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Coniacian and Santonian inoceramid bivalves from the Gosau-Group (Cretaceous, Austria) and their biostratigraphic and palaeobiogeographic significance.

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(With 3 plates, 4 text-figures and 15 tables)

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Abstract

Sixteen taxa of Inoceramidae (Bivalvia) are described from the Coniacian/Santonian of the Gosau-group of Austria, some for the first time. Inoceramid stratigraphy of the NW-German and Polish Late Cretaceous (TRÖGER 1989) is correlated with the inoceramid sequence of the Gosau-group. This sequence is based upon lithostratigraphic sections (KOLLMANN & SUMMESBERGER 1982 and unpublished data) and data from ammonoids (SUMMESBERGER 1979, 1985) and Foraminifera (WILLE-JANOSCHEK 1966; WEISS 1975). Newly collected well-horizoned Inoceramidae and the reinterpretation of previously collected material allow a more detailed biostratigraphical subdivision of the interval investigated than can be achieved by other methods. Separation of the Lower Coniacian of the Gosau-group and the determination of the stratigraphic succession of the Mid-Coniacian ammonite faunas are sucessfully achieved for the first time. Evidence of Upper Coniacian near the top of the Streiteck Formation and of immediately overlying Lower Santonian sediments provide proof that the major part of the Streiteck Formation is of Coniacian age.

Keywords: Upper Cretaceous, bivalves, Inoceramidae, stratigraphy, Eastern Alps, Middle Europe.

Zusammenfassung

Sechzehn Taxa Inoceramidae (Bivalvia) werden zum Teil erstmals aus dem Coniac/Santon der Gosau-Gruppe beschrieben. Die Inoceramenstratigraphie der NW-deutschen und polnischen Oberkreide (TRÖGER 1989) wird zur Inoceramenfolge der Gosau-Gruppe in Beziehung gesetzt. Diese Folge fußt auf lithostratigraphischen Profilaufnahmen (KOLLMANN & SUMMESBERGER 1982 und unpublizierte Daten) sowie auf stratigraphischen Daten der Foraminiferen (WILLE-JANOSCHEK 1966, WEISS 1975) und Ammoniten (SUMMESBERGER 1979, 1985). Horizontierte Aufsammlungen von Inoceramen und Neuinterpretation von Sammlungsmaterial erlaubt eine feinere biostratigraphische Gliederung der untersuchten Zeitabschnitte als die bisher angewandten Methoden. Erstmals ist die Abtrennung des Unterconiacs im Sinne der Inoceramenstratigraphie und die biostratigraphische Reihung der Ammonitenfaunen des Mittelconiac gelungen. Der Nachweis von Oberconiac im Hangendbereich der Streiteck-Formation ergibt zusammen mit dem unmittelbar darüber nachgewiesenen Untersanton Gewißheit, daß der größere Teil der Streiteck-Formation dem Coniac angehört.

Schlüsselwörter: Obere Kreide, Bivalven, Inoceramidae, Stratigraphie, Ostalpen, Mitteleuropa.

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Introduction

Biostratigraphic subdivision of the NW German and Sudetic (following SCUPIN 1910: Bohemian, Saxonian and Sudetian areas) Late Cretaceous is based on ammonites, inoceramids, belemnites and echinoids. The inoceramids are powerful tools in biostratigraphy because of their general abundance and relative facies independence. Detailed inoceramid stratigraphy of the North European Province (E.G. KAUFFMAN 1973) was established through investigations by ANDERT (1911, 1933, 1934), HEINE (1929), HEINZ (1928a, b; 1932), SEITZ (1961, 1965, 1967, 1970) and TRÖGER (1974, 1987). Modern biostratigraphical subdivision of the Gosau-group was carried out by micropaleontologists between 1954 and 1981 (see KOLLMANN & SUMMESBERGER 1982: 16) and refined by WAGREICH (1988, 1992). A wealth of systematic, biostratigraphic and biogeographic data resulted from the investigation of ammonites (WIEDMANN 1978; SUMMESBERGER 1979, 1980, 1985; KENNEDY, KLINGER & SUMMESBERGER 1981; KENNEDY & SUMMESBERGER 1986). SUMMESBERGER (1985: 154, tab. 2) attempted to establish the stratigraphic sequence of the Austrian Coniacian sites on the basis of the revision of the French Coniacian by KENNEDY (1984). An Upper Turonian age was suggested for the first time by SUMMESBERGER (1985, l.c.) for basal units of the Gosau-group of Brandenberg (Tyrol). The discovery of *Barroisiceras haberfellneri* (HAUER) also indicates the presence of top Turonian sediments in the Gosau basin (SUMMESBERGER & KENNEDY, in prep.). Ammonites made correlation possible between the "Tethyan Realm" of the Gosau occurrences and the "Northern Lower Temperate Realm". Inoceramids of the Gosau-group were described previously (e.g.: ZEKELI 1852, ZITTEL 1864, PETRASCHECK 1906, BRINKMANN 1935) but not used extensively for biostratigraphy. Few attempts were made to correlate the known inoceramids of the Gosau basin with those of well studied NW German and Polish Upper Cretaceous inoceramid assemblages.

The application herein of the NW German/Polish inoceramid stratigraphy to the alpine Gosau-group is based on fieldwork by the authors in selected Coniacian/Santonian sections, studies of the collections of the Naturhistorisches Museum Wien and the private collections of W. P. MAHERNDL (Bad Ischl) and Dr. P. SKOUMAL (Wien).

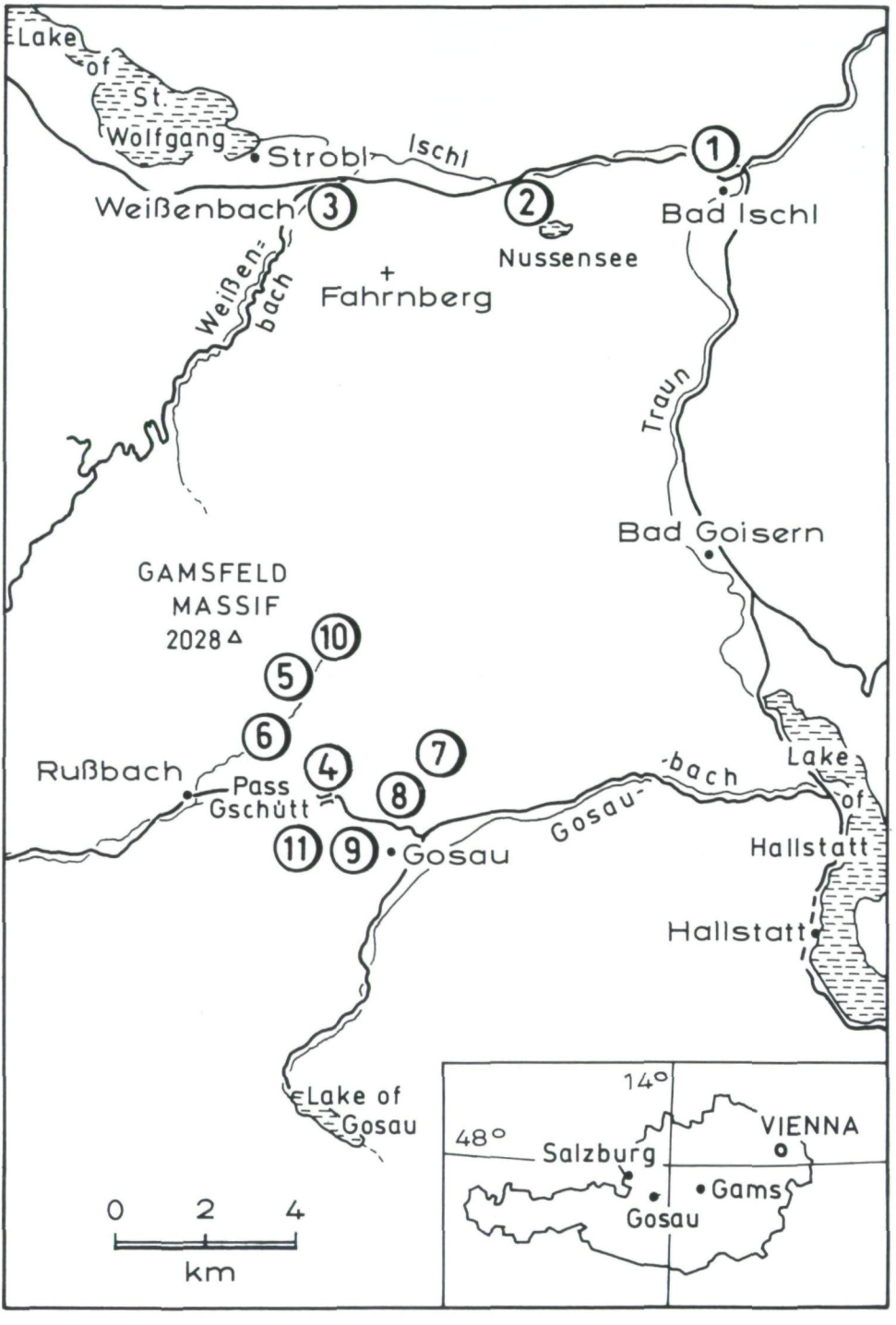
The major part of the recently collected material is stored in the Naturhistorisches Museum Wien, the minor part in the collections of the Bergakademie Freiberg (BAF). The systematic section deals with description, discussion and stratigraphic range of the described taxa. For full synonymies the reader is referred to the references given. Palaeobiogeographical conclusions are discussed below (p. 179).

Abbreviations

NHMW Naturhistorisches Museum Wien
SK Collection SKOUMAL, Wien
MA Collection MAHERNDL, Bad Ischl
BAF Bergakademie Freiberg/Sachsen (TU)
GIUW Geologisches Institut Universität Wien
BSP Bayerische Staatssammlung für Paläontologie und historische Geologie, München.

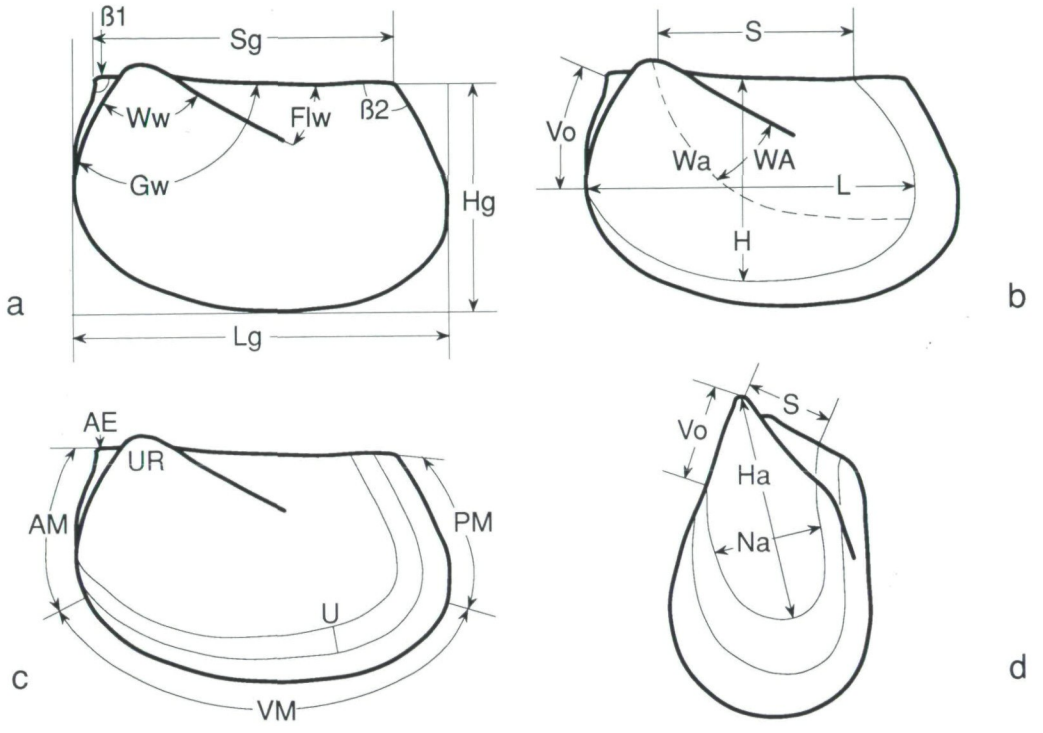
	Westphalia KAPLAN & KENNEDY 1994	France KENNEDY 1984	Central- and Eastern Europe TRÖGER 1989, this paper	
L. Santonian	*Texanites texanus*	*Texanites (Texanites)*	Zone 25 *S. cardissoides* *S. pachti*	L. Santonian
Upper Coniacian	*Paratexanites serratomarginatus*	*Paratexanites serratomarginatus*	Zone 24 *M. subquadratus*	Upper Coniacian
Middle Coniacian	*Gauthiericeras margae*	*Gauthiericeras margae*	Zone 23 *M. subquadratus* *Volviceramus involutus* *I. (S.?) subcardissoides*	
Lower Coniacian	*Peroniceras tridorsatum*	*Peroniceras tridorsatum*	Zone 22 *V. involutus* *V. koeneni* *P. mantelli*	Middle Coniacian
	Forresteria petrocoriensis	*Forresteria petrocoriensis*	Zone 21 *C. crassus* *C. ernsti*	Lower Coniacian
	No index ammonites		Zone 20 *C. rotundatus*	
		Hiatus		
Upper Turonian	*Prionocyclus germari*		Zone 19 *S. striatoconcentricus* *I. c. costellatus*	Upper Turonian

Tab. 1. Termini Upper and Middle Coniacian are used in this paper as suggested by KENNEDY (1984) and TRÖGER (1989). *C. crassus* replaces *C. schloenbachi* following WALASZCZYK (1992).



