

# The Upper Cretaceous of Piesting (Austria): Integrated stratigraphy of the Piesting Formation (Gosau Group)

Herbert SUMMESBERGER<sup>1</sup>, Michael WAGREICH<sup>2</sup>, Karl-Arnim TRÖGER<sup>3</sup>, Robert SCHOLGER<sup>4</sup>

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**Abstract:** The Upper Cretaceous Piesting Formation (Gosau Group, Grünbach Syncline) comprises a neritic to deep-water succession a few hundred meters thick. The recently established Piesting Formation replaces the old and confusing stratigraphical terms *Inoceramenschichten* and *Inoceramenmergel* (*Inoceramus* beds, *Inoceramus* marls), and *Orbitoidensandstein*. Three lithofacies can be distinguished: a lower part of grey marls with tempestites, a middle part of sandstones and conglomerates, and an upper part that consists of sandy marls with a few turbidites. The terrestrial to shallow-marine Grünbach Formation (formerly “Coalbearing Series”) underlying the Piesting Formation is Early Campanian in age. The Piesting Formation ranges in age from Campanian to Early Maastrichtian. A late Campanian age is indicated by *Pseudokossmaticeras brandti* (REDTENBACHER, 1873) and foraminifera (OBERHAUSER in: PLÖCHINGER, 1961). Early Maastrichtian is indicated by *Pachydiscus neubergicus* und inoceramid bivalves of the Muntigl fauna near Salzburg (TRÖGER et al., 2000, TRÖGER et al., in press) and by *Pachydiscus epiplectus* (REDTENBACHER, 1873) from the Piesting Formation of the nearby village of Muthmannsdorf. Inoceramids and trace fossils dominate in the section of the sports field of Piesting. Late Campanian nannozones CC18–CC22 are indicated from the section of the “Umfahrungsstraße” S Piesting, in palaeomagnetic terms probably chron 32 N. The Early Maastrichtian nannozone CC24 was proved in the sports field section, which can be correlated to chron 31 R.

**Keywords:** Late Cretaceous, Gosau Group, Piesting Formation, Ammonites, Nannofossils

## 1. INTRODUCTION

The Upper Cretaceous to Paleogene deposits of the Gosau Group of the Grünbach – Neue Welt – Piesting area form a continuous outcrop belt in the Grünbach Syncline (PLÖCHINGER, 1961, 1964) at the eastern margin of the Northern Calcareous Alps (Fig. 1). The Grünbach Syncline continues farther to the east, into the basement of the Neogene

<sup>1</sup> Naturhistorisches Museum, A-1014 Wien, Austria, E-mail: herbert.summesberger@nhm-wien.ac.at

<sup>2</sup> Institut für Geologie, Geozentrum Universität Wien, Althanstrasse 14, A-1090 Wien, Austria, E-mail: michael.wagreich@univie.ac.at

<sup>3</sup> Geologisches Institut, Meißer Bau; D-09596, Freiberg/Sachsen, Deutschland, E-mail: troeger@geo.tu-freiberg.de

<sup>4</sup> Paläomagnetisches Labor, Montanuniversität Leoben, A-8130, Austria, E-mail: scholger@unileoben.ac.at

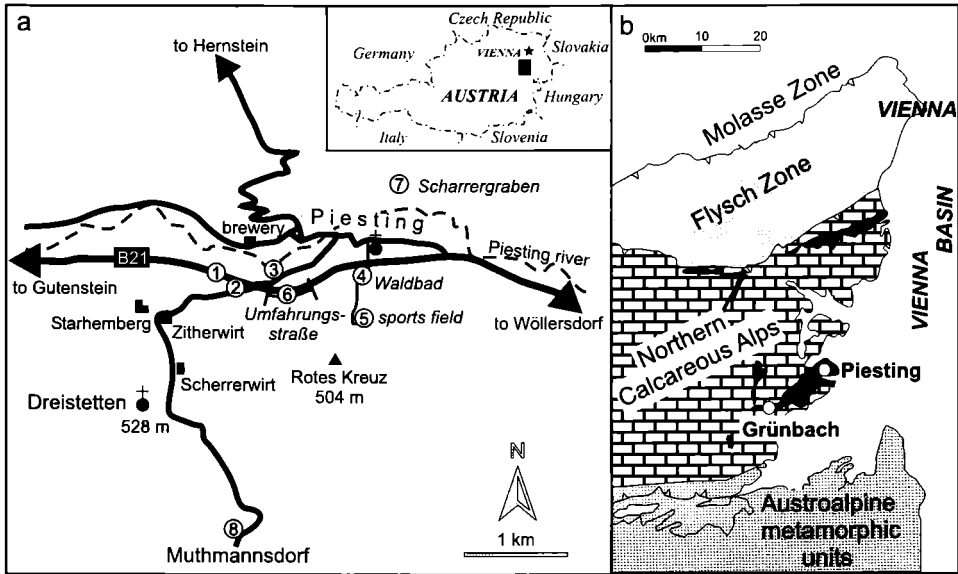


Fig. 1(a): Sketch map of the area around Piesting (Lower Austria) indicating the localities mentioned in the text. 1. Road cutting W Piesting next the ruins of Starhemberg. 2. Position of the 19<sup>th</sup> century coal shaft. 3. Position of house constructions (1996) with exposures of Grünbach Formation. 4. Exposure of conglomerates during investigation next to the Waldbad (forest bath) of Piesting. 5. Sports field of Piesting. 6. Road cutting exposures (1996/1998), "Umfahrungsstraße" S of Piesting; 5 and 6 represent the type section of the Piesting Formation. 7. Historic locality "Scharregraben" N of Piesting, famous for its Late Cretaceous corals and rudists. 8. Muthmannsdorf, site with *Pseudokosmaticeras brandti*. (b) Geological sketch map of the area of Piesting modified from WAGREICH & MARSCHALCO (1995). Black = Gosau Group.

