster, 1841, SNM Z 36948; G – H – *"Cidaris" waechteri* Wissmann in Münster, 1841, SNM Z 36949-36950. Scale bars equal 5 mm (horizontal, A – E) and 1 mm (vertical, F – H).

"Cidaris" flexuosa Münster, 1841
(Fig. 4F)

1855 *Cidaris flexuosa* Munst. – Desor, p. 22, Pl. 2, Figs. 30, 31
1865 *Cidaris flexuosa* Münster – Laube, p. 290, Pl. 10, Fig. 7
1973 *Cidaris flexuosa* Münster – Zardini, p. 25, Pl. 13, Figs. 16 – 19; Pl. 14, Figs. 1 – 17; Pl. 15, Figs. 1, 2; Pl. 22, Figs. 13, 15, 16

Material: One spine fragment.
Description: The fragment is cylindrical and about 5 mm long. The shaft is ornamented with the transversal ridges which have a wave-like form. More delicate ornamentation is represented by the densely arranged longitudinal crests which form a fine striation. Ornamentation on the opposite side of the spine fragment is composed of regularly arranged notches. Unfortunately this ornamentation is poorly preserved (for the better detail see Zardini, 1973, Pl. 14, Fig. 16a, c).
Remarks: *"C." flexuosa* is well known by its typical ornamentation composed of transversal ridges which may be oblique or wavy. Our material is almost identical to spines figured by Zardini (l. c.) on Pl. 14, Fig. 16.
Distribution: Common species in Cassian Formation.

"Cidaris" waechteri Wissmann in Münster, 1841
(Fig. 4H)

1855 *Cidaris waechteri* Wissmann – Desor, p. 22, Pl. 2, Fig. 27
1909 *"Cidaris" waechteri* Wissmann in Münster – Bather, p. 191, Pl. 12, Figs. 347 – 351
1973 *Cidaris waechteri* Wissmann in Münster – Zardini, p. 24, Pl. 10, Figs. 7, 12, 18, 31, 35, 36; Pl. 11, Figs. 32 – 43

Material: One complete spine and several spine fragments.
Description: Spines are small, narrow and fusiform. In the cross section they are circular with the stellate margin. The only one complete spine is tapering distally and posses a sharp tip. The shaft is ornamented by the several distinct longitudinal ribs which bear a single row of relatively large and densely arranged pustules. Pustules are generally uniform throughout the shaft, only slightly reduced in the lower part. Two adjacent ribs are well separated by a distinct furrow. Neck is very short and smooth. Margin of the acetabulum is non--crenulated.
Remarks: Described spines represent small specimens of *"C." waechteri*. They may be well compared with material known from the Cassian Formation (compare Zardini, 1973, Pl. 10, Figs. 7, 12 and 19). From the whole spectrum of Triassic cidarid the spines *"C." waechteri* mostly resemble *"C." hausmanni*. However, in *"C." hausmanni* the longitudinal rows of pustules are more densely spaced and they are not arranged on ridges as well.
Distribution: Common parataxon in Ladinian–Carnian deposits of St. Cassian and Bakony Mts.

"Cidaris" buchi Münster in Goldfuss, 1829
(Figs. $5A_1 – A_3$)

1855 *Cidaris buchii* Munst. – Desor, p. 20, Tab. 2, Fig. 8
1865 *Cidaris buchii* Münster – Laube, p. 288, Pl. 10, Fig. 2
1909 *Anaulocidaris buchi* – Bather, p. 155, Pl. 10, Figs. 245 – 255
1973 *Cidaris buchi* Münster – Zardini, p. 22, Pl. 17, Figs. 1 – 4; Pl. 19, Fig. 1

Material: One incomplete spine with the base.
Description: The spine is relatively small and has partly broken shaft. The broad flattened shaft is strongly inclined and possesses fine ornamentation of densely arranged longitudinal crests which form a fine striation. Neck is short, but it can be hardly distinguished from the shaft. Milled ring is also poorly preserved. The base is wide and non-crenulated and has a deep concave acetabulum.
Remarks: Spines of *"C." buchi* can be easily recognized by their flattened shaft which may lie in the vertical, horizontal or oblique position to the neck. The only species which resembles *"C." buchi* is *"C." testudo*. Bather (1909) gave a number of characters which can be used to distinguish these two species. However, if comparing their variability and morphology of their different forms, it is unlikely, that they represent separate parataxa.
Distribution: Until now, this species was known only from St. Cassian (if excluding *"C." testudo* from the Bakony Mts.).

