

Crinoids from the Late Jurassic of the Nutzhof section (Lower Austria, Gresten Klippenbelt)

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(With 6 text-figures)

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Abstract

Tithonian to Berriasian sediments of the Blassenstein Formation exposed at the Nutzhof section, 5 km north of Hainfeld, in the Gresten Klippen Belt were sampled for crinoids. Only the Tithonian part of the section proved suitable for bulk sampling. Four crinoid taxa (*Balanocrinus* sp., *Saccocoma tenella* (GOLDFUSS, 1831), *Crassicoma* ? sp., and *Phyllocrinus belbekensis* ARENDT, 1974) could be documented. Among these, only *S. tenella* and probably *Crassicoma* ? sp. appear to be autochthonous; the others are interpreted as transported based on preservation and size range. The observed changes in lithology and microfauna may reflect geodynamically induced palaeogeographic changes and/or basinal deepening.

Keywords: Crinoidea, Echinodermata, Gresten Klippenbelt, Austria, Tithonian, Jurassic

Zusammenfassung

Sediment der Blassenstein-Formation aus dem Tithon bis Berrias wurden am Profil Nutzhof, 5 km nördlich von Hainfeld in der Grestener Klippenzone auf Crinoiden beprobt. Nur der Tithon-Anteil des Profils war für Schlämmpfropfen geeignet. Vier Crinoidentaxa (*Balanocrinus* sp., *Saccocoma tenella* (GOLDFUSS, 1831), *Crassicoma* ? sp., und *Phyllocrinus belbekensis* ARENDT, 1974) konnten nachgewiesen werden. Von diese werden nur *S. tenella* und *Crassicoma* ? sp. als autochthone Elemente gedeutet. Der Erhaltungszustand und die Größensortierung der zwei anderen Formen weist auf Transport hin. Die beobachteten Änderungen von Lithologie und Mikrofauna könnten geodynamisch induzierte Veränderungen der paläogeographischen Position oder eine Vertiefung des Beckens widerspiegeln.

Schlüsselworte: Crinoidea, Echinodermata, Grestener Klippenzone, Österreich, Tithon, Jura

Introduction

Stalked crinoids were an important and diverse constituent of Palaeozoic and Mesozoic marine faunas, occurring abundantly in both shallow and deep water settings over a wide range of (palaeo-)latitudes (see HESS et al. 1999). This contrasts strongly with their modern distribution, where stalked crinoids are restricted to deeper water below 100 m. In shallow-water environments, only the stalkless comatulids, are found, with greatest abundance in the coral reefs of the tropical Indo-Pacific (MEYER & MACURDA 1976).

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Stalkless crinoids first evolved in the Triassic, including forms like the wide-spread osteocrinids (e.g. KRISTAN-TOLLMANN 1970; WANG et al. 2007). In the Late Jurassic to Early Cretaceous, another group of unstalked crinoids became prominent, the saccocomids. These microcrinoids were highly modified and apparently very successful, as documented by their wide-ranging occurrence (from Cuba to Japan; NICOSIA & PARISI 1979; MANNI et al. 1997) in rock-forming quantities (KEUPP & MATYSZKIEWICZ 1997; HESS 2002). Unlike most other crinoids, their abundance and brief temporal distribution accounts for their quality as index fossils for the Kimmeridgian to Tithonian (NICOSIA et al. 1979). Despite their common occurrence, their mode of life has been discussed controversially. Interpretations range from a benthic mode of life (MILSOM 1994; MILSOM & SHARPE 1995; MANNI, NICOSIA & TAGLIACCOZZO 1997) to a pelagic lifestyle (JAEKEL 1892; KEUPP & MATYSZKIEWICZ 1997; HESS 1999, 2000), including active snap-swimming (SEILACHER & HAUFF 2004; SEILACHER 2005).

Research on Upper Jurassic to Lower Cretaceous deposits in the Klippen Belt southwest of Vienna led to the discovery of a succession spanning a large time interval (see LUKENEDER 2009). This section exposes strata of the Blassenstein Formation and contains marls and limestones rich in saccocomid remains as well as in other crinoids. Unlike the situation in most other occurrences, the high marl content allowed bulk sampling and extraction of the saccocomid ossicles.

Study area

The studied outcrop is located at 48°04'50" N, 15°47'38" E, in an area called Kleindurlas, 5 km north of Hainfeld and 20 km south of Böhheimkirchen (fig. 1). There, strata of the Blassenstein Formation are exposed in a small, disused quarry near a farm called Nutzhof. The section comprises an 18-m-long succession of strongly tilted, inverse, well-bedded marls and limestones. At the base, marl and marly limestone bands dominate, being replaced by increasingly pure limestone towards the top. Based on preliminary data from palaeomagnetism, ammonites, and microfossils (LUKENEDER 2009; PRUNER et al. 2009; REHÁKOVÁ et al. 2009) the lower part can be assigned to the Early Tithonian and the upper part to the Middle Berriasian (fig. 2). In terms of microfacies, a change from a saccocomid facies to a calpionellid facies can be observed within the succession.

Geologically, the area belongs to the Gresten Klippen Belt, a small band of Upper Jurassic to Lower Cretaceous sediments situated north of the Northern Calcareous Alps. Adjacent units belong to the Rhenodanubian Flysch Zone.