Vienna Basin (SAUER et al., 1992; WAGREICH & MARSCHALCO, 1995). Geological investigations started early in the 19<sup>th</sup> century (e.g. BOUÉ, 1832, ZITTEL, 1866). Recent investigations concentrated on the biostratigraphy (SUMMESBERGER, 1997; HRADECKÁ et al., 1999) and lithostratigraphy (SUMMESBERGER, 1997; SUMMESBERGER et al., 2000) of the Gosau Group in this area.

This paper provides an overview of the lithostratigraphy of the Gosau Group of the Grünbach Syncline in the Piesting area, followed by a description and integrated biostratigraphy of the newly defined Piesting Formation. Data on inoceramids, ammonites, foraminifera, calcareous nannofossils and palaeomagnetism are included.

## 2. GEOLOGICAL SETTING

The Gosau Group of the Northern Calcareous Alps (NCA) comprises Upper Cretaceous to Paleogene strata unconformably overlying folded and faulted Permian to Lower Cretaceous rocks (e.g. WAGREICH & FAUPL, 1994; SANDERS et al., 1997; FAUPL & WAGREICH, 2000). The Late Cretaceous transgression within the NCA was diachronous, starting in the Late Turonian, e.g. in the type locality of Gosau in Upper Austria (SUMMESBERGER & KENNEDY, 1996), becoming younger towards the southeast of the NCA (WAGREICH, 1995; WAGREICH & MARSCHALCO, 1995).

The Gosau Group of the Grünbach – Neue Welt area in the southeastern part of the NCA is well known for its fossil content (ZEKELI, 1852; ZITTEL, 1860–66) and coal mining in the past (CZIZEK, 1851). Whereas the existence of an overturned syncline has been recognized, in the western part of the area, by CZIZEK (1851), i.e. in the vicinity of Grünbach, the structural relationships of the Upper Cretaceous strata in the eastern part, near Piesting, are more complicated and remained hardly resolved due to the poor exposures. Tertiary strike-slip faulting (DECKER & PERESSON, 1996), e.g. along the E-W trending Piesting valley, may have contributed to the complex structural situation; this complicates correlations from the north to the south of Piesting.

Because of the construction of a new road from 1989 onwards, a section at the southern flank of the Piesting valley was sampled in the last few years. The section begins with brachiopod limestones that rest transgressively upon Triassic limestones (see geological map of SUMMESBERGER, 1991). These limestones are overlain by a coal-bearing interval, followed by sandy to silty shales of the Piesting Formation.

## 3. LITHOSTRATIGRAPHIC AND BIOSTRATIGRAPHIC OVERVIEW

The Gosau Group of the Grünbach – Neue Welt – Piesting area is divided into several formations based on PLÖCHINGER (1961) and SUMMESBERGER et al. (2000). The new lithostratigraphic subdivision comprises 5 formations: the Kreuzgraben Formation (red conglomerates), the Maiersdorf Formation (limestones, sandstones and marls below the first coal seam, p.p. "Transgression series" of SUMMESBERGER, 1997), the Grünbach Formation ("kohleführende Serie" of PLÖCHINGER, 1961; "Coalbearing series" of KOLLMANN & SUMMESBERGER, 1982), the Piesting Formation ("Inoceramenmergel" and "Orbitoidensandsteine" of PLÖCHINGER, 1961 and BRIX & PLÖCHINGER, 1991) and the Zweiersdorf Formation (PLÖCHINGER, 1961: sandy turbidites including Danian strata). Whereas stratigraphic correlations to the section north of Piesting are still doubtful (SUMMESBERGER, 1997) and will not be discussed here, the E-W section south of Piesting (Piesting S section), from the ruins of the Starhemberg castle to the sports field of Piesting, will be described.

### 3.1 Maiersdorf Formation

The Maiersdorf Formation (SUMMESBERGER et al., 2000) along the Piesting S section contains carbonate breccias as well as rudist and brachiopod limestones (PLÖCHINGER,