Text-fig. 1. Sketch map of the localities mentioned in the text.

1. Bad Ischl, tunnel section, 2. Nussenseebach, 3. Schmolnauer Alpe, 4. Paß Gschütt Graben, 5. Stöcklwaldgraben, 6. Randobach, 7. Edelbach, 8. Grabenbach, 9. Bibereck/Finstergrabenwandl, 10. Neualpe, 11. Schattau.



Text-fig. 2. Shell terminology used in this paper, in brackets terminology in German literature.

Sg-hinge line length (Schloßrandlänge) Hg-height (Gesamthöhe)
Lg-length (Gesamtlänge)
Ww-beak angle (Wirbelwinkel)
Gw-total angle (Gesamtwinkel)
Flw-wing angle (Flügelwinkel)
1 anterodorsal angle (vorderer Dorsalwinkel)
2 posterodorsal angle (hinterer Dorsalwinkel)
AM=Vo-anterior margin (Vorderrand)
PM-posterior margin (Hinterrand)
VM-ventral margin (Unterrand)
UR=UP-umbonal region, umbonal part, umbonal pole, umbonal area (Wirbelspitze)
AE-length of anterior auricle (Länge des vorderen Ohrs)
U-distance between two undulations (Abstand zwischen zwei Undulationen)
DU-average distance between undulations (durchschnittlicher Undulationsabstand)
UD-Distance of undulations from the beak (Abstand der Undulation von der Wirbelspitze)
Wa-growth axis (Wachstumsachse)
WA-angle of the growth axis (Winkel der Wachstumsachse)
S-equidistance of an undulation at the hinge line (Schloßrandabschnitt einer Undulation)
H-height of an undulation (Höhe einer Undulation)
L-length of an undulation (Länge einer Undulation)
Ha-axial length of an undulation (Länge der Hauptachse einer Undulation)
Na-secondary axis of an undulation (Länge der Nebenachse einer Undulation).

Systematic palaeontology

Preservation

Inoceramids of the Gosau-group are generally preserved as internal moulds of separated right and left valves with adherent shell in most cases. The ligament area is usually missing. Isolated ligament ridges can occasionally be observed. All specimens are more or less crushed and occasionally shell fragments overlap or are even superimposed. When specimens are obliquely placed in the sediment their umbo can be situated beyond the commissure or above the auricles. Especially affected are the involute forms. No muscle scars were observed. Diagenetically caused radial cracks are common (figs. 17, 20). Also, prediagenetic decay is indicated by numerous shell fragments with shell thickness up to 7 mm (e.g. middle Santonian; Grabenbach, Gosau). Especially large forms (Hg > 10 cm) are usually broken up in this manner. The matrix of the studied steinkerns consists of clayey shales to marly limestones.

Family Inoceramidae GIEBEL, 1852

Genus *Inoceramus* J. SOWERBY, 1814

Inoceramus sp. aff. *percostatus* G. MÜLLER, 1888

(Pl. 2, fig. 6, 6a)

* 1888 *Inoceramus percostatus* G.MÜLLER: 413, 414, pl. 17, Fig. 3a–c.

Material: Internal mould of a right valve with adherent shell. GIUW 86/II/100. Gams (Steiermark), Anerlbauerkogel.

Description: Incomplete specimen, parts of the auricle and of the ventral margin are missing. Gw = 94°, Hg = 57.2 mm. The umbo is separated from the auricle, beak is slightly curved and inclined towards the anterior margin. WA from 60 to 64°. The average interval of the undulations at a distance of 30–50 mm from the umbonal pole is 6.5 mm, at a distance of 50–70 mm from the umbonal pole 10.6 mm.

UD	Na/Ha	Vo/Ha	S/Ha
10–30 mm	85 %	59 %	63 %
30–50 mm	80.8 %	59.7 %	65.6 %

Tab.2. The average Na/Ha-, Vo/Ha- and S/Ha-ratios in *Inoceramus* sp. aff. *percostatus* G. MÜLLER. UD = distance from the umbonal pole.

Remarks: The Gams specimen agrees well with *Inoceramus percostatus* G.MÜLLER for general features of shell and beak, for the Na/Ha ratio, and for the undulation intervals. It lacks the radial depression of the type specimen of *I. percostatus*, and it has a somewhat lower Vo/Ha ratio (59 % versus 81 %).

Inoceramus percostatus MÜLLER mentioned from the Lower Santonian shales of Brandenberg (Tyrol) by FISCHER (1964: 131) is not discussed here. His material could not be traced in the collections of the BSP, neither was it discussed by KAUFFMAN in: HERM, KAUFFMAN & WIEDMANN (1979) nor mentioned by IMMEL, KLINGER & WIEDMANN (1982: 7).

Stratigraphic occurrence: *Inoceramus percostatus* G.MÜLLER occurs in the Middle Coniacian. Some not specifically identified specimens from the Subhercynian Creta-

ceous basin, which is a southern part of the NW German-Polish basin, identical with the Gams specimen, are also of Mid Coniacian age.

Geographic distribution: Western-, Middle- and Eastern Europe.

Inoceramus cf. *simplex* LANGENHAN & GRUNDEY (non STOLICZKA 1871)

(Pl. 1, fig. 2)

* 1871 *Inoceramus simplex* – STOLICZKA: 408, pl. 28, fig. 3a, 4a.
v. 1891 *Inoceramus simplex* – LANGENHAN & GRUNDEY: 12, pl. 5, fig. 5.

Material: Internal mould of a right valve. NHMW/1994/256. Strobl/Weißenbachtal, 30 m E of the Schmolnauer Alpe.

Description: Slightly flattened incomplete right valve. The beak is separated from the auricle and distinctly curved to the concave anterior margin. Gw = 95°, Flw = 30°, WA increases from 51° (Ha = 16.5 mm) to 60°(Ha = 40 mm). The average undulation interval at a distance of 10–30 mm from the umbonal pole is 3.5 mm, Na/Ha is 78.4 %, Vo/Ha is 55.2% and S/Ha is 53.5 %.

Remarks: We compare the specimen from Strobl/Weißenbachtal with *Inoceramus simplex* described and figured by LANGENHAN & GRUNDEY (1891, pl. 5, fig. 5, 6, 7). The Na/Ha-, S/Ha-indices of the specimen figured by LANGENHAN & GRUNDEY are somewhat lower. This is also the case for the growth axis.

Stratigraphic distribution: Early to Middle Coniacian (in Silesia and the Subhercynian Cretaceous basin).

Genus *Mytiloides* BRONGNIART, 1822

Mytiloides cf. *sublabiatus* (G. MÜLLER, 1888)

(Pl. 1, Fig. 1, 1a)

v.* 1888 *Inoceramus sublabiatus* G.MÜLLER: 411, pl. 16, fig. 2.

Material: One bivalved specimen (NHMW/1989/50/5), Strobl/Weißenbachtal, 30 m E of the Schmolnauer Alpe.

Description: Both valves are slightly detached at the ligament area and somewhat flattened; the left valve is more completely preserved, but nevertheless, the auricle and the ventral commissure are not preserved. The characteristic mytiloid shape is accompanied by a slight inclination of the beak towards the anterior margin. In both valves the beak extends only just beyond the auricle. The anterior margin is directed steeply outward. Gw = 87°, WA increases from 45° at Ha 20 mm to 48° at Ha 60 mm. The Na/Ha-ratio ranges at Ha 56 from 65–71% (left valve) and from 60–71% (right valve). The Vo/Ha-ratio increases in both valves from 47–66% (right) and from 65–71% (left). The average undulation interval at a distance of 30–50 mm from the umbonal pole is 3.8 mm (right) and 4.7 mm (left).

Remarks: The Na/Ha-indices of the holotype of *Mytiloides sublabiatus* (G.MÜLLER) from the Subhercynian Cretaceous Basin are somewhat higher (average 10 %). Additionally, the curvature of the beak to the front margin is missing. Individuals from the Subhercynian Cretaceous Basin comparable with NHMW/1989/50/5 are thought to be within the limits of intraspecific variation.

Stratigraphic distribution: Early to Middle Coniacian (Europe, Western Asia).

Genus *Cremnoceramus* Cox, 1969 (non Heinz, 1932)

***Cremnoceramus crassus* (Petrascheck, 1903)**

(Pl. 1, figs. 4, 5)

1835 *Inoceramus cuvieri* Sow. – Goldfuss (non J. Sowerby): 114, pl. 111, fig. 1a–c.
v.* 1903 *Inoceramus crassus* nov. spec. – Petrascheck: 164–169, pl. 8, fig. 4a–c.
1913 *Inoceramus schloenbachi* J. Böhm – Böhm: p. 569.
v. 1934 *Inoceramus schloenbachi* J. Böhm – Andert: pl. 3, fig. 2, text-fig. 8.
v. 1992 *Inoceramus crassus* Petrascheck – Walaszczyk, p. 545, text-fig. 17; pl. 34, figs. 1–4; pl. 35, figs. 1–3. (with additional synonymy)

Material: Two right valves (NHMW/1989/51/2, 7) and several unregistered specimens in the Maherndl collection. Tunnel section N of Bad Ischl.

Description: The measured individuals (NHMW/1989/51/2, 7) are internal moulds of right valves. NHMW/1989/51/2 is flattened, NHMW/1989/51/7 obliquely flattened. Both specimens have distorted umbonal regions. Their ventral margins are also badly preserved. The heavy deformation makes a strong original inflation likely. The Na/Ha-ratio ranges from 70 to 80%, the undulation interval (NHMW/1989/5/2 below Ha 50 mm: 2–3.5 mm, above Ha 50 mm: 12–20 mm) and Gw = 110° are all within the the specific variation of *Cremnoceramus schloenbachi* (J. Böhm) (see Tröger 1967: 207, textfig. 42 under *Inoceramus deformis* Meek). The Na/Ha-indices of the crushed specimen NHMW/1989/51/7 are different. Undulations are scalariform.

Remarks: We agree with Walaszczyk (1992: 54), who considered *Cremnoceramus schloenbachi* (J. Böhm) to be a junior synonym of *Cremnoceramus crassus* (Petrascheck). The term *Schloenbachi*-Zone should be preserved for reasons of stability in the stratigraphical terminology. Čech (handwritten label) identified NHMW/1989/51/2 as *Inoceramus (Cremnoceramus) schloenbachi* J. Böhm.

Stratigraphic distribution: *Inoceramus crassus* Petrascheck is an index species of the Lower Coniacian. It is absent or very rare in the basal Coniacian.

Geographic distribution: Europe, N-America, Western Asia.

***Cremnoceramus ernsti* (Heinz, 1928)**

(Pl. 1, Fig. 6)

* 1911 *Inoceramus Lamarcki* Park. – Woods: 307–327, text-fig. 85.
1928a *Inoceramus ernsti* n.sp. – Heinz: 73–74.
v. 1967 *Inoceramus ernsti* Heinz – Tröger: 128–130, pl. 14, figs. 1–6.
1992 *Cremnoceramus ernsti* Heinz, 1928 – Walaszczyk: 55, text-fig. 18, pl. 32, figs. 1–3 (with synonymy).

Material: One specimen NHMW/1989/51/3 from the tunnel section N of Bad Ischl.

Description: The described specimen is a flattened internal mould of the umbonal region of a right valve. Large parts of the auricle and the ventral margin are missing. The anterior margin (Vo; Pl. 1, Fig. 6) is steeply inclined inwards and slightly bent. The stout beak does not extend beyond the auricle and is slightly curved towards the anterior margin.