Material & Methods

Apart from a survey of the thin sections, which were also employed to study calpionellids (REHÁKOVÁ et al. 2009), an effort was made to obtain three-dimensional specimens of the crinoids and other microfossils commonly observed in the thin sections (namely foraminifera, ostracods, rhyncholiths, small aptychi, ophiuroid remains, etc.). The older, marly part of the succession (metre 10 to 18) was sampled intensively. Wherever possible, samples were taken in marl layers adjacent to the limestone beds sampled for thin sections and palaeomagnetism (PRUNER et al. 2009). A general lack of marly horizons in

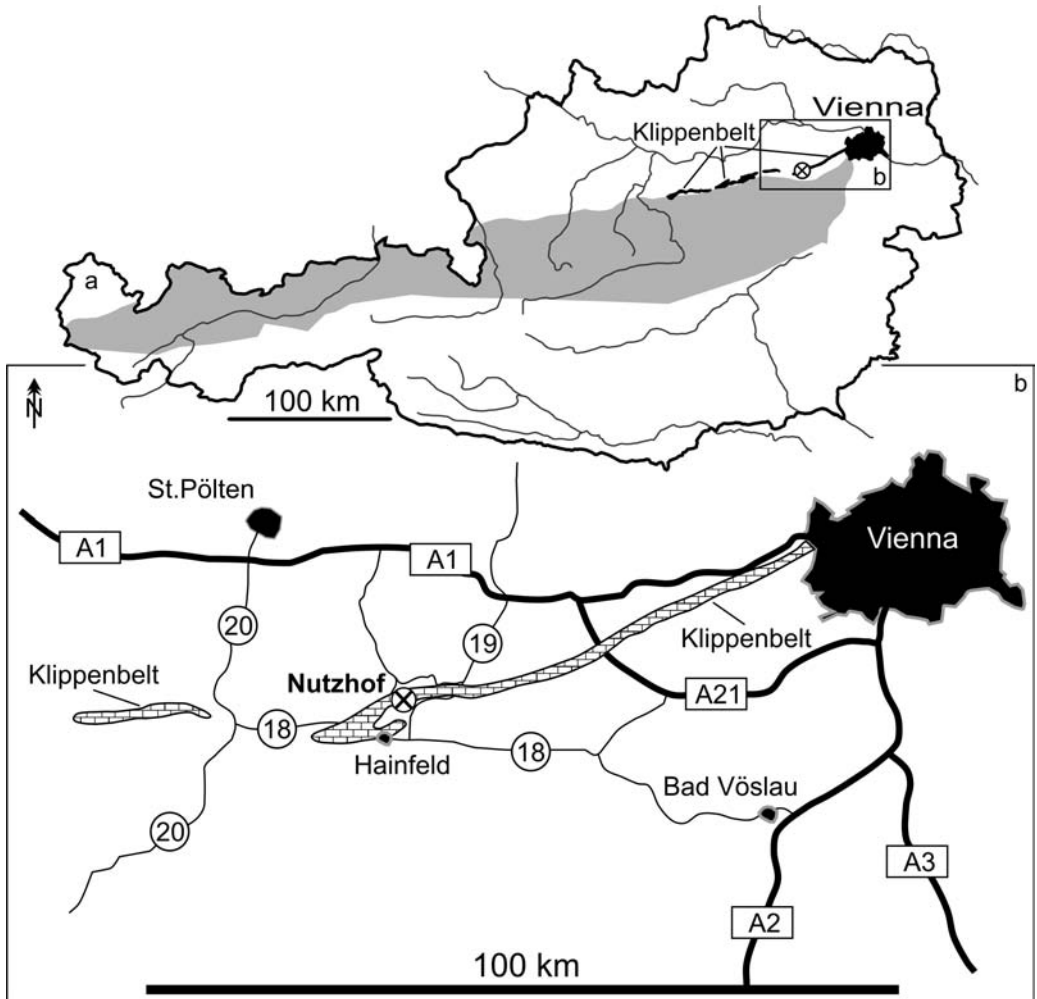


Fig. 1: Locality map of Austria with indicated position of the Klippenbelt in Lower Austria (A) and detailed map (B) of the area around Nutzhof showing the outcrop of Upper Jurassic to Lower Cretaceous sediments from the Klippenbelt (brick-structure).

part of the succession (metre 0 to 10.0) prevented bulk sampling in the younger strata. These beds were analysed by thin sections only.

Due to the high lithification of the samples traditional washing methods (hydrogen peroxide, boiling with sodium, petrol, etc.) were unsuccessful. Partial disaggregation was achieved by repetitive, combined treatment with hydrogen peroxide and the tenside Rewoquat (see LIERL 1992). Particularly well lithified aggregates that were unaffected by the treatment were removed from the samples after the first cycle. Accordingly, the quantitative data presented below are biased by lithification, but comparison with data