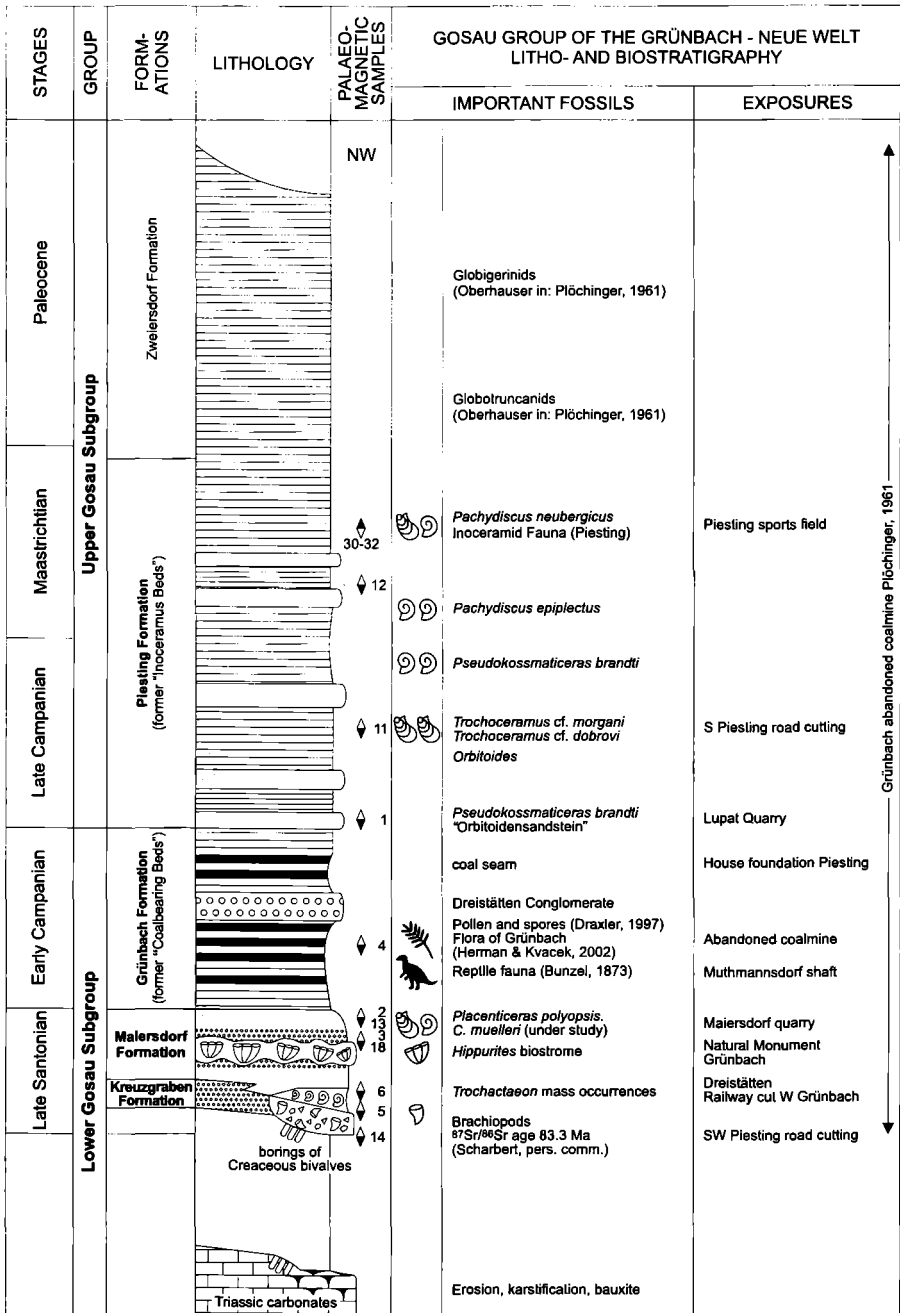


Fig. 2: Composite section of the Gosau Group in the area south of Piesting (modified from the section of the Grünbach – Neue Welt basin after SUMMESBERGER in PILLER et al., 1997, and EGGER et al., 2000).

1961; SUMMESBERGER 1991). A brachiopod limestone, a few-meters thick, is present at the base of the section above Triassic Dachstein limestone in the western road cutting of the "Umfahrungsstraße" Piesting. The Triassic substratum contains borings of bivalves, probably *Lithophaga* sp.

Stratigraphic data from the Maiersdorf Formation are scarce. New data from the type locality, a few kilometers SW of Piesting, indicate a Late Santonian age based on the presence of *Cordiceramus muelleri* ssp. and *Placenticeras polyopsis* (DUJARDIN). A (Late) Santonian to earliest Campanian age from the Piesting S section is indicated by a poorly preserved nannofossil assemblage from the brachiopod limestone (probably nannofossil standard zone CC16–17: *Marthasterites furcatus*, *Calculites* cf. *obscurus*) and by a  $^{87}\text{Sr}/^{86}\text{Sr}$  isotope dating from brachiopod shells (Dr. S. SCHARBERT, unpublished data). The  $^{87}\text{Sr}/^{86}\text{Sr}$  isotope ratio of 0.707480 indicates an age of 83.3 Ma ( $\pm 0.5$  Ma, including both analytical and correlation errors) according to the conversion table of HOWARTH & McARTHUR (1997, version 1999). This corresponds to a latest Santonian/ early Campanian age (GRADSTEIN et al., 1995).

The sediments of the Maiersdorf Formation give evidence of a late Santonian marine transgression in the Piesting area. Fully marine, shallow water conditions and rocky shores can be reconstructed. Brachiopod limestones as found in the Piesting S section interfinger with rudist limestones and shallow-marine sandstones farther to the west of the Grünbach Syncline.

### 3.2 Grünbach Formation

Exposures of the Grünbach Formation (SUMMESBERGER et al., 2000) are rare throughout the Grünbach Syncline. Near Piesting, building construction sites (300 m ESE of the junction of the 'Umfahrungsstraße' with the road to Dreistätten, Fig. 1) provided temporary exposures in 1996. The geological map of the area (SUMMESBERGER, 1991) indicates a shaft of a coalmine (Fig. 1), which is hardly visible today. The temporary sections exposed grey marls and fine-grained sandstones with thin coal seams. Foraminifera and calcareous nannofossils are rare, probably because of intermittently brackish waters (PLÖCHINGER, 1961). Overall, a Campanian age is indicated for the Grünbach Formation (HRADECKÁ et al., 1999). OBERHAUSER (in PLÖCHINGER, 1961) reported *Globotruncanita elevata*, *Globotruncana rugosa* and *Rosita* cf. *contusa*, indicating a Campanian age for the middle? to upper part of the Grünbach Formation in the Piesting S section. Heavy minerals from the sandstones are predominantly stable minerals and apatite, in agreement with the data of WOLETZ (1963) from the Grünbach Formation of the Grünbach area. The boundary between the Grünbach Formation and the Piesting Formation is not exposed today.