Cidaroidea indet.
(Figs. 5B, $C_1 – C_2$)

Material: 2 interambulacral plates.
Distribution: Interambulacral plates are wider than high and bear one large primary tubercle which occupies most of the plate surface. Both plates have distinctly crenulated primary tubercles with moderately large and perforate mamelon. Areoles are oval and slightly incised. Scrobicular tubercles are large and differentiated. They are sparsely arranged along adradial and interradial margins. Few extrascrobicular tubercles are heterogeneous and also confined to adradial and interradial parts of both plates. One interambulacral plate has visible denticulation at adradial margin.
Remarks: Kier (1977) described from the Cassian Formation several corona fragments and interambulacral plates which strongly resemble our material. He assigned them to three "species with crenulated tubercles". Because specimens from the Raming Fm. are so fragmental, no exact comparison can be made. However, basing on the morphology of the interambulacral plates, no significant differences can be recognized.
Distribution: Known from Raming Lm. and possibly Cassian Fm.

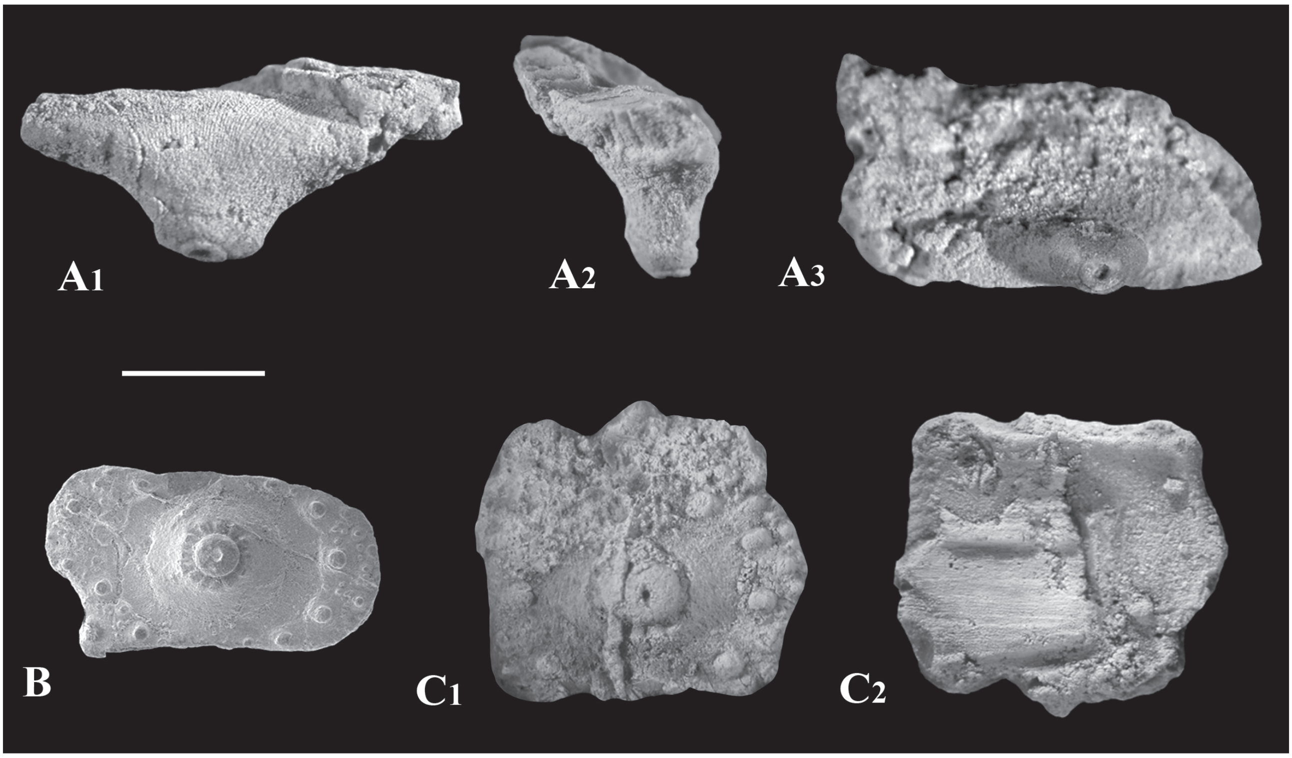

Fig. 5. Echinoid spines and interambulacral plates. $A_1 – A_3$ – *"Cidaris" buchi* Münster in Goldfuss, 1829, in the plane (A_1), lateral (A_2) and oral (A_3) views, SNM Z 36951; B, $C_1 – C_2$ – Cidaridae indet. in external (B, C_1) and internal (C_2) views, SNM Z 36952-36953. Scale bar equals 3 mm.