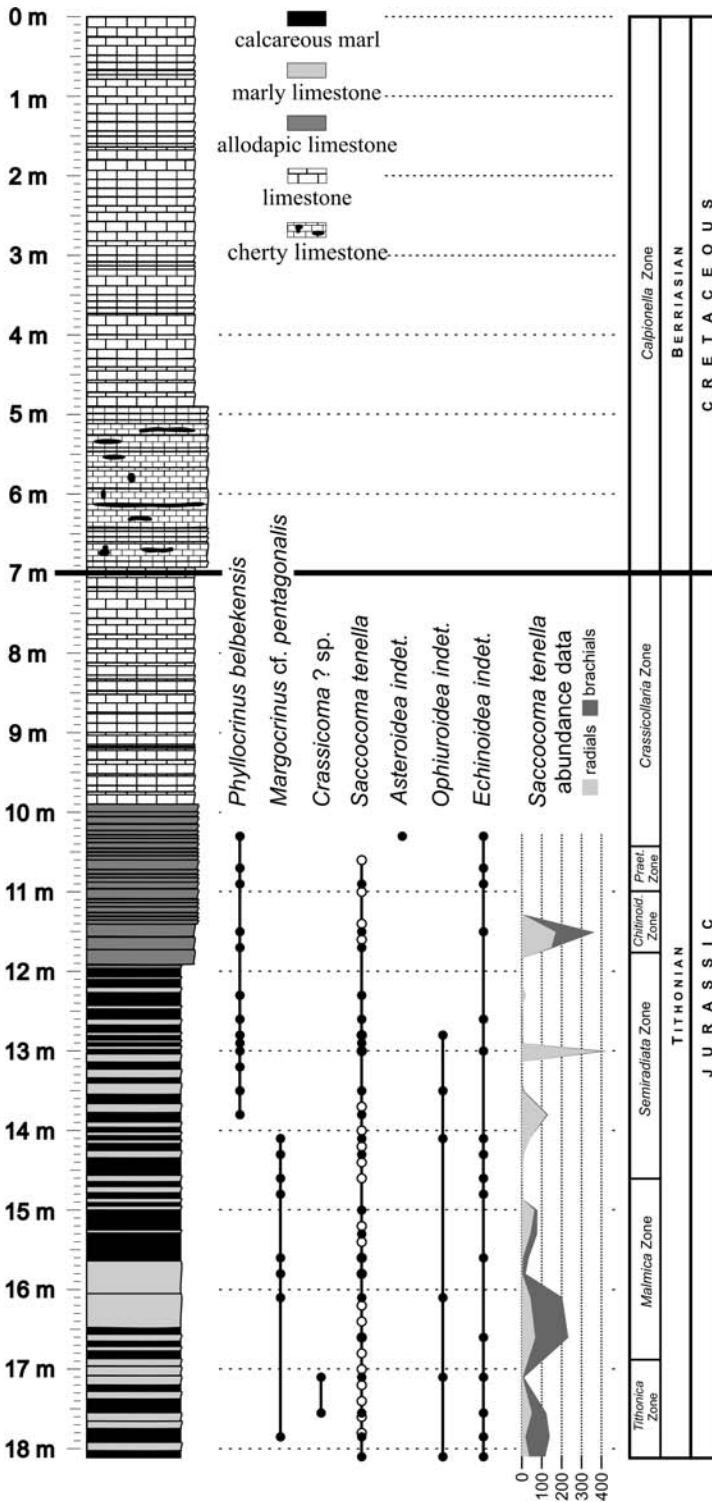


Fig. 2: Lithological log of the Nutzhof section with echinoderm ranges. Solid symbols indicate occurrences in the bulk samples, open symbols records observed in thin sections only. Note: *Saccocoma* abundance data is quantitative, but biased by sediment lithification. Stratigraphy from REHÁKOVÁ et al. (2009).

obtained from thin sections showed that this bias is small and the resulting abundance patterns largely comparable.

After disaggregation and cleaning, the microfossils were hand picked under a microscope. For the present study we used the sediment fractions $\geq 250 \mu\text{m}$ only.

All samples are stored at the Natural History Museum of Vienna, in the collection of the Department of Geology and Palaeontology. Echinoderms picked from the samples but not used in the present study are stored under the repository numbers NHMW 2008z0232/0001 to 0002 (Crinoidea indet.), 2008z0233/0001 (Asteroidea indet.), 2008z0234/0001 to 0016 (Ophiuroidea indet.), 2008z0235/0001 to 0006 (Echinoidea indet.).

Abbreviations:

NHMW – Naturhistorisches Museum Wien

Systematic part

Class Crinoidea MILLER, 1821

Order Isocrinida SIEVERTS-DORECK, 1953

Family Isocrinidae GISLEN, 1924

Genus *Balanocrinus* AGASSIZ, in DESOR, 1845

Balanocrinus sp.

(fig. 3)

Material: 13 columnals of immature (?) specimens from samples NU 14.10, 14.60, 14.80, 15.80, 16.10, and 17.85 (NHMW 2008z0228/0001, 2008z0229/0001 to 0006). Six brachial ossicles and 25 cirrals from samples NU 14.30, 14.60, 14.80, 15.60, 16.10, and 17.85 (NHMW 2008z0230/0001 to 0006, 2008z0231/0001 to 0005) are tentatively associated with the co-occurring columnals.

Description: The columnals recovered from the bulk samples are small, high and pentagonal in cross section. They are concave-sided and ornamented by small flanges on the lateral surfaces. The facets show pentaradiate symplexy with strong, but short marginal crenulae. Only a single nodal was found (sample NU 14.60), which is very similar to the internodals, apart from the synostosis on the distal facet and the large cirral facets.

Only distal and/or immature brachial ossicles were recovered. These are high, with concave sides and subequal pinnular and brachial articulation surfaces.

The proximal cirrals are short, rhomboidal in side view and bear a weak aboral rib. The distal cirrals are much longer and have a much more prominent distal rib, which is serrated.

Remarks: The present material is very scarce and consists of immature specimens. The association of columnals with brachial and cirral ossicles is mainly based on co-