The Grünbach Formation records an interval of prevailing lacustrine to brackish conditions with rare marine incursions. Coal formation was common in a swampy, low relief area, together with intermittent coarse clastic influence from alluvial fans at basin margins.



### 3.3 Piesting Formation

The term Piesting Formation (SUMMESBERGER et al., 2000) of the Gosau Group of the Neue Welt is introduced, replacing the obsolete terms "Inoceramenschichten" or "Inoceramenmergel". The latter were used traditionally for Cretaceous rock units of different age in different tectonic units (e.g. GÜMBEL 1856: p.4, Helvetic unit; STUR 1894: Flysch nappe; ZITTEL 1864: 94 ff: Gosau Group). Until recently, the terms were used for the Campanian to Maastrichtian strata of the Gosau Group of the Neue Welt (e.g. PLÖCHINGER in: BRIX & PLÖCHINGER, 1988; PLÖCHINGER in: SUMMESBERGER, 1991; SUMMESBERGER, 1997). The age assignment was based on planktonic foraminifera (OBERHAUSER in: PLÖCHINGER, 1961, 1967). The "Obitoidensandstein" (PLÖCHINGER 1961; originally "Orbituliten Sandstein", ZITTEL 1864:93 ff.) is understood as repeated intercalations of coarser siliciclastic material, and is included within the definition of the Piesting Formation.

The Piesting Formation in the Grünbach – Neue Welt area between Puchberg and Piesting comprises a several hundred-meters thick succession of silty to sandy grey marls to marly sandstones of Campanian to Maastrichtian age, with intercalated distinct sandstone beds and rare conglomerates. It is the eastern time-equivalent of the Nierental Formation and, in part, of the Zwieselalm Formation of the area west of the Grünbach Syncline. The definition of the Piesting Formation is based on data from the measured type sections at Piesting (sports field; road cutting 'Umfahrungsstraße') and data from the abandoned coal mines (PLÖCHINGER, 1961, text-fig. 1; PLÖCHINGER 1967, text-fig. 7), as reinterpreted by SUMMESBERGER (1982, in: KOLLMANN & SUMMESBERGER, p. 92), SUMMESBERGER (1997: text-fig. 13).

## 4. LITHOSTRATIGRAPHIC DEFINITION OF THE PIESTING FORMATION

The formation can be subdivided into three main lithofacies units:

- (1) Marls with intercalations of fine-grained sandstones, comprising the lower part of the succession. Sandstone beds show sharp bases, horizontal lamination, small-scale ripple cross-lamination and rare slump folds (Fig. 5). This marl-dominated succession crops out along the 'Umfahrungsstraße' S of Piesting. The outcrops are in poor condition today, but during road construction (in the early 1990s), a section with a thickness of about 130 m was exposed.
- (2) A more than 2.5 m-thick sandy conglomerate to sandstone interval is intercalated within the marls, exposed E of the parking area of the forest bath (Waldbad) of Piesting (Fig. 1) and at the western side of the Piesting sports field. Thin intercalations of sandy red and grey marls can be found within the conglomerates.
- (3) Sandy marls with intercalations of medium-grained sandstones. Sandstone beds display normal grading, and a succession from a sharp base to horizontal lamination, ripple cross-lamination and thin horizontal lamination. The bedding planes are covered by ichnofossils of an irregularly meandering browser. The 10- and 20-mm-wide traces completely cover the bedding planes (Fig. 5).

The outcrop at the sports field of Piesting formed in the year 2000 a maximum 8-m-high, 35-m-long, subvertical exposure at the eastern margin of the sports field, south of the "Waldbad" (forest bath). The stratigraphical thickness is about 22 m. The strata dip 180/26°.



Fig. 4: Exposure of the Maastrichtian part of the Piesting Formation (Gosau Group) at the sports field of Piesting (Lower Austria). Note turbiditic sandstone beds and bioturbated sandy marls.

The boundary to the underlying Grünbach Formation is defined by the change from varicoloured shales including coal seams to grey silty to sandy marls. The macrofauna of the Piesting Formation is characterized by abundant trace fossils, common inoceramids and a few ammonites versus a diverse macrofauna including plant fossils (HERMAN & KVACEK, 2000), reptiles (Muthmannsdorf; BUNZEL, 1871) and fresh-water molluscs in the Grünbach Formation. The clay mineral assemblages of the Piesting Formation are characterized by higher amounts of smectite in relation to illite and some chlorite than samples from the underlying formation (HRADECKÁ et al., 1999). Heavy mineral assemblages are dominated by garnet and/or stable minerals; chrome spinel is very rare. The main differences from the overlying Danian-Thanetian Zweiersdorf Formation (PLÖCHINGER, 1961; SAUER, 1980) are a higher clay content and a smaller amount of sandy material in the pelites, the lack of macrofauna, minor bioturbation, and the higher amount of sandstone beds with distinct grading and Bouma-divisions in the Zweiersdorf Formation. A higher mica content of the marls of the Zweiersdorf Formation was reported by HRADECKÁ et al. (1999).