Class CRINOIDEA Miller, 1821
Subclass Articulata Zittel, 1879
Order Isocrinida Sieverts-Doreck, 1952

Isocrinus tyrolensis (Laube, 1865)
(Figs. 6A – D)

1865 *Pentacrinus tyrolensis* Laube – Laube, p. 57, Pl. 8, Fig. 19
1909 *Isocrinus tyrolensis major* subsp. nov. – Bather, p. 32 – 36, Pl. 2, Figs. 39 – 50
1909 *Isocrinus tyrolensis* var. α-γ – Bather, var. α, p. 36, 37, Pl. 2, Figs. 51 – 53, 55, 56; var. β, p. 37, Pl. 2, Fig. 54; var. γ, p. 37, 38, Pl. 2, Figs. 57 – 60
1983 *Tyrolecrinus tyrolensis* – Klikushin, p. 87, text-fig. 4a
1992 *Tyrolecrinus tyrolensis* (Laube, 1865) – Klikushin, p. 117, text-fig. 17a, b; Pl. 13, Fig. 7
1995 *Tyrolecrinus* sp. cf. *T. tyrolensis* – Baumiller & Hagdorn, p. 227, Fig. 6a – c

Material: 15 columnals, 5 pluricolumnals – each with single nodal.

Description: Columnals are small, up to 3 mm in diameter. Internodals are sub-pentagonal to pentalobate, in small specimens almost circular. Nodals are distinctly sub-stellate with rounded interradii. They may be equal in size to internodals or slightly higher. Articulation between internodals represents symplexy with a distinct crenulation pattern. Marginal and adradial crenulae are mostly long. Marginal crenulae increase in length towards the radius and all reach the columnal margin. The adradial crenulae of adjacent areole may be indistinctly separated or more commonly fused with their distal ends. Symplectial areoles are slender and elliptical. Lumen is moderately small. Articulation between the nodal and infranodal is cryptosymplectial with the minute marginal and adradial crenulae. Latera of both nodals and internodals is straight or slightly concave and smooth. Indistinct radial pores are present. In the lateral side nodals have 5 relatively small cirral scars which can be circular or slightly depressed. Cirral scars are markedly sunken in the radial areas and projecting downwards. Noditaxis is composed of 6 columnals.

Remarks: *I. tyrolensis* represents the earliest known isocrinid with cryptosymplexy between nodals and infranodals. This is probably the most important feature which distinguishes the advanced isocrinids from *Holocrinus* species (Hagdorn, 1983). Considering the stem morphology of some Triassic isocrinid species Klikushin (1983) established new genus *Tyrolecrinus* and designated *I. tyrolensis* its type species. Klikushin (l. c.) distinguished *Tyrolecrinus* from other isocrinid genera by the equal size of nodals to internodals hawing both smooth latera, by nodals having 5 rather small cirral scars which are directed downwards and by the lanceolate or drop like areoles bordered by the large clenulae. However, these characters are not good