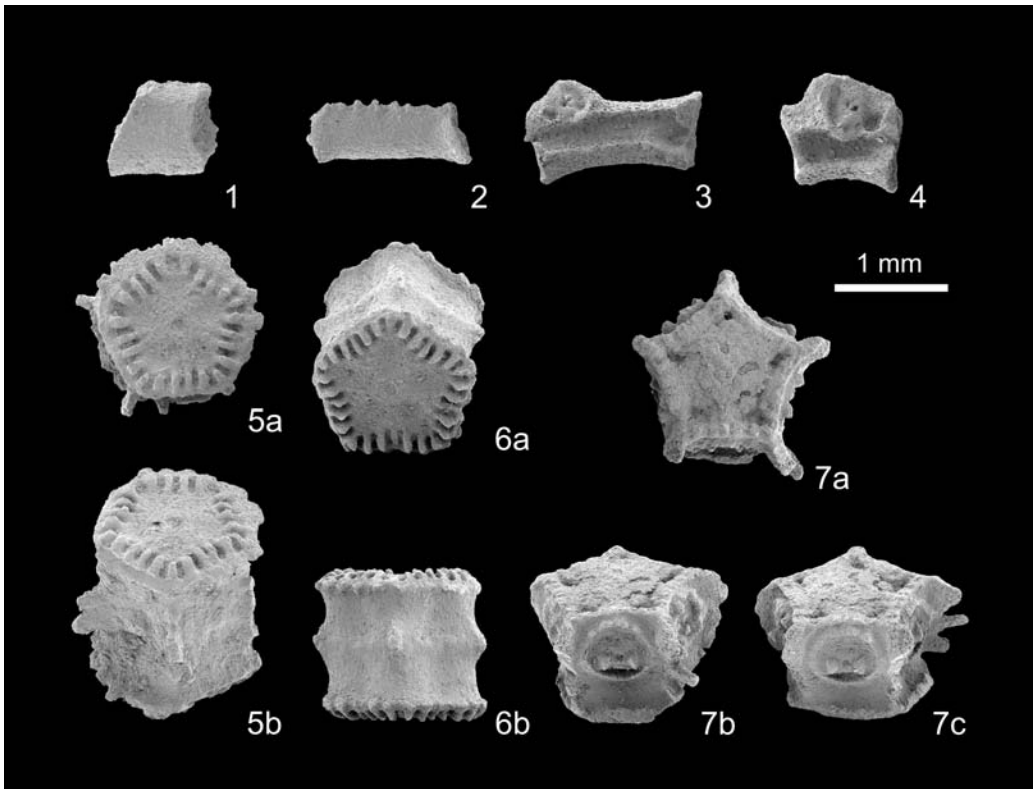


Fig. 3: *Balanocrinus* sp., Tithonian, Nutzhof, Austria (1, 2, 5: from sample NU 14.80, others from NU 14.60). **1**: proximal cirral (NHMW 2008z0230/0002); **2**: distal cirral (NHMW 2008z0230/0001); **3-4**: brachials (NHMW 2008z0230/0004, .../0005); **5-6**: internodals (NHMW 2008z0228/0001, .../0003); **7**: nodal, a = distal cryptosymplectial facet (?) (NHMW 2008z0228/0002).

occurrence. Due to the nature and scarcity of the material a specific identification is difficult. The specimens from Nutzhof are very similar to ossicles from juvenile *Balanocrinus* cf. *subterres* described by PISERA & DZIK (1979), but according to HESS (1975) and GŁUCHOWSKI (1984) a pentagonal columnal shape is more characteristic for *Balanocrinus pentagonalis*. The lateral flanges observed on the columnals, however, are unusual in *Balanocrinus* (compare e.g. HESS 1975: pl. 20, figs 1-8, 11; SALAMON & ZATOŃ 2008: figs 5e-g). Many *Isocrinus* species show rich lateral ornament, but differ by their different articular facets.

Occurrence: Early Tithonian (*Carpistomiosphaera tithonica* Zone to *Cadosina semiradiata* Zone) of Nutzhof, Klippenbelt, Austria (this study); *Balanocrinus pentagonalis* is a common member of crinoid associations in the Tithonian to Berriasian of the Pieniny Klippen Belt, Poland (GŁUCHOWSKI 1987), but has a wider range elsewhere (HESS 1975; SALAMON 2008).

Order Roveacrinida SIEVERTS-DORECK, 1953

Family Saccocomidae D'ORBIGNY, 1852

Genus *Saccocoma* AGASSIZ, 1853***Saccocoma tenella* (GOLDFUSS, 1831)**

(fig. 4)

- 1892 *Comatula tenella* nobis. – GOLDFUSS: 204; pl. 62, figs 1a-d.
 1892 *Comatula pectinata* nobis. – GOLDFUSS: 205; pl. 62, figs 2a-e.
 1892 *Camatula* [sic!] *filiformis* nobis. – GOLDFUSS: 205; pl. 62, figs 3a-b.
 1979 *Saccocoma tenella* GOLDFUSS, 1862 – PISERA & DZIK: 810-811; figs 3a-g; pl. 1, figs 8-9; pl. 2, figs 1-7; pl. 3, figs 1-3.
 1980 *Saccocoma tenella* (GOLDFUSS, 1831) – HOLZER & POLTNIG: 207-215; fig. 2; pl. 1, figs 1-13; pl. 2, figs 1-16; pl. 3, figs 1-3.
 1987 *Saccocoma tenella* GOLDFUSS, 1862 – GLUCHOWSKI: 39-40; figs 13.7-10; pl. 17, figs 1, 4-6; pl. 18, figs 1-5; pl. 19, figs 1-6.
 2002 *Saccocoma tenella* (GOLDFUSS, 1831) – HESS: 19; figs 12, 13.
 2006 *Saccocoma tenella* (GOLDFUSS, 1831) – BRODAKCI: 264-268; figs 3A-E, 4A, B, 5A-D, H, I, 6A, B, E, F, H, I.
 2008 *Saccocoma tenella* (GOLDFUSS, 1831) – KROH & LUKENEDER: 46

Material: 1248 radials (NHMW 2008z0236/0001 to 0004, 0010 to 0014, 2008z0237/0001 to 0021), 971 brachials (NHMW 2008z0236/0005 to 0009, 0015 to 0023, 2008z0238/0001 to 0019) from samples NU 10.90 to NU 13.00, NU 13.50 to NU 14.30, and NU 15.00 to NU 18.10.

Description: The radials (figs 4.11-4.19) are thin and arrow-head-shaped, with distinctly serrate sides and a prominent central rib. Their outer surface is sculptured by a reticulate meshwork. The pattern formed by the meshwork varies from irregular (fig. 4.18) to oblique, well-organized sub-parallel ridges (figs 4.15, 4.16). The inner surface (fig. 4.19) is more or less smooth, with a shallow central groove tracing the position of the rib on the outer side. The articulation facet is small and preserved in few ossicles only. The aboral part of the articulation facet is rounded, knob-like and does not bear any processes (figs 4.11-4.14).

The proximal brachials (I_{Br}2, I_{Br}2, I_{Br}4 and some of the more distal secundibrachials) bear distinct wings (figs 4.1-4.4). Although these wings are broken off in most Nutzhof specimens, they are more or less disc-shaped and subequal in size on both sides of the brachials. More distal brachials bear paired oral processes (fig. 4.5).

Remarks: The present material clearly belongs to *S. tenella*, agreeing in detail with material from the type-area Solnhofen (Bavaria, Germany; HESS 2002) and Poland (PISERA & DZIK 1979; BRODAKCI 2006). The largest radials recovered from the Nutzhof bulk samples barely reach 4 mm and are thus smaller than those reported elsewhere (HOLZER & POLTNIG 1980). Nevertheless, the ontogenetic change in radial sculpture documented by HOLZER & POLTNIG (1980: 207-214) can be observed in the present material as well.