The relationship between the Piesting Formation and the sandstones with orbitoids ('Orbitoidensandsteine') as defined by PLÖCHINGER (1961) in the Neue Welt area remains somewhat unclear, although at least parts of these sandstones and conglomerates can be included into the Piesting Formation:

1. In the Piesting S section, no sandstones with orbitoids were found. Although PLÖCHINGER (1961) mapped these sandstones from the Grünbach area up to the north of Piesting, the continuation of the up to 30-m-thick sandstone beds from the Neue Welt into the Piesting area is not indicated by our data and remains dubious. However, the sporadic outcrops of sandy conglomerates in the middle of the Piesting Formation south of Piesting are attributed to this sandstone interval.
2. Based on biostratigraphic data (*Pseudokosmaticeras brandti* REDTENBACHER, not "*Pachydiscus neubergicus*"; as indicated in PLÖCHINGER, 1961, p. 394; 1967, pl. 1, fig. 2), at least the 1st and the 2nd layer of the "Orbitoidensandstein" of PLÖCHINGER (1961) should be below or at the base of the Piesting Formation. No thick sandstone interval, however, was found in this stratigraphic position during road construction of the Piesting 'Umfahrungsstraße'.

#### 4.1 Facies interpretation

The environment of deposition of the Piesting Formation is interpreted as fully marine. Sandstone beds in the lower part of the Piesting Formation resemble shelf tempestites from other successions of the Gosau Group (WAGREICH, 1988). Low to medium percent-

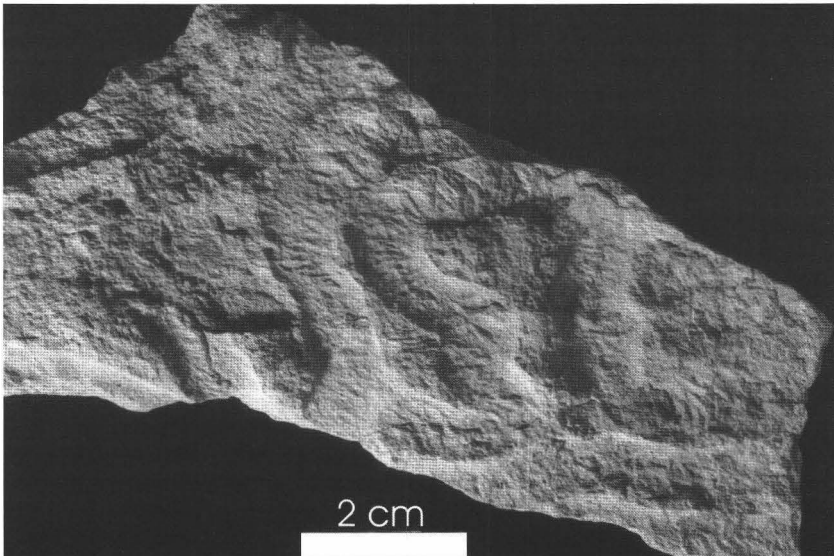


Fig. 5: Trace fossils of an unknown animal irregularly meandering on the sea-floor from the bedding planes of the exposure of Piesting Formation at the sports field of Piesting, Lower Austria.

ages of planktonic foraminifera (PLÖCHINGER, 1961) indicate middle to outer neritic depths of deposition. The following interval of conglomerates and sandstones can be interpreted as the marine proximal part of a fan delta, which grades into the finer-grained, distal part higher up-section. Weak grading and chaotic texture of the conglomerates indicate deposition by submarine mass flows and minor reworking by marine currents. The succession of thin-bedded marly to sandy siltstones and intercalated medium-grained sandstones at the Piesting sports field is bioturbated throughout by an unknown organism grazing on the sea-bottom, indicating oxygenated bottom waters. Macrofossils are generally rare, with the exception of inoceramids. This also suggests a relatively pelagic, quiet-water environment of deposition. Sandstone beds display normal grading. They are interpreted as turbidites, although a tempestite origin for some thinner beds cannot be ruled out completely, due to the lack of distinct grading. The high sand content of the marls is due to bioturbation of thin sand layers. The turbidite origin of the sandstone beds, together with the sand-rich, turbidite-dominated succession of the overlying Zweiersdorf Formation, suggests deposition within a deep-water clastic fan or apron. No distinct cyclicity is recorded within the Piesting Formation.

Nektonic organisms such as ammonites had a certain chance of fossilization under the conditions of a strong clastic influx as recorded in the sports field section; for inoceramids life conditions were apparently good, as they were for a certain bottom dweller, which left its distinctive style of bioturbation. Gastropods, echinoids, molluscan infauna and brachiopods are not preserved and were apparently unable to exist under deep water conditions and high sedimentation rates.

## 5. INTEGRATED STRATIGRAPHY OF THE PIESTING FORMATION

Inoceramids and trace fossils are the dominant faunal elements in the sports field section. Trace fossils occur throughout the section, inoceramids (TRÖGER et al., in press) predominantly in the upper half; most of the ammonites occur in the upper third. Inoceramids are also common in the lower section, the 'Umfahrungsstraße' S of Piesting; ammonites are absent there, and the nannofloras are very poor. Additional macrofossils from other localities of the Piesting Formation (e.g. Muthmannsdorf, Grünbach) are listed under "Inoceramenmergel" in PLÖCHINGER (1961).