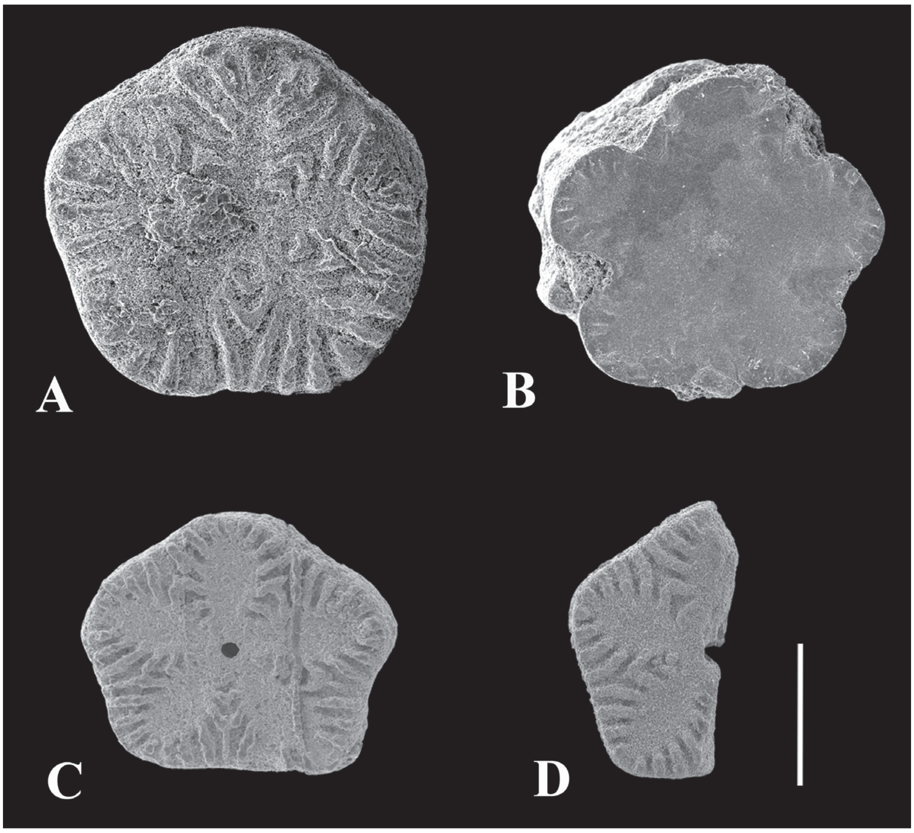

Fig. 6. Columnals of *Isocrinus tyrolensis* (Laube, 1865). A, C, D – articular surfaces of internodals (all represent symplexy), SNM Z 36954-36956; B – cryptosymplexy of infranodal with minute adradial and marginal crenulae, SNM Z 36957. Scale bar equals 1 mm.

indicators for establishing a phylogenetic relationship because they are highly influenced by the ontogeny and position of columnals in the stem. Therefore, and according to the presence of cryptosymplexial articulation between nodals and infranodals with the minute marginal and adradial crenulae, the present species is assigned back to *Isocrinus*.

Distribution: *I. tyrolensis* was reported from the Ladinian – Carnian deposits of Italy, Hungary, and Russia and sporadically from other regions of the Western Europe. Poruba (1951) reported this species also from the Wetterstein Limestone, Muráň nappe.

Discussion and conclusion

As seen from the fauna described above, echinoderms from the Raming Limestone are preserved exclusively as disarticulate ossicles. This unfavourable preservation results from their delicate skeletons and from original environment conditions.

In the case of Triassic echinoids their bodies were composed mostly of imbricate plates which could easily disjoin after death. Disintegration of echinoid skeletons could also be accelerated if exposed to strong currents, common in the shallow reef environments. Crinoids have also multi-element skeletons composed of many ossicles connected with soft tissue. Consequently crinoids can disarticulate into fragments within a few days after death (Cain, 1968; Meyer, 1971). Only if buried alive or immediately after death echinoids and crinoids could be preserved intact. This however, has not been observed in the case of Raming Limestone.

Most Triassic echinoids belong to primitive cidaroids which lived on the sea floor using their strong jaws to rasp algae and small epibionts. Recent cidaroids are relatively abundant and well diversified in the reef dwelling communities. Because of the fragmentary nature of the echinoids found in the Raming Limestone, their diversity can not be clearly determined.

Only one crinoid species *Isocrinus tyrolensis* has been recognized in the Raming Limestone. This species belongs to isocrinids, a large group of free living crinoids which use their cirri for attachment and locomotion. They anchor to a hard or soft sediment and use their crowns to filter small microorganisms from the sea water. *I. tyrolensis* represents one of the earliest isocrinids with cryptosymplectial articulation between the lower facet of a nodal and the adjacent internodal. Cryptosymplexy is a type of articulation with strongly reduced crenularium and thus represents the weakest point in the crinoid stalk. If exposed to strong currents, crinoid stalks could brake preferably between columnals with cryptosymplexies. Because the cryptosymplexy occurs always at the lower surface of a nodal element, breaking of the stalk in this point would give crinoids a great opportunity to re-anchor again. Cryptosymplexies represent also specialized sites for the autotomy (Emson and Wilkie, 1980).

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