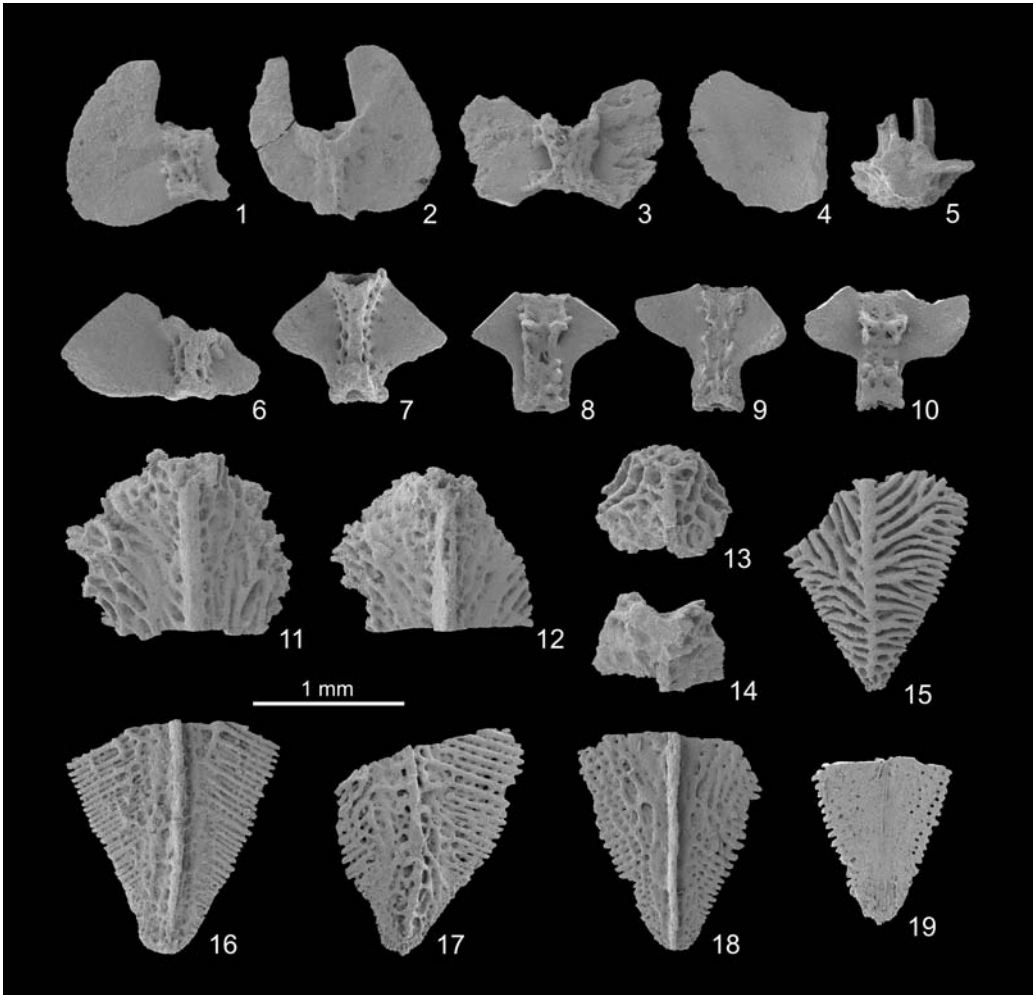


Fig. 4: *Saccocoma tenella* (GOLDFUSS, 1831), Tithonian, Nutzhof, Austria; **1-4, 6-10**: proximal brachials (1: NU 17.85; NHMW 2008z0236/0016; 2: NU 11.50; NHMW 2008z0236/0015; 3: NU 13.00; NHMW 2008z0236/0017; 4: NU 16.60; NHMW 2008z0236/0018; 6-10: NU 17.85; NHMW 2008z0236/0005 to .../0009); **5**: distal brachial (NU 15.60; NHMW 2008z0236/0019); **11-14**: parts of radials with articulation socket (11-12: NU 13.00; NHMW 2008z0236/0010, .../0011; 13-14: NU 16.10; NHMW 2008z0236/0013, .../0014); **15-18**: broken radials, outer surface (15: NU 13.00; NHMW 2008z0236/0012; 16-18: NU 17.85; NHMW 2008z0236/0002 to .../0004); **19**: broken radial, inner surface (NU 17.85; NHMW 2008z0236/0001).

S. quenstedti SIEVERTS-DORECK & HESS, in HESS, 2002 and *S. vernioryi* MANNI & NICOSIA, 1984 differ by their paired, antler-like processes attached to the aboral part of the articulation facet of the radial ossicles (two in *S. quenstedti*, four in *S. vernioryi*; HESS 2002; BRODACKI 2006). *S. longipinna* HESS, 2002 (*Saccocoma* sp. of VERNIORY 1962) differs by its highly asymmetrical proximal brachials with one strongly elongated and one rudimentary wing.

S. schwertschlagerei WALTHER, 1904 is a synonym of *S. tenella* and according to MANNI & NICOSIA (1984: 183), representing cases of special preservation after total autotomy of the arms.

Occurrence: Late Kimmeridgian to Late Tithonian

Late Kimmeridgian of Dorset, UK (MILSOM 1994) and France (VERNIORY 1960); Early Tithonian of Southern Germany (JAEKEL 1892; SIEVERTS-DORECK 1955; HESS 2002); Early to Middle Tithonian of the Pieniny Klippen Belt, Poland (PISERA & DZIK 1979; GLUCHOWSKI 1987; BRODAKCI 2006); Early to Late Tithonian (*Carpistomiosphaera tithonica* Zone to *Praetintinnopsella* Zone) of Nutzhof, Klippenbelt, Austria (this study).

Genus *Crassicoma* SIEVERTS-DORECK & HESS, in HESS, 2002

***Crassicoma?* sp.**
(fig. 5)

Material: 20 brachial ossicles from samples NU 17.10 and NU 17.55 (NHMW 2008z0240/0001 to 0009).

Description: Primibrachials – the ossicle tentatively identified as IBr1 (fig. 5.4) is slightly elongated and dorso-ventrally flattened. The proximal part is slightly wider and shows a muscular articulation, the distal articulation is non-muscular and sloping. The external surface is devoid of ornamentation. The second primibrachial (IBr2 = IAx; figs 5.5-5.6) is strongly wedge-shaped with a triangular profile. It lacks both wings and oral processes. The proximal facet is non-muscular (probably a cryptosynarthry), whereas the two distal facets are muscular.