Obtainable H/L-ratios are between 85–90%, the Vo/L-ratios between 45–55%. GW is presumed to be greater than 90°. The beak is smooth until H = 23 mm, followed by *costellatus*-like undulations (9.2 mm, 9.0 mm, 13.5 mm, 8.5 mm). All indices lie within the variation of *Inoceramus (Cremnoceramus) ernsti* HEINZ (see TRÖGER 1967: 41).

Remarks: The description of the species (HEINZ 1928: 73, 74) is based only upon text-figure 85 of WOODS (1911) which represents a specimen of unknown origin.

Stratigraphic distribution: The vertical and geographic distribution of *Cremnoceramus ernsti* is identical to *C. crassus* (PETRASCHECK).

Cremnoceramus sp. aff. *deformis* MEEK, 1877

(Pl. 1, Fig. 7, 7a)

v.* 1877 *Inoceramus deformis* MEEK: 146–148, pl. 14, fig. 4.
v. 1992 *Cremnoceramus deformis* (MEEK) – WALASZCZYK: 52–53, text-fig. 17, pl. 29, fig. 4; pl. 30, fig. 4. (with additional synonymy).

Material: 2 specimens. MA (unregistered) is an internal mould of a right valve, NHMW/1989/51/4a of a left one. Tunnel section N of Bad Ischl.

Description: Both individuals have large parts of the auricle and the whole ventral margin missing. The umbonal region of NHMW/1989/51/4a protrudes obliquely over the anterior margin. The specimen from the MA collection is flattened with distinct radial cracks. Adherent shell remains are up to 6.5 mm thick. NHMW/1989/51/4a additionally has parts of the ligament ridge preserved (Pl. 1, fig. 7). Both individuals are elongate. In MA (unregistered) Na/Ha lies between 100 and 88% and Vo/Ha between 34 and 56 % at Ha 50 mm. Conspicuous in both individuals is the increasing undulation interval from 4.5–5.5 mm to more than 35 mm in the preserved ventral region.

Remarks: Concerning the overall shape and the undulation intervals, both individuals differ considerably from the holotype of *Cremnoceramus deformis* (MEEK) (a cast has been studied). On the holotype the undulations are closer together at equal distance from the umbonal pole than on the Gosau specimens. The same is also true for the specimens of *Cremnoceramus deformis* (MEEK), figured by WALASZCZYK (1992: textfig. 17). The specimen figured by HEINZ (1928 a: pl. 2, fig. 1) differs from the holotype but is similar to the specimens from the Gosau. ČECH (handwritten label) associated NHMW/1989/51/4a with the *I. deformis*-group.

Stratigraphic distribution: *Cremnoceramus deformis* (MEEK) occurs frequently in strata of Early Coniacian age. Specimens with differing undulation intervals are characteristic of the middle and higher part of the Lower Coniacian *Schloenbachi*-Zone of the NW German and Polish Cretaceous basin (HEINZ 1928 a: pl.3; TRÖGER 1974: 115, 116).

Geographic distribution: N-America, Europe, Western Asia.

Genus *Volviceramus* STOLICZKA, 1871

Volviceramus koeneni (G. MÜLLER, 1888)

(Pl. 2, fig. 1, 2, 3)

* 1888 *Inoceramus (Volviceramus) Koeneni* G.MÜLLER: 412–413, pl. 17, fig. 1.
v. 1969 *Inoceramus koeneni* G. MÜLLER – TRÖGER: 68–81, pl.1, figs.1–6; pl.2, figs. 1–5; text-figs. 1–8.

Material: Two bivalved specimens (MA unregistered, NHMW/1989/51/6) from the tunnel section N of Bad Ischl and a single left and two isolated right valves (NHMW/1989/50/4, 11) from Strobl/Weißenbachtal, 30 m E of the Schmolnauer Alpe.

Description: All specimens are internal moulds with adherent shell remains. Parts of the auricles and the ventral margins and large parts of the ligament ridge are generally missing. The beaks are slightly involute and turned towards the anterior margin. The tapering beak of the left valve of this inequivalved species is visible (Pl. 2, fig. 2). Both valves are very strongly inflated. The umbonal region is damaged by flattening in some specimens (e.g. NHMW/1989/51/6). Superimposed shell fragments render measurement of these specimens pointless. Even the data of the better ones, NHMW/1989/50/4 and MA (unregistered; the original of pl. 2, fig. 2) are more or less changed by compaction. Obtainable NA/Ha-ratios are between 60 and 91% in right valves, between 65–85% in left ones.

Distance from UP	DU/SCB	DU/GG
30–50 mm	r 4.0 – 8.0 mm	5.1 mm/4.75 mm
	l 2.1 – 8.0 mm	3.25 mm
50–70 mm	r 5.1 – 9.0 mm	5.1 mm
	l 5.1 – 10.0 mm	7.37 mm

Tab. 3. Comparison of undulation intervals (DU) of specimens from the Subhercynian Cretaceous basin (SCB) and from the Gosau-group (GG).

Remarks: The NA/Ha-ratios of the Gosau specimens are within the variation range of *Volviceramus koeneni* (G. MÜLLER) from the Middle Coniacian of the type locality Steinholz (NW Quedlinburg) in the Subhercynian Cretaceous basin.

The same is the case of the average undulation intervals (DU) in 30–50 mm and 50–70 mm distance from the umbonal pole (tab. 3). Taking the considerable deformation into account, the total angle (Gw) also has comparable values: 115–165° in the SCB (complete variability of undeformed specimens), 110° (crushed) and 125° (not deformed) in the Gosau. Radial grooves between undulations (pl. 2, fig. 2) occur in specimens from both areas. The shell thickness in different parts of the valves is also comparable.

Stratigraphic occurrence: *Volviceramus koeneni* (G. MÜLLER) occurs frequently together with different species of *Peroniceras* and with *Scaphites kieslingswaldensis* LANGENHAN & GRUNDEY in the Middle Coniacian. Together with inoceramids of the *Magadiceramus subquadratus*-group it occurs through the *Volviceramus involutus*-Zone to the base of the Upper Coniacian.

Geographic distribution: N-America, Europe, Western Asia, N-Africa.

Volviceramus involutus (J. de C. SOWERBY, 1828)

(Pl. 2, fig. 5, aff.: fig. 4)

* 1828 *Inoceramus involutus* J.de C. SOWERBY: 160–161, pl. 583, figs. 1–3.
1992 *Volviceramus involutus* (SOWERBY, 1828) – WALASZCZYK: 5, pl. 37, fig. 5 (with additional synonymy).

Material: Two right and several fragments of left valves. (NHMW/1994/238), BAF/Tr./1993/Go.1) from the Stöcklwaldgraben (Rußbach). One bivalved specimen (MA unregistered) from the ditch close to Paß Gschütt is tentatively assigned to *Volviceramus* sp. aff. *involutus* SOWERBY.

Description: All specimens are strongly flattened internal moulds, mostly with adherent shell fragments. The type of flattening indicates originally strongly inflated shells with especially thin umbonal regions. Inflation of left valves must have been even more pronounced than characteristic for involute inoceramids. The narrowly rounded beak is visible. Shell surface is ornamented by growth striae only. Shell thickness increases towards the ventral margin (6 mm). The reason for the assignment of the specimen from the Paß Gschütt area to the *V. involutus*-group is the particularly narrowly rounded beaks on both valves.

Stratigraphic distribution: *Volviceramus involutus* (SOWERBY) occurs in the Middle and basal Upper Coniacian (N-America, Europe, Western Asia). The acme is above that of *Volviceramus koeneni* (G. MÜLLER).

Geographic distribution: world-wide.

Genus *Platyceramus* HEINZ, 1932

Platyceramus mantelli mantelli (de MERCEY, 1872; sensu BARROIS, 1878)

(Pl. 2, figs. 7, 8)

1872 *Inoceramus Mantelli* de MERCEY: 21.
* 1877 *Inoceramus Mantelli* de MERCEY: 324, pl. 1, 2.
1878 *Inoceramus Mantelli* de MERCEY – BARROIS: 478.
1879 *Inoceramus Mantelli* de MERCEY; BARROIS: 454, pl. 54, figs. 1, 2.
1962 *Inoceramus (Platyceramus) mantelli* MERCEY (BARROIS) – SEITZ: 355–363, text-figs. 1, 3, 4; pl. 10, pl. 11, figs. 1, 2, 6; pl. 12, figs. 3.
1990 *Inoceramus (Platyceramus) mantelli* de MERCEY – NODA & TOSHIMITSU: 485–512, 16 figs.

Remarks: Reinterpretations were given by SEITZ (1962) and NODA & TOSHIMITSU (1990).

Material: Two internal moulds of left valves preserved partially with shell from Nussenseebach (NHMW/1994/239) and from the tunnel section N of Bad Ischl (NHMW/1989/51/1).

Description: Both specimens are incomplete, parts of the auricle and the ventral margin are missing. Radial cracks (Pl. 2, fig. 7, 8) indicate slight flattening. The geniculated anterior margin slopes towards the commmissure. The existence of an anterior auricle is indicated in NHMW/1989/51/1.

Distance from UP	Na/Ha 1 2	Vo/Ha 1 2	S/Ha 1 2
10–30 mm	78.1% / 86.5%	50.5% / 50.5%	53.6% / 51.7%
30–50 mm	86.2% / 76.0%	51.4% / 43.7%	47.3% / 47.8%
50–70 mm	80.6% / 82.o%	56.0% / 49.4%	—— / 54.3%

Tab. 4. Averages of the Na/Ha-,Vo/Ha and S/Ha indices with increasing distance from the umbonal pole (UP).1: NHMW/1994/239, 2: NHMW/1989/51/1.

Generally the undulations equal those figured by SEITZ (1962: fig. 4). They are evenly rounded to wavelike. The distance between the undulations becomes narrower towards the ventral margin. Gw in the juvenile stage is from 96 to 100°. WA increases in NHMW/1994/239 from 28° in the umbonal region to the maximum of 65°. This is in accordance with the lectotye of *Platyceramus mantelli mantelli* (MERCEY). The pointed beaks are

slightly bent towards the anterior margin (Vo) and do not project over the auricle. The ligament ridge of NHMW/1989/51/1 measures 3.5 x 2.5 mm below the beak.

Stratigraphic distribution: *Platyceramus mantelli* (de MERCEY) occurs from basal Lower Coniacian to basal Upper Coniacian (SEITZ: 1962: 370, fig. 6) in Western Europe (*P. mantelli mantelli* especially Middle Coniacian; TRÖGER 1974: tab. 3).

Geographic distribution: Western and Middle Europe.

Platyceramus mantelli beyenburgi (SEITZ, 1965)

(Pl. 3, fig. 1, 1a)

1929 *Inoceramus circularis* SCHLÜTER var. *oblonga* n.v. – HEINE: 54.
1962 *Inoceramus mantelli angustus* n.nom. SEITZ: 367–370, pl.12, figs. 2, 5, 7; pl. 13, fig. 1.
1965 *Inoceramus mantelli beyenburgi* n.nom. SEITZ: 96, footnote.

Material: NHMW/1989/50/6, a fragment of an internal mould from Strobl/ Weißenbachtal, 30 m E of the Schmolnauer Alpe.

Description: The umbonal region of a left valve is preserved with adherent shell fragments. The fragment is diagenetically flattened and the anterior margin deformed. Gw. of the juvenile is 105°. Undulations are elongatedly ellipsoidal.

Distance from UP	Na/Ha	Vo/Ha
30–50 mm	70.4 %	60.2 %
50–70 mm	73.1 %	68.4 %

Tab. 5. Na/Ha-, Vo/Ha- and S/Ha-ratios of *Platyceramus mantelli beyenburgi* (SEITZ); (NHMW/1989/50/6).

The acute beak projects a little over the auricle and is bent slightly towards the anterior margin. WA is 50–68° and the Na/Ha-ratio is identical with the data given by SEITZ (1962: 367).

Remarks: The specimen was identified by ČECH (handwritten label) as *Inoceramus (Platyceramus) mantelli angustus* SEITZ.

Stratigraphic distribution: *Platyceramus mantelli beyenburgi* (SEITZ) occurs from basal Lower Coniacian to basal Upper Coniacian (Western Europe).

Platyceramus mantelli cf. *subrhenanus* (SEITZ, 1962)

(Pl. 2, fig. 9)

* 1962 *Inoceramus mantelli subrhenanus* n. subsp. SEITZ: 366–367, pl. 11, figs. 3, 4; pl. 12, fig. 1.

Material: NHMW/1989/50/1: a fragmentary internal mould of a right valve from Strobl/Weißenbachtal, 30 m E of the Schmolnauer Alpe.