### 5.1. Cephalopods

The first ammonite mentioned from the Piesting Formation was "*Hamites Hampeanus*" (CZIZEK, 1851), possibly *Diplomoceras* sp. In 1873 REDTENBACHER described the ammonites and nautiloids from Muthmannsdorf (Fig. 1), presumably all from the Piesting Formation. His original locality could not be identified with certainty in this study. In the area of Muthmannsdorf (Fig.1/8), *Pseudokosmaticeras brandti* (REDTENBACHER) was recently found (Pl. 2, Fig. 2). *Belemnitella hoeferi* (SCHLOENBACH, 1867; see CHRISTENSEN, 1998) was described from Grünbach, presumably also from the Piesting Formation. A revised list of cephalopods from the Piesting Formation is given below:

"*Nautilus*" *sublaevigatus* D'ORBIGNY  
*Baculites* sp. indet.  
*Menuites sturi* (REDTENBACHER)  
*Pachydiscus epiplectus* (REDTENBACHER)  
*Pseudokossmaticeras brandti* (REDTENBACHER)  
*Pseudokossmaticeras duereri* (REDTENBACHER)  
?*Diplomoceras* sp  
*Scaphites* sp. indet.  
*Belemnitella hoeferi* (SCHLOENBACH)

REDTENBACHER (1873, p. 118, pl. 27/fig. 2) described *Ammonites Düreri* nov. sp., which was thought by him to be from the type locality of the Gosau Group, the Gosau valley in Upper Austria. We reinterpret his original, revised *Pseudokossmaticeras duereri* (REDTENBACHER), stored in the collections of the Austrian Geological Survey, to be also from the Piesting Formation of the Neue Welt area. Nannofossils from the specimen (WAGREICH unpublished) indicate a Campanian to Maastrichtian age. Campanian and Maastrichtian formations cropping out in the Gosau valley are lithologically different and barren of ammonites (e.g., WAGREICH & FAUPL, 1994). Moreover, the term "Gosau" was used in different ways in the last decades of the 19<sup>th</sup> century: on the one hand as a distinct locality, on the other as a stratigraphical concept without locality significance. It seems that there are reasons enough to doubt the origin of *Pseudokossmaticeras duereri* (REDTENBACHER) from Gosau in Upper Austria. Its origin from the Grünbach – Neue Welt area seems highly likely (see also comments of THIEDIG & WIEDMANN, 1976, p.14).

Besides the taxa in REDTENBACHER'S list we collected from the Piesting sports field section a small and poorly preserved but diverse ammonite fauna (6 taxa), which is described in more detail below:

*Pseudophyllites* sp.indet.  
*Saghalinites* sp. indet.  
*Hauericeras* sp. indet.  
*Pachydiscus* (*P.*) *neubergicus Neubergicus* (HAUER)  
Nostoceratidae genus et sp. indet.  
*Diplomoceras* sp. indet.

A specimen of *Pseudokossmaticeras brandti* (REDTENBACHER) (Pl. 2, Fig. 2) was found recently (2001) at Muthmannsdorf, possibly indicating at least one part of the area from which REDTENBACHER'S fauna was collected. No ammonites were found in the lower part of the type section (Piesting "Umfahrungsstraße").

#### 5.1.1. Age indication of the ammonite fauna

*Saghalinites* sp. indet. is the only ammonite present in the lower part of the sports field section, the remaining ammonites were collected from the upper 7 m of the section. This is also the level where *Pachydiscus* (*P.*) *neubergicus* appears. *Pachydiscus* (*P.*) *neubergicus Neubergicus* (HAUER) is the index fossil for the base of the Maastrichtian (ODIN, 1996). It ranges up into the late Early Maastrichtian. As typical Campanian ammonites are absent, and as *Pachydiscus* (*P.*) *neubergicus* is a long-ranging species, it remains unclear if its first appearance in the section indicates the base of the Maastrichtian; it

does, however, reliably indicate Lower to middle Maastrichtian for the Piesting sports field section.

A more precise indication of an Early Maastrichtian age is provided by *Pachydiscus epipectus* (REDTENBACHER), which occurs in the Piesting Formation at Muthmannsdorf. On the other hand, the occurrence there of *Pseudokossmaticeras brandti* (REDTENBACHER, 1873, p. 107) indicates Late Campanian (KENNEDY et al., 2000). The vanished outcrop of Muthmannsdorf may therefore have comprised a considerable stratigraphic range in REDTENBACHER 's time. The occurrences of *Pseudokossmaticeras brandti* in the Neue Welt area are typically immediately above the Grünbach Formation, possibly linked to the first bed of the "Orbitoidensandstein". In terms of ammonite stratigraphy, the Piesting Formation ranges from the Late Campanian *Nostoceras hyatti* Zone to the Early Maastrichtian *Pachydiscus epipectus* Zone (cf. WARD & KENNEDY, 1993).