The secundibrachials (figs 5.1-5.3) are stout, dumbbell-shaped and lack wings. Instead, they possess a pair of oral projections or ridges. In profile they are distinctly triangular. One facet is muscular, the other one a horseshoe-shaped synostosis. The latter is strongly inclined in relation to the long axis of the ossicle. None of the brachials shows a pinnulae socket. Assignment to specific positions is difficult, but it appears that no IIBr1 are preserved among the material.

Distal brachials (fig. 5.7) are rectangular, slightly elongated and dorso-ventrally flattened. They bear muscular articulations on both ends, which are perpendicular to the long axis of the ossicle.

Remarks: The present brachial ossicles are distinctly larger than the *Saccocoma* brachials encountered in the same and adjacent samples. Furthermore, they lack the wings but show relatively blunt (compared to *Saccocoma*) oral projections. They are similar to proximal brachials of *Crassicoma schattenbergi* SIEVERTS-DORECK & HESS, in HESS, 2002 and *Crassicoma subornata* SIEVERTS-DORECK & HESS, in HESS, 2002 figured in HESS (1972: pl. 3, fig. 50a-b; 2002: pl. 2, fig. IIBr4; pl. 3, figs 6-9; pl. 7, fig. 19). They differ from those ossicles by lacking a reticulate ornament on the surface.

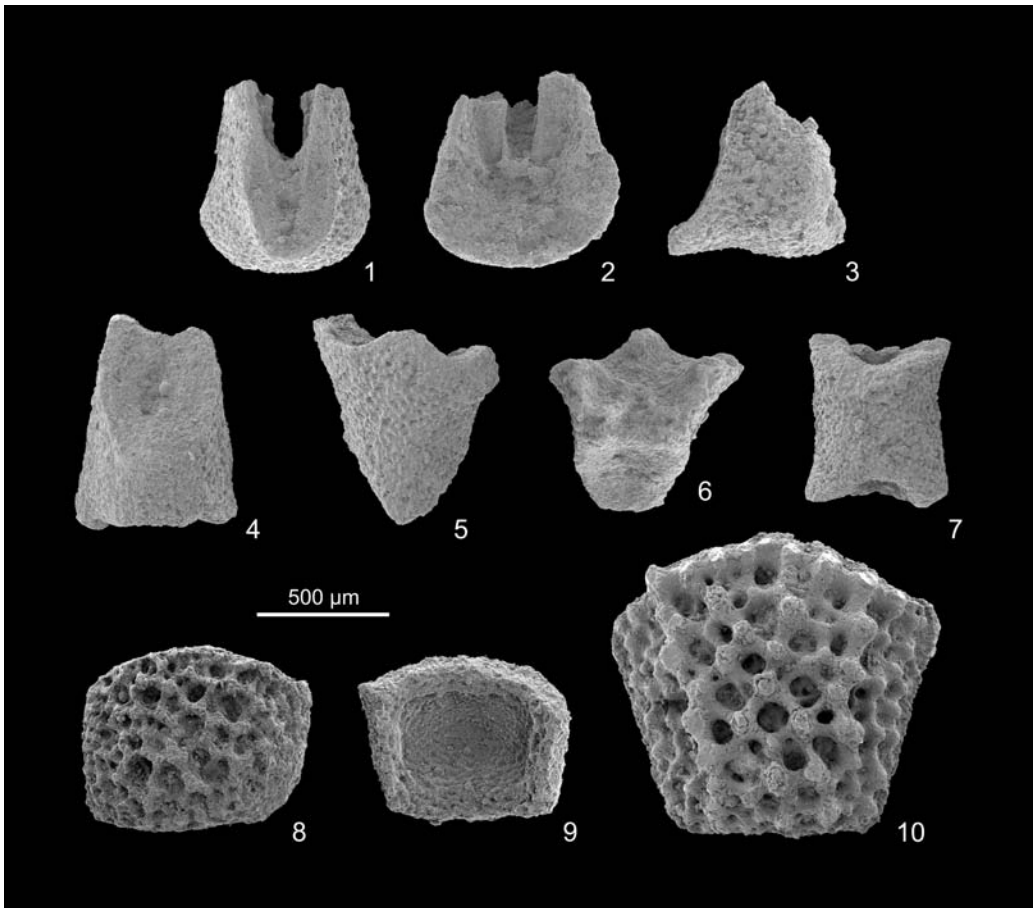


Fig. 5: 1-7: *Crassicoma?* sp., brachials, Tithonian, Nutzhof, Austria (from sample NU 17.10); **1-3**: secundibrachials (NHMW 2008z0240/0002, .../0003, .../0005); **4**: IBr1 (NHMW 2008z0240/0004); **5-6**: IBr2 (NHMW 2008z0240/0006, .../0007); **7**: distal brachial (NHMW 2008z0240/0008). **8-10**: Undetermined echinoderm ossicles (possibly radials of *Crassicoma*), Tithonian, Nutzhof, Austria (NHMW 2008z0239/0001, .../0004, .../0005).

Additionally, five echinoderm ossicles resembling *Crassicoma* radials (figs 5.8-5.10) have been recovered from samples NU 11.50, NU 11.70, NU 16.10, NU 16.60 (NHMW 2008z0239/0001 to 0005). Their external surface shows a coarse reticulate ornament much like that seen in *C. schattenbergi*. Although their general shape suggests that these may be radials, they lack a well-defined articulation facet and, thus, may not represent crinoid ossicles at all.

Occurrence: Early Tithonian (*Carpistomiosphaera tithonica* Zone to *Parastomiosphaera malmica* Zone) of Nutzhof, Klippenbelt, Austria (this study).