Description: Only the umbonal area is preserved. The steeply inwards sloping and compressed anterior margin indicates diagenetic crushing. The prominent and tapering beak turns towards the anterior margin and is shifted partially over the auricle. An anterior auricle is present on the specimen studied. Gw. is 120° in the umbonal area. The Na/Ha-ratio increases between UP and Ha 55 mm from 47 to 69%, the Vo/Ha-ratio from 21 to 38% and

WA from 40 to 65°. Apparently due to deformation, the course of the undulations is pentagonally rounded.

Remarks: The prominent and tapering beak and the elongate pentagonal undulations (originally possibly oval) indicate *Inoceramus (Platyceramus) mantelli subrhenanus* SEITZ. The circular ribbing typical of the gerontic stage of the subspecies cannot be observed due to the poor state of preservation of the specimen. This is the reason for the use of open nomenclature here.

Stratigraphic distribution: The subspecies is described from the Middle Coniacian (SEITZ 1962: 366) of Western Europe.

Platyceramus cycloides ahsenensis (SEITZ, 1961)

(Text-fig. 3)

1931 *Inoceramus cycloides* WEGNER var. *quadrata* n. var. – RIEDEL: 662, pl. 74, fig. 4.
1961 *Inoceramus (Platyceramus) cycloides ahsenensis* n.nom. – SEITZ: 63–63, pl. 1, figs. 3, 7, 9, 10; textfigs. 12, 13.

Material: Internal moulds of a right (NHMW/1994/242) and a left valve (BAF/Tr./1993/Go.2) collected by the authors in 1993. Grabenbach/ Gosau.

Description: Both valves of the bivalved specimen were slightly displaced in the umbonal region. The right one is more complete. Parts of the auricle, of the anterior and ventral margin are missing. (Hg = 330 mm, Lg = 268 mm, Sg = 49 mm, Vo = 165.5 mm, Gw = 110°; Gw is possibly reduced due to crushing. In addition the left valve lacks the umbonal area. Probably the specimen was equivalve originally. Except for DU, measurements pertain to the right valve only. Both valves are flattened. Radial cracks are visible. The beak is turned slightly towards the anterior margin. It is not distinctly separated from the auricle and does not project over it. Anterior margin is slightly convex and heavily compressed. It is partially inclined towards the commissure. Due to compression, undulations are acute in the umbonal area, in non compressed areas rounded. They become flatter towards the ventral margin.

Distance from beak	Na/Ha	S/Ha	WA (°)
10–30 mm	94.4 %	———	48
30–50 mm	82.5 %	83.75%	
50–70 mm	74.75%	72.4 %	
70–130 mm	79.0 %	———	55
130–180 mm	77.3 %	———	60

Tab. 6. Average of Na/Ha-, Vo/Ha- and S/Ha-ratios at different distances from the top of the umbo. The indices lie within the variation range of *Platyceramus cycloides ahsenensis* (SEITZ).

Distance from UP	DU (SEITZ)	DU Grabenbach
20–60 mm	5.81 mm	5.81 mm
60–100 mm	7.93 mm	7.62 mm
100–140 mm	8.46 mm	7.67 mm
140–180 mm	10.40 mm	11.05 mm

Tab. 7. Average undulation intervals of the Grabenbach individual in relation to the measurements of SEITZ (1962: 67). The course of the undulations is subquadrate, particularly in the umbonal area.

Text-fig. 3. *Platyceramus cycloides ahsenensis* (SEITZ); NHMW/1994/242; reduced x 0,38.

Stratigraphic distribution: According to SEITZ (1961: 68) *Platyceramus cycloides ahsenensis* appears in the *undulatoplicatus*-Zone (Lower Santonian) and occurs throughout the Santonian up to the lowermost Campanian (very rare).

Geographic distribution: *Platyceramus cycloides ahsenensis* is recorded abundantly from Spain (LOPEZ, MARTINEZ & LAMOLDA 1992: 254), from the Pacific coast (Japan, California, Mexico and the Caribbean; l.c.: 256). It also occurs in Western, Middle and Southern Europe.

Genus *Cladoceramus* HEINZ, 1932

***Cladoceramus undulatoplicatus* (ROEMER, 1852) subsp. indet.**

(Pl. 3, fig. 2)

1852 *Inoceramus undulato-plicatus* n.sp. ROEMER: 59, pl.7, fig. 1.
1961 *Inoceramus (Cladoceramus) undulatoplicatus* ROEMER subsp. indet. – SEITZ: 106–108, pl. 5, fig. 5; pl. 10, figs. 1, 2; textfigs. 22, 24, 25.

Remarks: The species was mentioned briefly by ROEMER 1849. The complete description with figure by ROEMER followed 1852. Holotype by monotypy is the original of ROEMER 1852: 59, pl. 7, fig. 1 (SEITZ 1961: 97).

Material: Internal moulds of two left and two right valves with shell remains. Three individuals (SK/B/RA/1982/1, 2; SK/B/RA/1983/3) are from the Randobach (Rußbach, Salzburg; stop 26 of KOLLMANN & SUMMESBERGER 1982: 72), the type area of *"Hemitissotia" randoi* GERTH. SK/B/EB/1985/1 is from the Edlbachgraben (Gosau, Upper Austria) where it is also associated with *"Hemitissotia" randoi.*

Description: On the strongly flattened specimens from the Gosau, only the umbonal areas extending to the onset of the diverging ribs are preserved. This deformation influences Na/Ha-ratio (>100 %).

	Na/Ha	Vo/Ha	S/Ha
SK/B/RA/1982/1	119%	86.3%	77.9%
SK/B/RA/1983/3	130.4%	78.7%	77.1%
SK/B/EB/1985/1	103%	52%	60%

Tab. 8 Average values for the Na/Ha-, Vo/Ha- and S/Ha-ratios in 10–30 mm distance from the umbonal pole.

Gw values for the umbonal sections vary from 115 to 130°. The angles of the growth axes (WA) at Ha = 20 are between 55 and 75°. All measurements indicate a cycloid initial stage. About 5 to 6 divaricating ribs arise at different distances from the umbonal pole (15–20 mm). Ribs of SK/B/RA/1982/2, B/RA/1983/3 bifurcate. Thickness of the shell is from 0.1 to 0.2 mm.

Remarks: The described specimens differ in their cycloid initial stage from *Cl. u. undulatoplicatus* (ROEMER) and *Cl. undulatoplicatus michaeli* (HEINZ). SEITZ (1962: 106) also mentions a cycloid undulation course in *I. (Cladoceramus) undulatoplicatus* ROEMER subsp. indet. SK/B/RA/1982/2 could belong to *Cl. u. undulatoplicatus* (ROEMER). However, definite subspecific assignment of this specimen is impossible due to its incomplete umbonal region.

Stratigraphic and geographic distribution: *Cladoceramus undulatoplicatus* ROEMER is a distinct marker fossil of the Lower Santonian, predominantly of the *undulatoplicatus*-assemblage zone. It is of world-wide occurrence (N-America, N-Africa, Madagascar, Europe, Western Asia, Eastern Asia). It is recorded from the Gosau-group of Brandenberg (Tyrol), where it co-occurs with *Platyceramus cycloides* (WEGNER), *Sphenoceramus* sp. and *Texanites quinquenodosus* (REDTENBACHER) at the distinct horizon *e* (KAUFFMAN in HERM, KAUFFMAN & WIEDMANN 1979: 39, fig. 6). *Magadiceramus subquadratus* (SCHLÜTER) additionally mentioned by KAUFFMAN (l.c.) is quoted here with some doubt.

Genus *Cordiceramus* HEINZ, 1932

Cordiceramus cordiinitialis (SEITZ, 1961) subsp. indet.

(Pl. 3, fig. 4, 4a, 4b)

1961 *Inoceramus (Cordiceramus) cordiinitialis* n.sp. – SEITZ: 150–151, pl. 12, fig. 2.

Material: One bivalved specimen. Right valve: NHMW/1994/241, left valve: BAF/Tr./1993/Go.3, collected by the authors in 1993 from the Grabenbach (Gosau, Upper Austria).

Description: Bivalved specimen. The valves were found displaced about 10 cm from each other. They are strongly flattened and incomplete. Radial cracks (pl. 3, fig. 4) indicate post mortem crushing. The right valve lacks the umbo, parts of the auricle, parts of the anterior and the whole ventral margin. The left valve (pl. 3, fig. 4a) consists of the umbonal region only. Right valve (pl. 3, fig. 4): Gw: 140°, Flw: 40°; Hg (incomplete): 226 mm, Lg (incomplete): 208 mm, Sg (incomplete): 62.5 mm, Vo.: 120 mm. The prominent beak of the left valve is slightly bent to the anterior margin and distinctly separated from the auricle. The *Cordiceramus*-stage with the corners K1, K2 and K3 (left valve; pl. 3, fig. 4b) passes into a *Platyceramus*-stage at H 92.5 mm. The latter is relatively flat with slight undulations only.

Distance from UP	H/L	Vo/L	S/L	
50–80 mm	73.4 %	76.6 %	48.7 %	*Cordiceramus*-stage
80–110 mm	84.2 %	76.3 %	49.2 %	
120–150 mm	88.0 %	79.2 %	43.1 %	*Platyceramus*-stage

Tab. 9. Average ratios of H/L, Vo/L and S/L in *Cordiceramus cordiinitialis* SEITZ subsp. indet.

Distance from UP	DU
50–80 mm	6.1 mm
80–110	8.8 mm
110–130 mm	13.8 mm

Tab. 10. Average undulation interval (DU) in distances from the umbonal pole.

Stratigraphic distribution: The species occurs in the upper part of the middle Santonian *Cordiformis*-Zone (SEITZ 1961: 150) of Western Europe.

Cordiceramus muelleri germanicus (HEINZ, 1928)

(Pl. 3, fig. 5)

* 1928 *Inoceramus germanicus* – HEINZ: 82, footnote 1.
1934 *Germanoceramus germanicus* HEINZ – HEINZ: 250, pl. 21, fig. 2 (only).
1961 *Inoceramus (Cordiceramus) mülleri germanicus* HEINZ – SEITZ: 131–135, pl. 7, fig. 6.; pl. 8, figs. 1, 6, 7; pl. 15, fig. 1; text-figs. 29, 30.

Material: Internal moulds of a right (NHMW/1990/29/201) and a left valve (NHMW/1990/29/195: cf.-determination) from Finstergrabenwandl, Zwieselberg forest road, Gosau, Upper Austria; Sandkalkbank member of the Hochmoos Formation.

Description: The incomplete internal mould of the right valve is flattened considerably. Umbonal top, parts of the auricle and the ventral margin are missing. The beak is slightly turned towards the anterior margin. The course of the undulations is elongated oval in the initial stage, pentagonally rounded in the gerontic stage. On the auricle, undulations are turned towards the beak. Undulations cross the growth lines (pl. 3, fig. 5). This is only poorly indicated on the left valve. Gw values lie between 105° for the incomplete left valve and 110° for the right one.

Distance from UP	NHMW/1990/29/201		NHMW/1990/29/195	
	H/L	Vo/L	H/L	Vo/L
20–40 mm	57.5 %	71.2 %	67.1 %	
40–60 mm	66.3 %	71.8 %	———	
60–90 mm	70 %	71.0 %	———	

Tab. 11. Average H/L- und Vo/L-ratios for both valves of *Cordiceramus muelleri germanicus* (HEINZ).

Distance from UP	DU
30–50 mm	6.73 mm
50–70 mm	6.76 mm
70–90 mm	6.50 mm
90–130 mm	14.70 mm

Tab. 12. Average undulation intervals (DU) in distances from UP (NHMW/1990/29/201).

DU values agree with the indices measured by SEITZ (1961: 134). NHMW/1990/29/195 = *Cordiceramus muelleri* cf. *germanicus* (HEINZ) bears an *Endocostea* scar. Open nomenclature is used because the growth lines are not visible.

Stratigraphic distribution: Upper Santonian (SEITZ 1961).

Genus *Sphenoceramus* J.BÖHM, 1915

Sphenoceramus cardissoides (GOLDFUSS, 1835) subsp. indet.

{transition to *Sphenoceramus pachti* (ARKHANGUELSKY, 1916)}

(Pl. 3, fig. 3, 3a, 3b)

* 1835 *Inoceramus cardissoides* GOLDFUSS: 112, pl. 110, fig. 2.
1965 *Inoceramus (Sphenoceramus) cardissoides* GOLDF. – SEITZ: 34–44.

Material: 1 bivalved fragment of the umbonal area (collected by the authors in 1993, NHMW/1994/240). Stöcklwaldgraben/Rußbach, Streiteck Formation.