## 5.2. Inoceramids

The wealth of inoceramids was mentioned from the very beginning of exploration (BOUÉ, 1832; CZIZEK, 1851), and described by ZEKELI (1853) and ZITTEL (1864). The inoceramid fauna is rich in individuals, most of them broken and difficult to collect. They indicate a Late Campanian to Early Maastrichtian age, although no detailed zonation could be applied. Two lists from the two parts of the type section are given below. A detailed description is given elsewhere (TRÖGER et al., in press). Inoceramids from the 'Umfahrungstraße' (TRÖGER et al., in press) indicate a latest Campanian age:

*Trochoceras* cf. *morgani* (SORNAY)

*Trochoceras* cf. *dobrovi* PAVLOVA

At the Piesting sports field, fossils are generally very scarce in the lower 10 m of the section. From the middle part of the section upward, inoceramids are common to abundant. They indicate an Early Maastrichtian age (TRÖGER et al., in press):

*Inoceramus* sp. aff. *planus* MÜNSTER (sensu WALASZCZYK et al., 1996)

*Cataceramus* sp. ex gr. *balticus* (BÖHM)

*Cataceramus* ? *glendivensis* WALASZCZYK, COBBAN & HARRIES

*Platyceramus salisburgensis* (FUGGER & KASTNER)

*Platyceramus alaeformis* (ZEKELI),

*Trochoceras* cf. *tenuiplicatus* (TZANKOV)

*Trochoceras* cf. *monticuli* (FUGGER & KASTNER)

*Trochoceras* sp. aff. *helveticus* (HEINZ)

*Spyridoceras* cf. *tegulatus* (HAGENOW)

*Spyridoceras* sp.

*P. salisburgensis* and *T. monticuli* are typical representatives of the Muntigl fauna (Rhenodanubian Flysch zone near Salzburg; FUGGER & KASTNER, 1885), which is now reported for the first time from the Gosau Group of the Northern Calcareous Alps.

### 5.3. Calcareous Nannofossils

The nannofossil assemblages from the Piesting sports field section show poor preservation and low abundances due to the high amounts of non-calcareous silt. Marker species include *Lucianorhabdus cayeuxii*, *Micula decussata*, *Arkhangelskiella cymbiformis*, *Ceratolithoides aculeus*, *Lithraphidites cf. praequadratus* and *Quadrum* sp. This most probably indicates standard zone CC24 of PERCH-NIELSEN (1985) and WAGREICH & KRENMAYR (1993), above the last occurrence of *Broinsonia parca parca*. (*Aspidolithus parvus parvus* of ODIN et al., 2001). This zone corresponds to nannofossil zone UC17 of BURNETT (1998), which includes the Campanian-Maastrichtian boundary as defined by the FO of *Pachydiscus neubergicus*.

Calcareous nannofossils from the road cutting 'Umfahrungsstraße' yielded even worse results. Ten of the fifteen samples were barren or contained only a few, badly preserved specimens of long-ranging taxa such as *Watznaueria*. One sample near the location of the inoceramid fauna in the middle of the section contained *Broinsonia parca parca*, indicating a Campanian age, at least nannofossil zone CC18. However, no *Ceratolithoides aculeus* has been found in this section. Therefore, Lower and Upper Campanian have not been distinguished by means of nannofossils.

### 5.4. Foraminifera

Foraminifera determined by OBERHAUSER (in PLÖCHINGER, 1961) indicated a Late Campanian to Early Maastrichtian age for the Piesting Formation of the Grünbach – Neue Welt syncline. Also, HRADECKÁ et al. (1999) reported a Late Campanian (*Globotruncana ventricosa* Zone) to Early Maastrichtian age (*Gansserina gansseri* Zone) from the Grünbach area. During the construction of the "Umfahrungsstraße", 18 samples were taken for foraminifera and nannoplankton. Most of the foraminiferal samples had an extremely high sand content and were barren. One sample yielded *Bolivinooides decoratus decoratus* (JONES), which indicates a Campanian age.

### 5.5. Magnetostratigraphy

At each site, 6 to 10 oriented cores were collected using standard palaeomagnetic techniques. Laboratory procedures included stepwise demagnetization of the natural remanent magnetization using alternating-field and thermal treatment. After removal of a low-temperature overprint (carried by goethite), characteristic magnetization components could be isolated that were stable up to 550°C and decayed rapidly at higher temperatures (see HAUBOLD et al., 1999). IRM experiments indicated magnetite as the dominant carrier of the characteristic magnetization. The low field anisotropy of the magnetic susceptibility implied undeformed sedimentary fabrics. The pre-folding age of the magnetization is proved by positive fold tests on a regional scale and by antipodality tests. Palaeomagnetic data indicate normal polarity in the 'Umfahrungsstraße' section, whereas a reverse polarity was found at the sports field section.

## 5.6. Chronostratigraphic correlation

The lower part of the Piesting Formation in the 'Umfahrungsstraße' road cutting yielded *Trochoceras* cf. *morgani* (SORNAY) and *Trochoceras* cf. *dobrovi* PAVLOVA, and a poor nannoplankton assemblage of nannozones CC 18–22. Thus, this part of the Piesting Formation can be correlated with the (late) Late Campanian (TRÖGER et al., 2000). Based on the biostratigraphic correlation, the reversed palaeomagnetic data indicate most probably Chron 32N (SCHOLGER in: TRÖGER et al., 2000).

The upper part of the Piesting Formation in the sports field section can be dated as Early Maastrichtian. This is indicated by the ammonite *Pachydiscus* (*P.*) *neubergicus* (HAUER), even if it remains unclear whether or not its appearance indicates the base of the Maastrichtian, because of the long range of this species (e.g., CHRISTENSEN et al., 2000; WAGREICH et al., in press). Nannofossils indicate nannozone CC24, above the last occurrence of *Broinsonia parca parca*. This zone corresponds to nannofossil zone UC17 of BURNETT (1998), which spans the Campanian-Maastrichtian boundary as defined by the FO of *Pachydiscus Neubergicus*. Together with the biostratigraphic data, the most likely interpretation of the palaeomagnetic data is Chron 31R, just above the Campanian-Maastrichtian boundary. GRADSTEIN et al. (1995) correlate this magnetochron with the *neubergicus/tridens* ammonite zone. Based on the Bottaccione section, Chron 31R can be correlated with the upper part of the *Gansserina gansseri*-zone up to the FO of the planktonic foraminifer *Abathomphalus mayaroensis* (PREMOLI SILVA & SLITER, 1995). Results from Tercis (BARCHI et al., 1997; LEWY & ODIN, 2001) did not recognize Chron 31R. However, according to BARCHI et al. (1997), Chron 31R starts already in the latest Campanian, whereas LEWY & ODIN, (2001) correlate this reversed interval in Tercis with Chron 32R.