Order Cyrtocrinida SIEVERTS-DORECK, 1953

Family Phyllocrinidae JAEKEL, 1907

Genus *Phyllocrinus* D'ORBIGNY, 1850***Phyllocrinus belbekensis* ARENDT, 1974**

(fig. 6)

- 1974 *Phyllocrinus belbekensis* sp.nov. – ARENDT: 118-119; figs 14Д-К; pl. 14, figs 1-21.
 1979 *Phyllocrinus belbekensis* ARENDT, 1974 – PISERA & DZIK: 824-825; figs 11c-d, 13d; pl. 4, fig. 1.
 1984 *Phyllocrinus belbekensis* ARENDT, 1974 – ŽÍTT, J. & MICHALÍK: 605-607; pl. 1, figs 1-2; pl. 2, figs 1-2; pl. 3, figs 1-2; pl. 4, figs 1-2; pl. 5, figs 1-2; pl. 6, figs 1-2, 4; pl. 7, figs 1-3.
 1987 *Phyllocrinus stellaris* ZARĘCZNY, 1876 – GŁUCHOWSKI: 32-34; figs 15.3; pl. 11, figs 1-6; pl. 12, figs 1-6; pl. 13, figs 1-4.
 ?1987 *Phyllocrinus belbekensis* ARENDT, 1974 – GŁUCHOWSKI: 34; figs 15.5; pl. 14, figs 1-6.
 2008 *Phyllocrinus belbekensis* ARENDT, 1974 – ZATOŃ, SALAMON & KAZMIERCZAK: 563-564; figs 2.D₁-D₃.

Material: 32 cups and 7 cup fragments from samples NU 10.30 to NU 13.80 (NHMW 2008z0226/0001 to 0005, 2008z0227/0001 to 0013). No columnals or brachials were found that could be assigned with confidence to this taxon.

Description: Small cups with pentagonal outline, usually reaching a horizontal diameter of 1.5 mm only. Rarely, larger specimens of up to 2.4 mm were recovered from the samples. The thecal outline and shape varies from more flattened forms to forms with subequal diameter and height. In profile, the cup expands gradually upward to the proximal margin of the arm facets (figs 6.3b, 6.4a). More distally, it becomes narrower again.

The cup consists of 5 radials only; no basals are present. The sutures between the radials are poorly visible and are in broad but shallow furrows on the proximal part of the cup. The radials bear a sharp median keel on the aboral surface (fig. 6.1b). The articulation facets are small and set in a deep radial notch (fig. 6.3a), separated from the deep oral cavity by a transversal septum. Distinct ledges that are sharply separated from the remaining radial surface are situated around the arm facets (fig. 6.3a). The interradial processes are high, narrow and acute triangular. The base is very regularly pentagonal and sharply delimited. The facet to the stem shows a central elevation pierced by an axial canal (fig. 6.1a). The surface of the cup is smooth.

Remarks: The mature specimen figured by PISERA & DZIK (1979: figs 11c; pl. 4, fig. 1) differs from the present specimens by its larger stem facet. The same is true for some of the specimens figured by ARENDT (1974: figs 9ġ, 20), but is here considered to represent natural variation by allometric growth. Otherwise, the present material is almost identical to the material of ARENDT (1974).

According to PISERA & DZIK (1979: 823, 825), *P. belbekensis* differs from *Phyllocrinus stellaris* ZARĘCZNY, 1876 by its angular radials with sharp median keel, sharply delimited ledges around arm facets and the narrow interradial processes. Specimens attributed to *P. stellaris* by GŁUCHOWSKI (1987: 32-34) are unlike those described by ZARĘCZNY

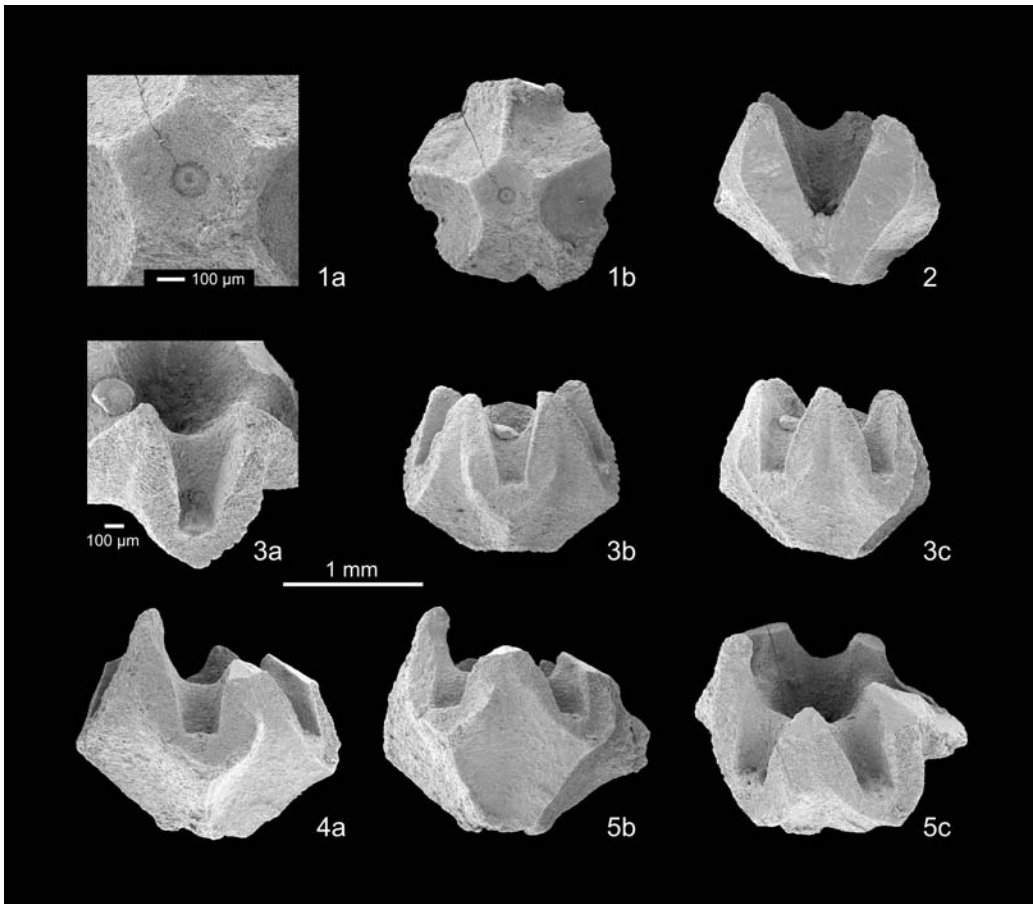


Fig. 6: Cups of *Phyllocrinus belbekensis* ARENDT, 1974, Tithonian, Nutzhof, Austria (sample NU 12.30); 1a-b: NHMW 2008z0226/0003; 2: NHMW 2008z0226/0004; 3a-c: NHMW 2008z0226/0001; 4a-c: NHMW 2008z0226/0002).