Description: The uncrushed valves are slightly displaced. The preserved part of the umbonal area is distinctly wedgelike. The anterior margin is inclined steeply towards the commissure, as is characteristic for the genus (pl. 3, fig. 3a). The acute umbo is turned slightly towards the anterior margin and ends at the auricle. Gw = 73°. The left valve shows growth lines up to Ha 12.5 mm, then undulations in intervals of 1.8 to 2.2 mm. WA is slightly inclined (48–42°). Corners K1, K2, K3 and radial depression are well developed. The Na/Ha-ratio varies between 62 and 73% (Ha-interval 6–16.5 mm), the Vo/Ha-ratio between 60 and 86% and the S/Ha-ratio between 40 and 60% (left valve). Averages of the right valve are 5–10% lower.

Remarks: According to SEITZ (1965: 52) the decisive criterion for identification is the Vo/Ha-ratio. The above determined ratios lie within the transition range between *Sphenoceramus pachti* (ARKHANGUELSKY) and *Sphenoceramus cardissoides* (GOLDFUSS). Subspecific assignation is impossible due to the fragmentary preservation of the specimen studied.

Stratigraphic distribution: *Sphenoceramus cardissoides* (GOLDFUSS) occurs frequently in the Lower to Middle Santonian and very rare in the Upper Santonian strata.

Geographic distribution: Western, Middle and Eastern Europe.

	1	2	3	4	5	6	7	8	9
Mytiloides cf. *sublabiatus* G. MÜLLER		+							
Cremnoceramus sp. (*inconstans*-group)	+								
Cremnoceramus crassus (PETRASCHECK)	+								
Cremnoceramus ernsti (HEINZ)	+								
Cremnoceramus sp. aff. *deformis* (MEEK)	+								
cf. *simplex* LANG. & GRUND.		+							
Platyceramus mantelli mantelli (MERCEY)	+								
Platyceramus mantelli beyenburgi (SEITZ)		+							
Platyceramus mantelli cf. *subrhenanus* (SEITZ)		+							
Platyceramus cycloides (WEGNER) ssp. ind.					+	+			
Platyceramus cycloides ahsenensis (SEITZ)						+		+	
Volviceramus koeneni (G. MÜLLER)	+	+							
Volviceramus involutus (SOWERBY)					+				
Cladoceramus undulatoplicatus (ROEM.) ssp. ind.				+					+
Cordiceramus cordiinitialis (SEITZ) ssp. ind.						+			
Cordiceramus muelleri muelleri (PETRASCHECK)								+	
Cordiceramus muelleri germanicus (HEINZ)							+		
Cordiceramus muelleri gosauensis (SEITZ)							+		
Sphenoceramus cardissoides (GOLDFUSS)					+				
Sphenoceramus angustus? (BEYENBURG)					+				
	1	2	3	4	5	6	7	8	9

Tab. 13. Inoceramids of the Coniacian/Santonian of the Gosau-group (Eastern Alps) after DHONDT (1987), SEITZ (1961, 1965, 1967) and investigations of the authors. 1. Bad Ischl (tunnel section), 2. Strobl/Weißenbachtal, 30 m E of the Schmolnauer Alpe. 3. Randobach (Rußbach). 4. Randobach, stop 26 of KOLLMANN & SUMMESBERGER 1982. 5. Stöcklwaldgraben (Rußbach). 6. Grabenbach (Gosau). 7. Schattau (Lower Campanian; Gosau). 8. Zwieselberg forest road "Finstergrabenwandl" (Gosau). 9. Edelbachgraben (Gosau).

Biostratigraphic correlation between the Coniacian and Santonian of the Eastern Alps and the NW German – Polish basin.

The authors follow KENNEDY's (1984 a) definition of the Coniacian and Santonian stages based on the ammonite sequence of France. Correlation with the Coniacian ammonite zones was already introduced by TRÖGER (1989: text-fig. 3). As the index fossil for the definition of the base of the Coniacian –*Forresteria petrocoriensis* (COQUAND)– is absent in the Gosau-group, the authors follow SEIBERTZ (1979) and TRÖGER (1981) who defined the boundary of the Coniacian by the appearance of *Cremnoceramus rotundatus* FIEGE. This allows rather precise correlation with the *Didymotis* event II in Westphalia (KAPLAN & KENNEDY 1994: text-fig. 2).

The Lower and Middle Coniacian seem to be relatively complete in the sections N of Bad Ischl and at the Schmolnauer Alpe near Strobl/Weißenbach. The assemblage-zones 21, 22 of TRÖGER (1989: 917, text-fig. 3) are represented here. No data are available for assemblage zone 20 in the area investigated. Inoceramids of this level could be expected above the *Didymotis*-event ("Ofenwand", Weißenbach valley near Strobl; SUMMESBERGER 1985, SUMMESBERGER & KENNEDY, in prep.).

Assemblage zone 20 is represented by *Cremnoceramus? rotundatus* (FIEGE), *Inoceramus* sp. aff. *I. ernsti* HEINZ and *Mytiloides?* sp. aff. *M? stantoni* (SOKOLOW) at the marker bed *h* above the rudist reef in the Atzlgraben section of Brandenberg (Tyrol; KAUFFMAN in HERM, KAUFFMAN & WIEDMANN 1979: 78).

There is no evidence for the occurrence of *Magadiceramus* species (Upper Coniacian assemblage-zones 23 and 24) in the sections investigated. The level could be present in the Stöcklwaldgraben (Rußbach) between the occurrence of *Volviceramus involutus* (SOWERBY) and the appearing of *Sphenoceramus cardissoides* (GOLDFUSS) (pl. 3, fig. 3). To date, however, there is no record of inoceramids from this part of the section.

On the other hand, *Magadiceramus* is mentioned by SEITZ (1970: 36, 37) from the Eiberg near Kufstein (Tyrol) and by KAUFFMAN (in: HERM, KAUFFMAN & WIEDMANN 1979: 39) from the level *e* of the section Brandenberger Ache–Mösl–Mühlbach at Brandenberg (Tyrol). Co-occurrence with Lower Santonian ammonites at both localities (BRINKMANN 1935: 2; KATSCHTHALER 1935: 175, 178; IMMEL, KLINGER & WIEDMANN 1982) and inoceramids of the Lower Santonian assemblage zone 26 at the latter one (*Cladoceramus undulatoplicatus* (ROEMER), *Platyceramus cycloides* (WEGNER) and *Sphenoceramus sp.*; after KAUFFMAN, l.c.) make the Tyrolean occurrences of *Magadiceramus* doubtful in our opinion.

Inoceramids recorded from the Santonian of the Gosau-group and the corresponding parts of the formations allow correlations with the biostratigraphical scheme of the NW German-Polish basin.

The authors follow KENNEDY's suggestion (1984 a: 156) to use the entry of the genus *Texanites* for definition of the base of the Santonian. This is also the base of inoceramid assemblage zone 25. The subdivision of the Santonian follows TRÖGER (1989: text-fig. 4).

There is no safe evidence in the sections of Rußbach/Gosau for the assemblage-zone 25. *Sphenoceramus cardissoides* (GOLDFUSS) occurring just above *Texanites quinquenodosus* (REDTENBACHER) seems to be the first inoceramid representative of basal Santonian, immediately followed by *Cladoceramus undulatoplicatus* (ROEMER).

A contrast to the Coniacian is the absence of a large number of Santonian taxa frequent or important for biostratigraphic subdivision in northwestern and eastern Europe (e.g. *Cordiceramus cordiformis*-group, *Sphenoceramus pachti* (ARCH.), *Sphenoceramus pinniformis*-group, *Sphenoceramus patootensiformis*-group). The absence of these otherwise world-wide occurring taxa might still be due to collection failure and should not be used for premature palaeobiogeographic conclusions.

Palaeobiogeographical conclusions

There is a strong similarity between the NW German-Polish Cretaceous basin, which is generally regarded as being a part of the Northern Temperate Realm, and the Austroalpine Gosau-group of the Tethyan Realm. Occurrence of inoceramid taxa in both areas indicate the exisence of extensive migration routes following the transgression which began in the Upper Turonian (SUMMESBERGER & KENNEDY, in prep.) and continued through Lower and Middle Coniacian. The Upper Coniacian was not investigated sufficiently to be taken into consideration in the present paper.

The Santonian inoceramid fauna reflects a more differentiated paleogeographic pattern. In particular, sphenoceramids of the *Sph. pachti-cardissoides*-group, of the *Sph. pinniformis*-group and the *Sph. patootensiformis*-group, common and widespread in the Northern Temperate Realm are apparently missing in the Gosau-group. They are regarded as a boreal element. Further research in the higher parts of the Grabenbach formation (p. 187) and in the Hochmoos formation (p. 187) is needed for palaeogeographical conclusions. On the other hand, cordiceramids of the *C. muelleri*-group seem to be tethyan. *Sphenoceramus cardissoides* (GOLDFUSS) together with the occurrence of *Cladoceramus undulatoplicatus* (ROEMER) could indicate migrations directed from north to south in the Lower Santonian. The scarcity of *Cordiceramus muelleri* (PETRASCHECK) in the NW German-Polish basin could be interpreted as an indication of migrations from south to north in the Upper Santonian. In this context the rare occurrence of nerineids (BAF collection, unregistered; collection of the Staatliches Museum für Mineralogie und Geologie zu Dresden; NHMW collection) and the solitary coral *Cyclolites* (BAF collection) in the Upper Santonian Heidelberg- and Heimburg Formations (GEINITZ 1848–1849: 41–42, SCHROEDER & DAHLGRÜN 1927) of the southern Subhercynian Cretaceous basin near Blankenburg should be mentioned.

Short description of the localities investigated:

A) The St. Wolfgang basin

1., 2. Bad Ischl (tunnel section):

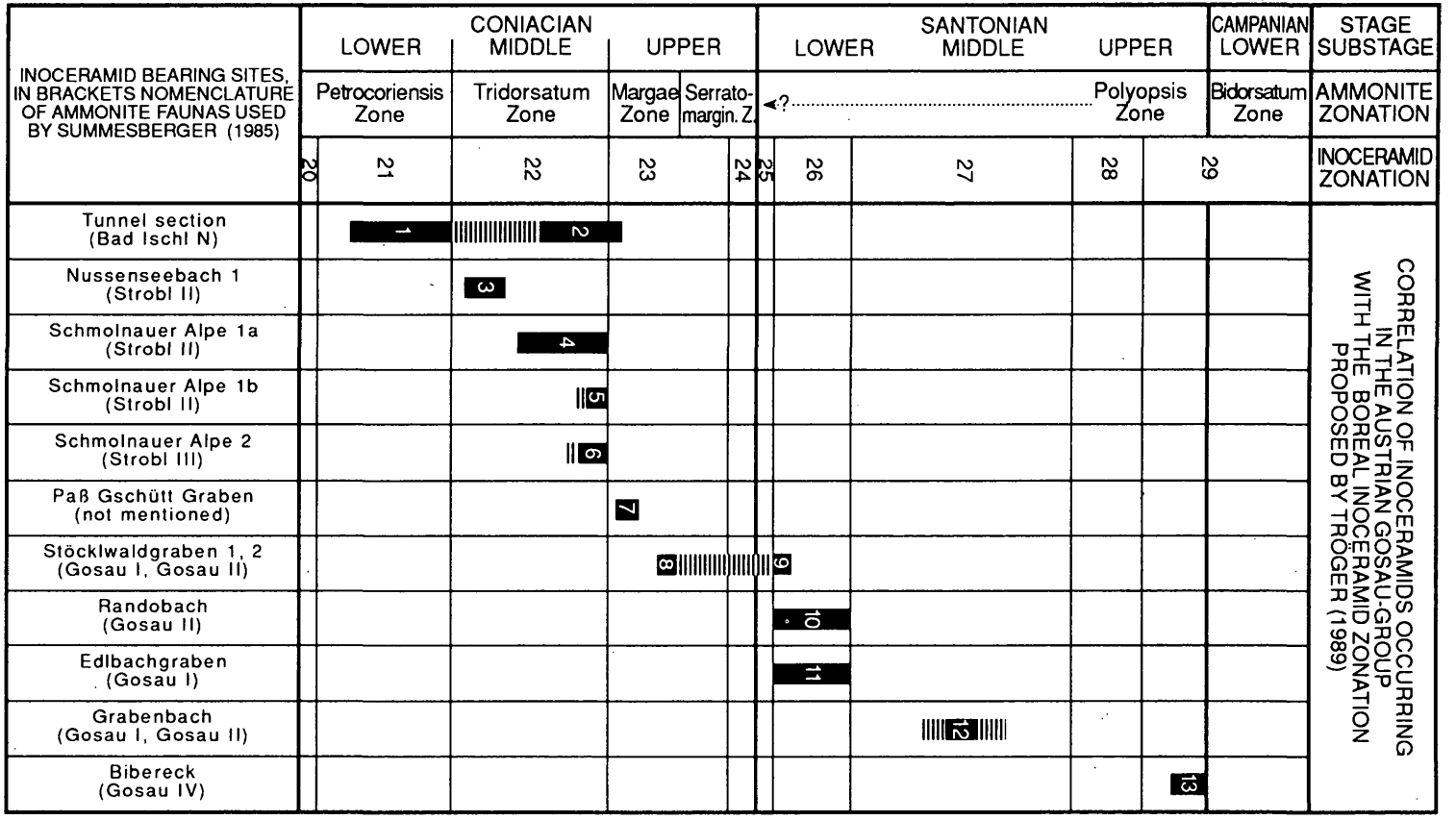
Tunnel section N of Bad Ischl approximately 600 metres long. Fossils were collected by Wolf-Peter MAHERNDL (Bad Ischl) while construction was in progress. Bed by bed collecting and measurement of the section was impossible. Investigation of inoceramids revealed two different faunas: one of Lower Coniacian, the other of Middle Coniacian age. Predominant *Forresteria (F.) alluaudi* (BOULE, LEMOINE & THÉVENIN) is thought to belong to the Lower Coniacian (1.) because none of the Middle Coniacian ammonite sites in the neighbourhood yields even a single specimen of *Forresteria*. Peroniceratidae represent the Middle Coniacian (2.).

1.
Forresteria (Forresteria) alluaudi (BOULE, LEMOINE & THÉVENIN),
Cremnoceramus crassus (PETRASCHECK)
Cremnoceramus ernsti HEINZ
Cremnoceramus sp. aff. *deformis* (MEEK)

2.
Peroniceras (Peroniceras) tridorsatum (SCHLÜTER)
Volviceramus koeneni (G. MÜLLER)
Platyceramus mantelli mantelli (MERCEY)

Age: Lower to Middle Coniacian; assemblage-zones 21 and 22 according to the scheme established by TRÖGER (1989).

3. Nussenseebach: (stop 5 of KOLLMANN & SUMMESBERGER 1982)
Platyceramus mantelli mantelli (MERCEY)
Gaudryceras cf. *beantalyense* (COLLIGNON)



Tab. 14. Application of the boreal inoceramid assemblage zonation (TRÖGER 1989: text-fig. 2, 3) to the Coniacian and Santonian of the Gosau-group of the Tethyan realm. Numbers 1–13 correspond to the site numbers below.

Tetragonites cf. *superstes* VAN HOEPEN 1921
Peroniceras (P.) tridorsatum (SCHLÜTER)
Tissotia sp.
Scaphites sp.

A g e : Middle Coniacian; assemblage-zone 22 (TRÖGER 1989).

4. Schmolnauer Alpe 1a
This site is probably the type locality of *Tissotioides haplophyllus*. Several individuals and fragments were recently collected by one of us (H. S.) together with *Tetragonites*, *Pseudophyllites*, *Jimboiceras*, Peroniceratidae, Scaphitidae, Baculitidae and large inoceramids. The exposure of about 2 metres thickness is separated by unexposed area from Schmolnauer Alpe 1b. No measurable sequence.

Platyceramus mantelli beyenburgi (SEITZ)
Platyceramus mantelli cf. *subrhenanus* (SEITZ)
Mytiloides cf. *sublabiatus* (G. MÜLLER)
Volviceramus koeneni (G. MÜLLER)

A g e : Middle Coniacian; assemblage-zone 22 (TRÖGER 1989).

5. Schmolnauer Alpe 1b
Bivalves are the dominating faunal elements. *Barroisiceras haberfellneri* and *Tissotioides haplophyllus* do not occur here. There is no exposure at this site. The fossils were collected near the surface from a layer of less than half a meter thickness. There is no measurable sequence at this site.

Tetragonites cf. *superstes* VAN HOEPEN
Metatissotia sp.
Hauericeras schlueteri (REDTENBACHER)
Peroniceratidae,
Scaphitidae,
Baculitidae
Volviceramus koeneni (G. MÜLLER)

A g e : Middle Coniacian; assemblage-zone 22 (TRÖGER 1989).

D i s c u s s i o n : The faunas of Schmolnauer Alpe 1a and 1b were still considered as coeval by SUMMESBERGER (1985, p. 150: "Strobl II") and are for the first time separated here. According to the inoceramids it seems likely that the fauna of Schmolnauer Alpe 1a with *Tissotioides haplophyllus* is older than that of Schmolnauer Alpe 1b.

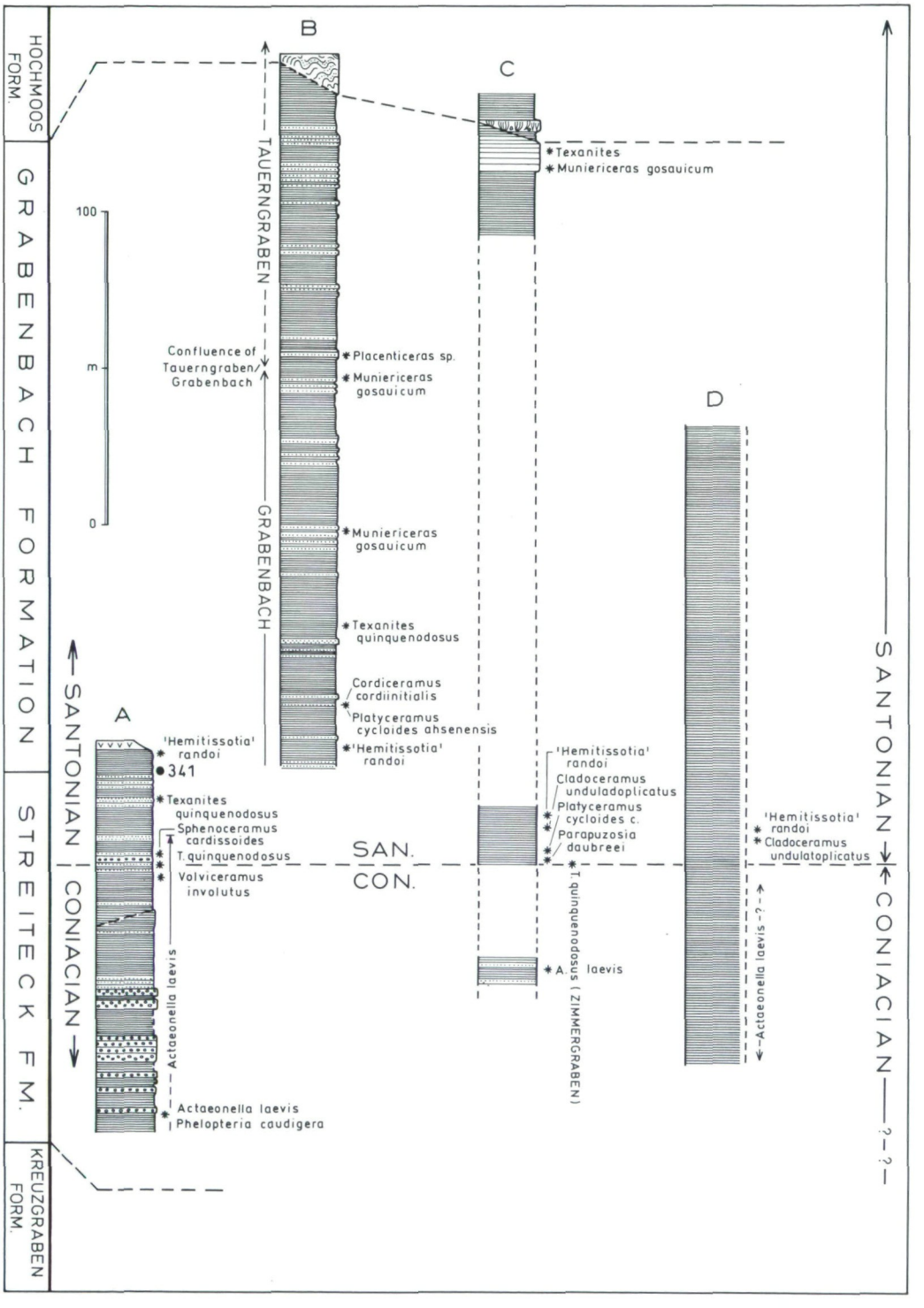
Text-fig. 4. Correlation of Coniacian/Santonian sections of the Gosau basin (Upper Austria/Salzburg) by the local marker fossil "*Hemitissotia*" *randoi* GERTH, the appearance of *Texanites* and by *Cladoceramus undulatoplicatus* (ROEMER). Numbers indicate excursion stops in KOLLMANN & SUMMESBERGER (1982).

A) Stöcklwaldgraben section: About 120 m of continuously exposed section were measured by KOLLMANN & SUMMESBERGER (1982). The Coniacian/Santonian boundary is based on the first appearance of *Texanites quinquenodosus*. Nr. 341 indicates the sample number of WAGREICH (1992: 509, fig. 3).

B) The Grabenbach section of about 230 m was measured by KOLLMANN & SUMMESBERGER (1982 and unpublished data).

C) The faulted and not continuously exposed Randobach section is compiled by indication of fossils.

D) The thickness of the inaccessible Edlbach section is estimated. Accessible outcrops are in the riverbed and tributaries.


HOCHMOOS FORM.
GRABENBACH FORMATION
STREITECK FM.
KREUZGRABEN FORM.
A
B
C
D
TAUERNGRABEN
GRABENBACH
100
m
0
Confluence of Tauerngraben/ Grabenbach
*Placenticeras sp.
*Muniericeras gosauicum
*Muniericeras gosauicum
*Texanites quinquenodosus
Cordiceramus cordiinitialis
Platyceramus cycloides ahsenensis
*'Hemitissotia' randoi
'Hemitissotia' randoi
● 341
*Texanites quinquenodosus
Sphenoceramus cardissoides
*T. quinquenodosus
Volviceramus involutus
Actaeonella laevis
Actaeonella laevis
Pholopteria caudigera
*Texanites
*Muniericeras gosauicum
'Hemitissotia' randoi
Cladoceramus undulatoplicatus
Platyceramus cycloides c.
Parapuzosia daubreei
*T. quinquenodosus (ZIMMERGRABEN)
*A. laevis
'Hemitissotia' randoi
*Cladoceramus undulatoplicatus
Actaeonella laevis -?-
SAN.
CON.
SANTONIAN
CONIACIAN
SANTONIAN
CONIACIAN
-?-?-

6. Schmolnauer Alpe 2 (fauna Strobl III of SUMMESBERGER 1985: 151).
Outcrop on the side of the forest road. There is also no measurable sequence at this site.

Peroniceras sp.
Metatissotia robini THIOLLIÈRE
Platyceramus mantelli subrhenanus (SEITZ)
Platyceramus mantelli cf. *subrhenanus* (SEITZ)

A g e : Middle Coniacian; assemblage-zone 22 (TRÖGER 1989).

B) The Gosau basin

7. Paß Gschütt Graben:
Site N of the Paß Gschütt. No ammonites from this locality. Streiteck Formation.

Volviceramus sp. aff. *involutus* (SOWERBY)

A g e : Upper Coniacian; assemblage-zone 23 (TRÖGER 1989)

8. Stöcklwaldgraben (Gosau) (Stop 22 of KOLLMANN & SUMMESBERGER 1982: 68, 69).
The section was measured and sampled by KOLLMANN & SUMMESBERGER (1982: 69). Additional collecting was done in 1982 by SUMMESBERGER and KOLLMANN and in 1993 by SUMMESBERGER and TRÖGER. The boundary of the Streiteck and Grabenbach Formations is tentatively drawn above disappearance of the conglomerates and sandstones. Upper Coniacian is recognized on the basis of the presence of *Volviceramus involutus* (SOWERBY).

9. Stöcklwaldgraben (Gosau) (Stop 21 of KOLLMANN & SUMMESBERGER 1982: 68, 69).
Basal Santonian is indicated by the appearance of *Texanites quinquenodosus* (REDTENBACHER) and *Sphenoceramus cardissoides* (GOLDFUSS) ssp. indet. *Actaeonella laevis* (SOWERBY), common in the Streiteck Formation, becomes abundant in the basal Grabenbach Formation and disappears before "*Hemitissotia*" *randoi* GERTH appears at the top of the section.

Volviceramus involutus (SOWERBY)
Sphenoceramus cardissoides (GOLDFUSS)

A g e : Evidence is present for Upper Coniacian, assemblage-zone 23 and for Lower Santonian, assemblage-zone 26 (TRÖGER 1989).