(1876: 213-214, pl. 1, fig. 9) and PISERA & DZIK (1979) and are referred to *P. belbekensis* here. Under the latter name, GŁUCHOWSKI (1987: pl. 14, figs 1-6) illustrated strongly corroded *Phyllocrinus* cups of questionable specific affinity. *Phyllocrinus minutus* ZARĘCZNY, 1876 is the only other *Phyllocrinus* similar in shape, but like *P. stellaris* lacks the characteristic ledges around the arm facets of *P. belbekensis*.

Occurrence: Early to Middle Oxfordian of the epicratonic shelf deposits in southern Poland (ZATOŃ, SALAMON & KAZMIERCZAK 2008); Oxfordian of the Western Carpathians, Slovakia (ŽÍTT & MICHALÍK 1984); Early to Middle Tithonian of the Pieniny Klippen Belt, Poland (PISERA & DZIK 1979; GŁUCHOWSKI 1987); Early to Late Tithonian (*Semiradiata* Zone to *Praetintinnopsella* Zone) of Nutzhof, Klippenbelt, Austria (this study); Hauterivian of Krimea, Ukraine (ARENDR 1974).

Results

The crinoid fauna recovered from the bulk samples of Nutzhof is typical for Upper Jurassic strata of Central and Eastern Europe. The low diversity may be interpreted as a result of the distal position of the section, which represents a deep water facies. It seems possible, that the crinoid material, apart from the saccocomids, is of allochthonous origin. Indeed, microfacies analysis carried out by LUKENEDER (2009) indicates the presence allodapic material. This is also supported by the narrow size ranges represented by the isocrinid and phyllocrinid ossicles that could be explained by transport-induced size-sorting. Additionally, only the calyces of *Phyllocrinus* are preserved, whereas more fragile parts of the skeleton (columnals and brachials) are missing. Saccocomid remains, in contrast, do not show sorting and include abundant fragile elements. This part of the crinoid fauna is thus interpreted as being autochthonous.

Biostratigraphically, only the saccocomid remains are useful, *S. tenella* being restricted to the Late Kimmeridgian to Late Tithonian. The other species recovered, *Balanocrinus* sp. and *P. belbekensis*, have long stratigraphic ranges. From a biogeographic point of view the faunal composition indicates connections with the contemporaneous units in Eastern Europe. This is a result of the palaeogeographic position of the section on the Helvetic Shelf, on the southern slope of the European Massif (Northern Tethys Shelf; HOFMANN et al. 2002).

The replacement of saccocomid marl and limestone by calpionellid limestone in the Late Tithonian, as observed at the Nutzhof section, appears to be very characteristic. Similar successions were reported from numerous other regions in Austria (e.g. KRISTAN-TOLLMANN 1962: Gresten Klippen Belt, Frankenfels Nappe; FLÜGEL 1967: Northern Calcareous Alps; HOLZER 1968, 1980: Northern Calcareous Alps; HOLZER & POLTNIK 1980: Karawanken Mts.; REHÁKOVÁ et al. 1996: Gresten Klippen Belt, Frankenfels Nappe), Germany (LACKSCHEWITZ et al. 1989: Northern Calcareous Alps), Poland (PSZCZÓŁKOWSKI & MYCZYŃSKI 2004: Pieniny Klippen Belt) and Slovakia (VAŠIČEK et al. 1992: Western Carpathian Klippen Belt). Many of these occurrences, however, differ lithologically from the Nutzhof section. In most cases the saccocomid-bearing beds are pure, reddish limestone.

In many cases the saccocomid limestones have been interpreted as Kimmeridgian deposits (e.g. FLÜGEL 1967: 35; SAUER et al. 1992: 183; WESSELY 2008: 210, fig. 5) and have been used as a marker bed for that stage (BERNOULI 1972). Good stratigraphic evidence, however, is lacking in most cases and detailed analyses are needed to verify the supposed Kimmeridgian ages. Based on well-date sections, the major occurrences of saccocomids are of Tithonian age (NICOSIA et al. 1979; KEUPP & MATYSZKIEWICZ 1997), which holds true for the present section as well.

The distribution pattern (fig. 2) of the crinoids in the Nutzhof section is clearly non-random. *Saccocoma tenella* is restricted to the lower 6 m of the section; co-occurring with juvenile isocrinid columnals attributed to *Balanocrinus* sp. in the lower part (samples NU 17.85 to 14.10). Above (NU 13.80 to 10.30), calyces of the cyrtocrinid *Phyllocrinus belbekensis* appear, while saccocomid remains become rare and vanish (last abundant occurrence in sample 11.50). The replacement of the isocrinids by the cyrtocrinid *P. belbekensis* is clearly not a stratigraphic signal because both taxa have longer ranges elsewhere. Rather, this change reflects biotic changes in the source area of the

re-deposited bioclasts. Likewise, the switch to more pure carbonates upsection and thinning of the intercalated marls may relate to changes of current patterns, possibly caused by geodynamically induced palaeogeographic changes and/or basinal deepening.

Conclusions

Four crinoid taxa were documented from the Tithonian Blassenstein Formation of the Nutzhof section: *Balanocrinus* sp., *Saccocoma tenella* (GOLDFUSS, 1831), *Crassicoma*? sp., and *Phyllocrinus belbekensis* ARENDT, 1974. Of these, only *S. tenella* is abundant. The other taxa, in particular the benthic isocrinids and phyllocrinids, are rare. The preservation state and ossicle size range of the latter groups indicate their allochthonous origin.

The saccocomid remains are restricted to the Tithonian at the Nutzhof section, the saccocomid-rich facies being replaced by calpionellid limestones upsection. Literature data suggests that this is the main interval of saccocomid distribution. The use of an abundant occurrence of saccocomids as a marker for Kimmeridgian strata appears unsuitable.

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