10. Randobach (Stop 25/26 and 29 of KOLLMANN & SUMMESBERGER 1982): Several metres of Grabenbach Formation are exposed in the riverbed of the Randobach. Stratigraphically lower parts of the outcrop yielded *Parapuzosia daubreei* (GROSSOUVRE) approximately at the level of the first appearance of *Texanites quinquenodosus* (REDTENBACHER). Higher up in the section is the type locality of "*Hemitissotia*" *randoi* GERTH. This is also the level in which *Cladoceramus undulatoplicatus* (ROEMER) occurs, the former is of local value for correlation, the latter is widely used to indicate the base of the Santonian. It seems likely that *Texanites quinquenodosus* and *Cladoceramus undulatoplicatus* co-occurring in the Mühlbach section of Brandenberg (Tyrol) are separated by few metres of sediment in the Gosau basin (text-fig. 4). *Platyceramus cycloides cycloides* (WEGNER) was observed by the authors (1993) in the riverbed.

A g e : Lower Santonian; assemblage-zone 26 (TRÖGER 1989)

Cladoceramus undulatoplicatus (ROEMER)
Platyceramus cycloides cycloides (WEGNER)
Sphenoceramus cardissoides (GOLDFUSS)

11. Edelbachgraben:
In the easily accessible basal parts of the large outcrops of the Edelbachgraben, *"Hemitissotia" randoi* GERTH occurs together with *Cladoceramus undulatoplicatus* (ROEMER).

A g e : Lower Santonian; assemblage-zone 26 (TRÖGER 1989)

12. Grabenbach:
Five sections separated by faults were measured by KOLLMANN & SUMMESBERGER (1975/76) before dam construction destroyed large parts of these formerly excellent outcrops. The Grabenbach Formation is exposed throughout up to the confluence with the Tauerngraben (basal Hochmoos Formation). The absence of *Actaeonella laevis* indicates, together with a single specimen of *"Hemitissotia" randoi* GERTH, that the basal parts of the Grabenbach section more or less continue the section of the Stöcklwaldgraben. Here the occurrence of *Texanites quinquenodosus* (REDTENBACHER) does not represent the first appearance of the species. *Platyceramus cycloides ahsenensis* SEITZ and *Cordiceramus cordiinitialis* (SEITZ) collected in 1993 by the authors indicate assemblage-zone 27 (TRÖGER 1989), which is tentatively middle Santonian. Higher up in the section, *Muniericeras gosauicum* (HAUER) allows correlation with the downstream locality of the Randobach (stop 29 of KOLLMANN & SUMMESBERGER 1982).

Muniericeras gosauicum (HAUER)
"Hemitissotia" randoi GERTH
Texanites quinquenodosus (REDTENBACHER)
"Muramotoceras" sp. indet.
Platyceramus cycloides ahsenensis (SEITZ),
Cordiceramus cordiinitialis (SEITZ)

A g e : Middle Santonian

13. Bibereck (local name "Finstergrabenwandl" at the Zwieselberg forest road; stop 11 of KOLLMANN & SUMMESBERGER 1982).
Ammonites were published by WIEDMANN (1978) and SUMMESBERGER (1979, 1980, 1992), gastropods by KOLLMANN (1980) and bivalves including inoceramids by DHONDT (1987). The Sandkalkbank Member of the Hochmoos Formation, about 20 m thick, is well exposed along the forest road. Fossils were collected from 1971–1975 while and immediately after the road was constructed.

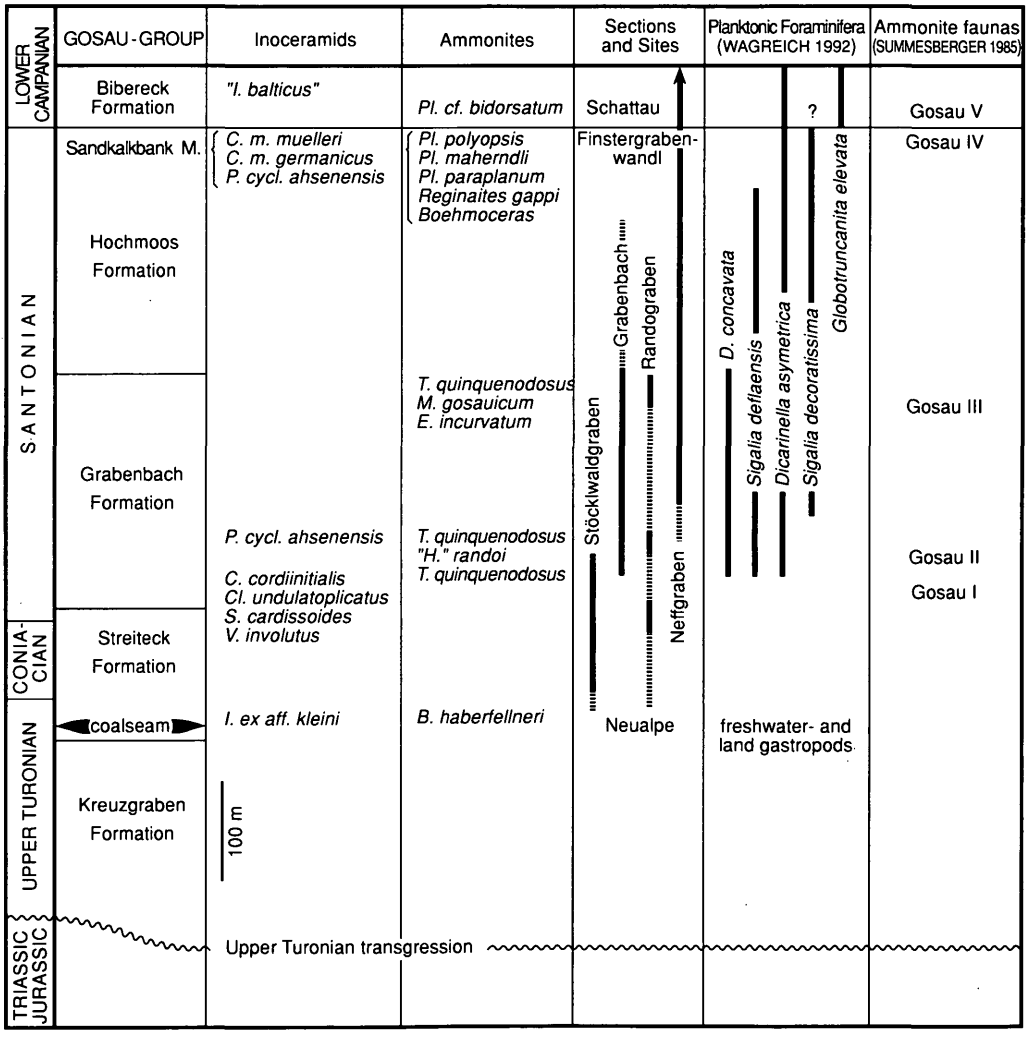
Placenticeras polyopsis (DUJARDIN)
Placenticeras paraplanum WIEDMANN
Placenticeras maherndli SUMMESBERGER.
Boehmoceras arculus (MORTON)
Boehmoceras krekeleri (WEGNER)
Cordiceramus muelleri muelleri (PETRASCHECK),
Cordiceramus muelleri germanicus (HEINZ),
Platyceramus cycloides ahsenensis (SEITZ).

Placenticeras polyopsis (DUJARDIN) is indicative for Santonian, the genus *Boehmoceras* for Upper Santonian (KENNEDY & COBBAN 1991: 185; SUMMESBERGER 1979: 122). The association of inoceramids confirms a top Santonian age (lower part of assemblage-zone 29; TRÖGER 1989).

Lithologic units (Upper Turonian through Santonian) of the Gosau basin

Kreuzgraben Formation (WEIGEL 1937: 13)

The Kreuzgraben Formation is the basal transgressive series of the Gosau-group in the basin of Gosau. Predominant conglomerates were interpreted (WAGREICH 1988: 665) as proximal to distal areas of alluvial fans. Intercalations of sandstones indicate the distal end of the alluvial fan area.



Tab. 15. Lithologic units (Upper Turonian through Santonian) of the Gosau basin.

Streiteck Formation (WEIGEL 1937: 14)

The Lower Streiteck Formation comprises nearshore marine conglomerates with sandstone intercalations (offshore transition) of a fan delta environment (WAGREICH 1988: 669). A coal seam with freshwater mollusks indicates paralic to lacustrine environments (STOLICZKA 1860). A recently discovered (H. S. together with P. SKOUMAL 1993) shaly intercalation with *Barroisiceras haberfellneri* (HAUER) and other marine mollusks (*Inoceramus* ex aff. *kleini* G. MÜLLER; det. K.-A. TRÖGER) is a strong indication for Late Turonian age (SUMMESBERGER & KENNEDY, in prep.).

The Upper Streiteck Formation consists mainly of shales with sandy layers. It represents an offshore shelf environment with occasional storm events. The greater part of the formation is of Coniacian age based on the presence of late Coniacian *Volviceramus involutus* (SOWERBY) and subsequent appearance of *Texanites quinquenodosus* (REDTENBACHER) near the top of the sequence (Text-fig. 4). Fossils are abundant and concentrated into shell beds.

Grabenbach Formation (WEIGEL 1937: 16)

The Grabenbach Formation consists of pelitic shales with occasional sandy/silty storm layers. It was built up under normal shelf conditions (WAGREICH 1988: 670). Fossils are scarce and never occur in lumachelles. Assuming an equal sedimentation rate, the Grabenbach Formation comprises approximately one half of the Santonian (Tab. 15).

Hochmoos Formation (WEIGEL 1937: 16)

The Hochmoos Formation is a complex series of fossiliferous shales, sandstones, conglomerates, bioclastic storm layers and the first rudist bioherms and biostromes occurring in the Gosau basin. Conglomerates and sandstones are compared by WAGREICH (1988: 674) with the fan deltas of the Streiteck Formation. Rudists indicate shallow marine environments. In this paper only the top Santonian Sandkalkbank member (WEIGEL 1937, geol. map) is taken into consideration (see above; locality Bibereck).

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Plate 1

Fig. 1, 1a: *Mytiloides* cf. *sublabiatus* (G. MÜLLER); NHMW/1989/50/5; Strobl/Weißenbach, 30 m E Schmolnauer Alpe.

Fig. 2: *Inoceramus* cf. *simplex* LANGENHAN & GRUNDEY non STOLICZKA; NHMW/1994/256. Strobl/Weißenbach, 30 m E Schmolnauer Alpe.

Fig. 3: *Inoceramus* sp. (*inconstans*-group); NHMW/1989/51/3; Bad Ischl, tunnel section.

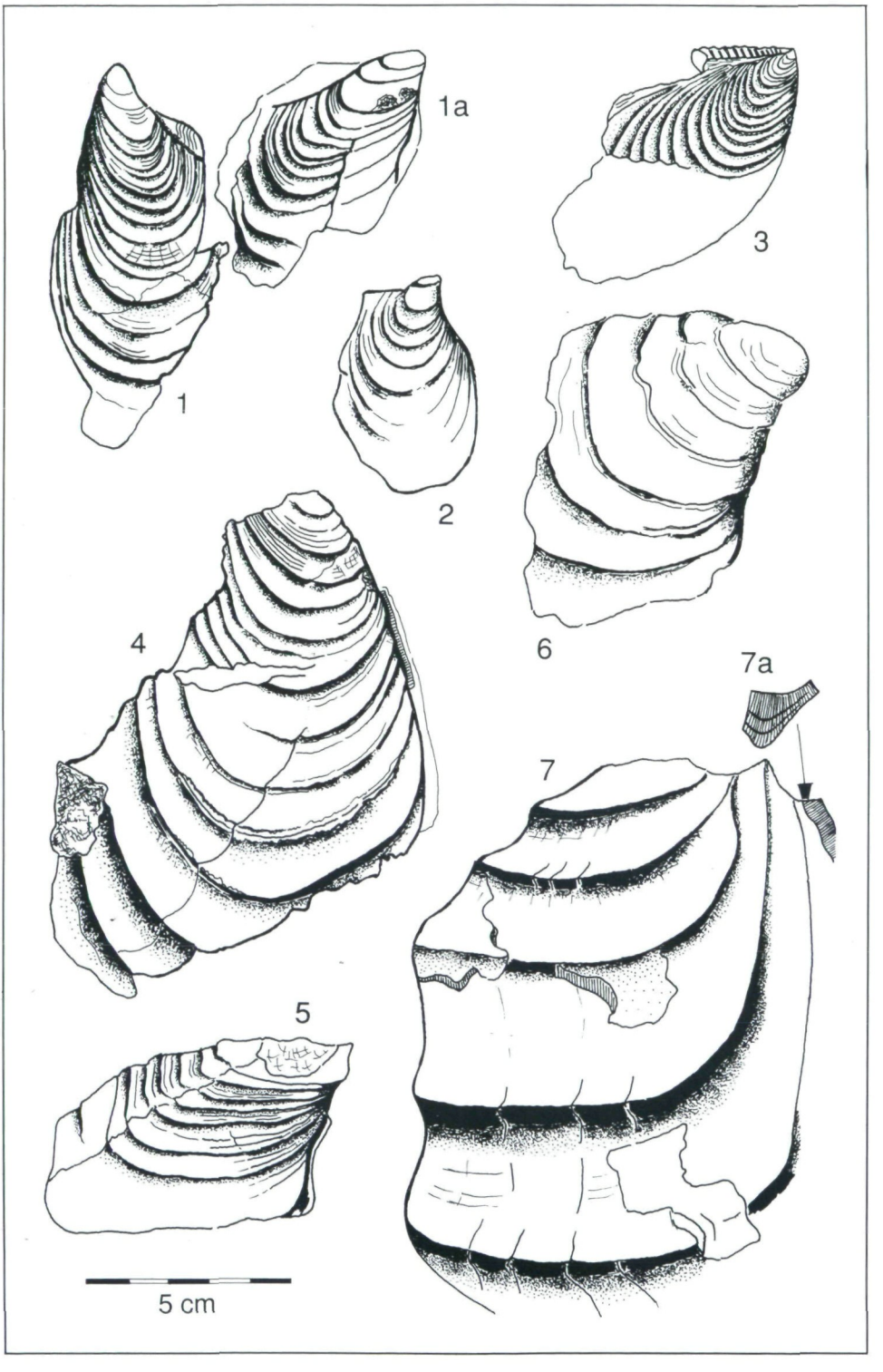
Fig. 4: *Cremnoceramus crassus* (PETRASCHECK); NHMW/1989/51/2; Bad Ischl, tunnel section.

Fig. 5: *Cremnoceramus crassus* (PETRASCHECK); NHMW/1989/51/7; Bad Ischl, tunnel section.

Fig. 6: *Cremnoceramus ernsti* (HEINZ); NHMW/1989/51/3; Bad Ischl, tunnel section.

Fig. 7, 7a: *Cremnoceramus* sp. aff. *deformis* (MEEK); NHMW/1989/51/4a; Bad Ischl, tunnel section.

All figures x 0,6.


1a
1
2
3
4
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7
7a
5 cm

Plate 2

Fig. 1: *Volviceramus koeneni* (G .MÜLLER); NHMW/1989/50/4; Strobl/Weißenbach, 30 m E Schmolnauer Alpe.

Fig. 2: *Volviceramus koeneni* (G. MÜLLER); MA unregistered; Strobl/Weißenbach, 30 m E Schmolnauer Alpe.

Fig. 3: *Volviceramus koeneni* (G. MÜLLER); NHMW/1989/50/11; Strobl/Weißenbach, 30 m E Schmolnauer Alpe.

Fig. 4: *Volviceramus* sp. aff. *involutus* (SOWERBY); MA unregistered; Paß Gschütt Graben, upper part.

Fig. 5: *Volviceramus involutus* (SOWERBY); NHMW/1994/238; Gosau, Stöcklwaldgraben.

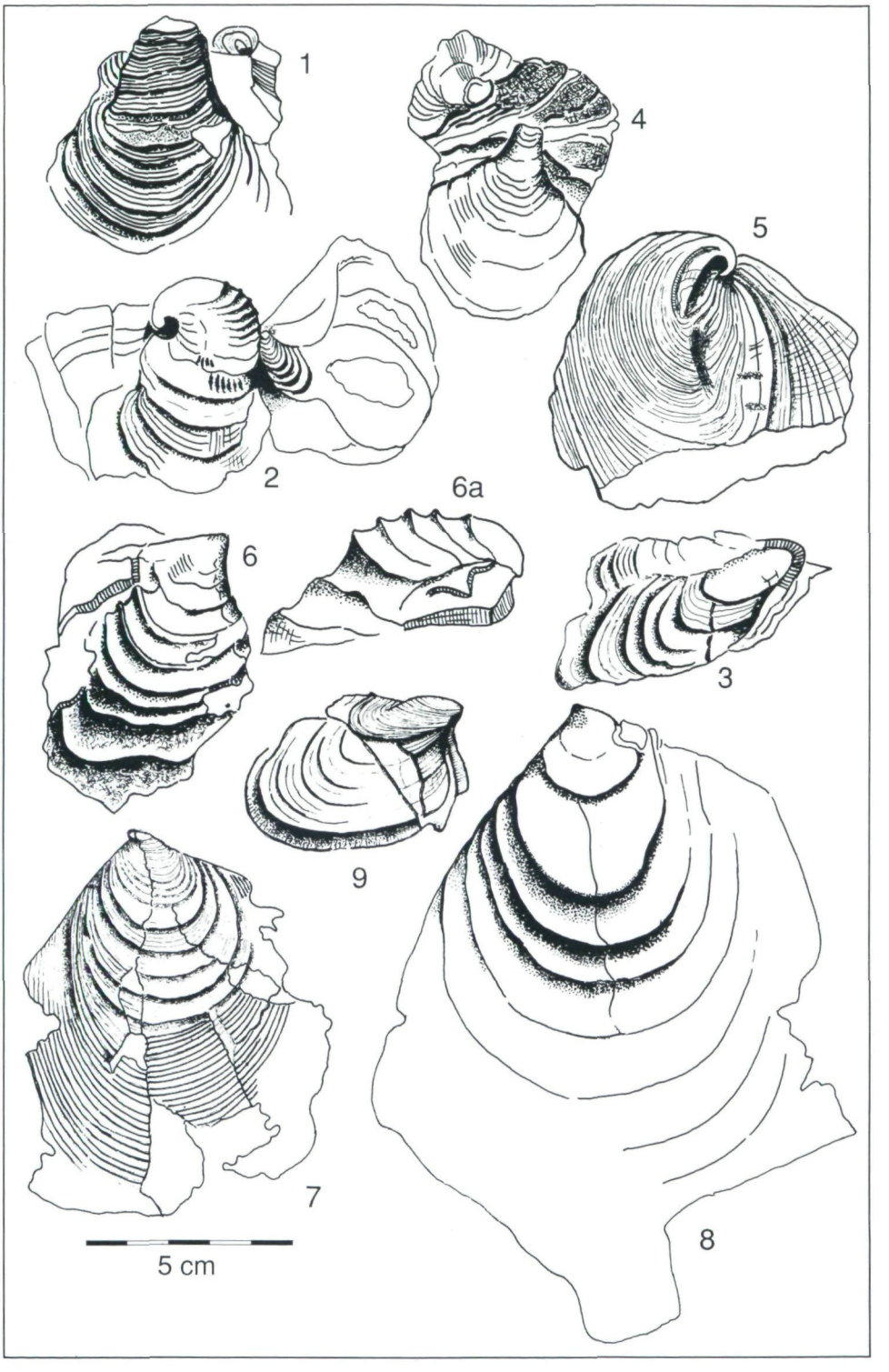
Fig. 6, 6a: *Inoceramus* sp. aff. *percostatus* G. MÜLLER; GIUW 1886/II/100; Gams, Anerlbauerkogel.

Fig. 7: *Platyceramus mantelli mantelli* (MERCEY); NHMW/1994/239; Nussenseebach.

Fig. 8: *Platyceramus mantelli mantelli* (MERCEY); NHMW/1989/51/1; Bad Ischl, tunnel section.

Fig. 9: *Platyceramus mantelli* cf. *subrhenanus* (SEITZ); NHMW/1989/50/1; Strobl/Weißenbach, 30 m E Schmolnauer Alpe.

All figures x 0,6.


1
4
5
2
6a
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7
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5 cm

Plate 3

Fig. 1, 1a: *Platyceramus mantelli beyenburgi* (SEITZ); NHMW/1989/50/6;1a: side view. Strobl/Weißenbach, 30 m E Schmolnauer Alpe.

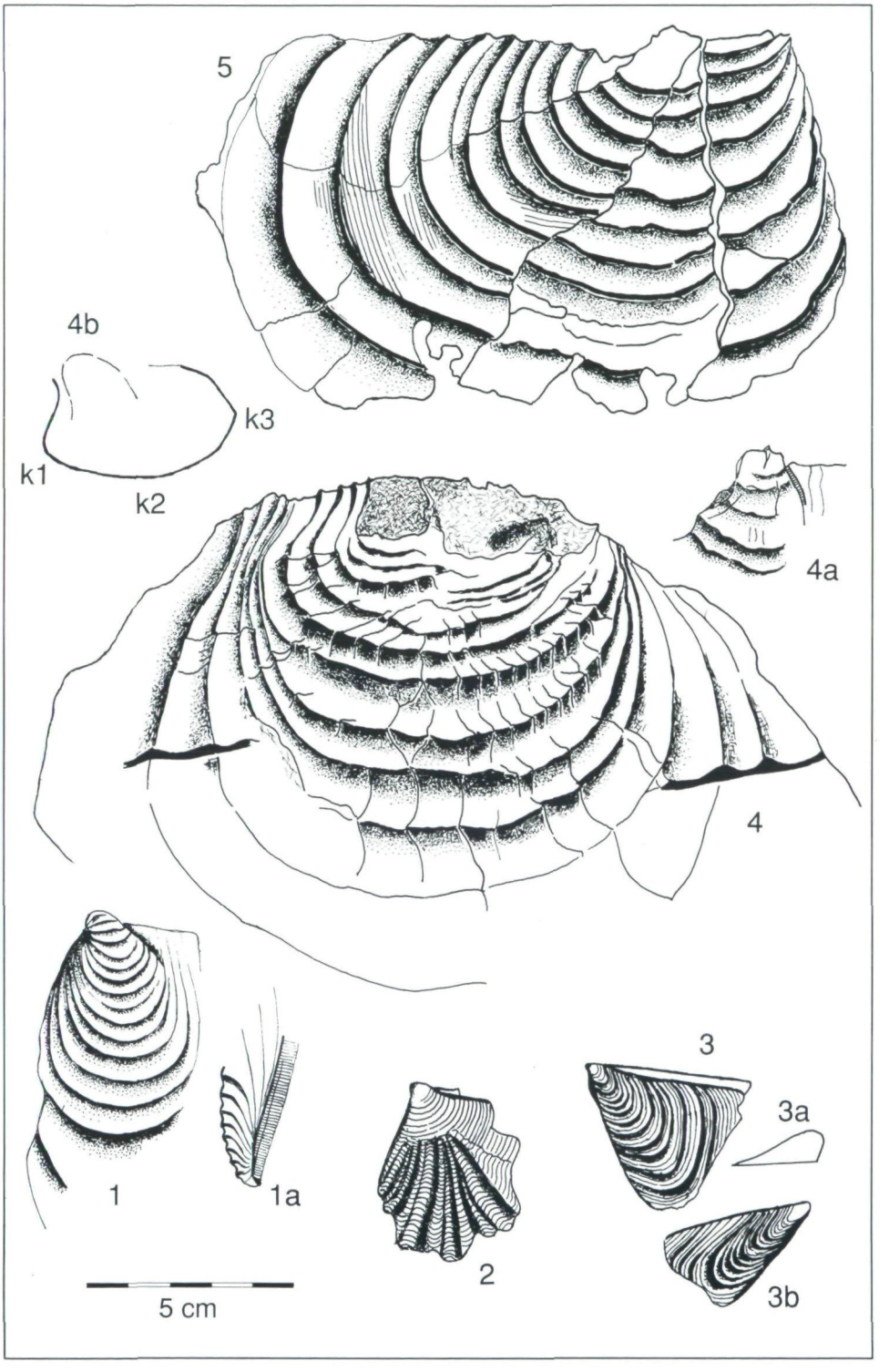
Fig. 2: *Cladoceramus undulatoplicatus* (ROEMER) subsp. indet.; SK/B/RA/1982/2; Rußbach, Randobach.

Fig. 3: *Sphenoceramus cardissoides* (GOLDFUSS) subsp. indet. (transition to *Sphenoceramus pachti* (ARCH.); 3, 3b: view of both valves; 3a: section of the left valve in the umbonal area; NHMW/1994/240; Rußbach, Stöcklwaldgraben.

Fig. 4: *Cordiceramus cordiinitialis* (SEITZ) subsp. indet.; right valve; NHMW/1994/241. – 4a: *Cordiceramus cordiinitialis* (SEITZ) subsp. indet.; Umbonal area of the left valve; BAF/Tr./1993/Go.3; natural size. – 4b: *Cordiceramus cordiinitialis* (SEITZ) subsp. indet.; sketch of the left valve with corners K1, K2, K3; BAF/Tr./1993/Go.3; Gosau, Grabenbach.

Fig. 5: *Cordiceramus muelleri germanicus* (HEINZ); NHMW/1990/29/201; Gosau, Bibereck/Finstergrabenwandl.

All figures x 0,6.


5
4b
k3
k1
k2
4a
4
1
1a
2
3
3a
3b
5 cm