## 6. SYSTEMATIC PALAEONTOLOGY

Order Ammonoidea ZITTEL, 1884

Lytoceratina HYATT, 1889

Superfamily Tetragonitaceae HYATT, 1900

Family Tetragonitidae HYATT, 1900

Subfamily Tetragonitinae HYATT, 1900

Genus *Pseudophyllites* KOSSMAT, 1895

*Pseudophyllites* sp. indet.

Plate 2, Fig. 6

**Material:** a single juvenile specimen (NHMW/2001z0122/0004) from the Piesting Formation of the Piesting, sports field section.

**Description:** NHMW/2001z0122/0004 is an internal mould of a phragmocone with traces of shell and fragments of the suture, and a fragmental part of the septal face preserved. Oligogyral with rapidly increasing whorl height, and a deep, rather narrow umbilicus. It measures: D 26 mm, Wh 11.7, U 4.6, U% 17.7%.

**Discussion:** All discernible elements are those of a *Pseudophyllites*. Due to the poor preservation and the juvenile stage of the specimen, specific identification is left open.

**Occurrence:** Lower Maastrichtian of the Piesting Formation of Piesting (Lower Austria)

Genus *Saghalinites* WRIGHT & MATSUMOTO 1954

*Saghalinites* sp. indet.

Plate 2, Figs. 3, 3a

**Material:** NHMW/2001/z/0122/0005 consists of fragments of an internal and an external mould belonging to the same individual from the lower part of the Piesting sports field section.

**Description:** The external mould is a distorted ellipse of about 51 mm diameter. It shows several distinct, irregularly spaced constrictions. Wh 16.2 is measurable on the internal mould, which also displays the aperture.

**Occurrence:** Lower Maastrichtian of the Piesting Formation of Piesting (Lower Austria)

Suborder Ammonitina HYATT, 1889

Superfamily Desmocerataceae ZITTEL, 1895

Family Desmoceratidae ZITTEL, 1895

Subfamily Hauericeratinae MATSUMOTO, 1938

Genus *Hauericeras* GROSSOUVRE, 1894

*Hauericeras* sp. indet

Plate 2, Fig. 4

**Material:** a single specimen (NHMW/2001/z/0122/0006) from the Piesting Formation of Piesting, sports field section.

**Description:** NHMW/2001/z/0122/0006 is an internal mould of a phragmocone without traces of shell and covered by a faint limonitic crust. Three constrictions are visible, one of them indicating the aperture. Close to the aperture some growth striae can be observed in oblique light. Total length is about 28 mm. The other measurements are meaningless. The typical hollow keel of *Hauericeras* cannot be seen.

**Discussion:** Due to the poor preservation specific identification is left open.

**Occurrence:** Lower Maastrichtian of the Piesting Formation of Piesting (Lower Austria)

Family Kossmaticeratidae SPATH, 1922

Subfamily Kossmaticeratinae SPATH, 1922

Genus *Pseudokossmaticeras* SPATH, 1922

Type species: *Ammonites pacificus* STOLICZKA (1866) by original designation.

*Pseudokossmaticeras brandti* (REDTENBACHER, 1873)

Plate 2, Fig. 2

Synonymy

- 1873 *Ammonites Brandti* REDTENBACHER, p. 106, pl. 24, fig. 1  
1935 *Kossmaticeras brandti* REDT.; BRINKMANN, p. 6.  
1958 *Pseudokossmaticeras brandti* (REDTENBACHER); REYMENT, p. 34, pl. 10, fig. 1 a–c.  
1967 *Pachydiscus (Parapachydiscus) neubergicus* HAUER; PLOCHINGER, p. 49, pl. 1, fig. 2.  
1993 *Pseudokossmaticeras brandti* (REDTENBACHER); HANCOCK & KENNEDY, p. 155; pl. 2, figs. 4–6, pl. 4, figs. 1–5, pl. 5, figs. 1–8, pl. 6, figs. 1–9, pl. 7, figs. 5–11. With full synonymy.  
1995 *Pseudokossmaticeras brandti* (REDTENBACHER); KENNEDY & BILOTTE, p. 362, pl. 50, fig. 1 a–c.  
1997 *Pseudokossmaticeras brandti* (REDTENBACHER); MARTINEZ, p. 375, fig. 1a.  
2001 *Pseudokossmaticeras brandti* (REDTENBACHER); KENNEDY, BILOTTE. & MORALA, p. 259, fig. 2  
2001 *Pseudokossmaticeras brandti*; KENNEDY & ODIN, pl. 1, fig. 3,  
2001 *Pseudokossmaticeras brandti*; COURVILLE & ODIN, p. 532, pl. 7, fig. 52–54.

Lectotype is the original of REDTENBACHER 1873, (p.106, pl. 24, fig. 1) from the Piesting Formation of Grünbach, Lower Austria (GBA 1873/01/11) designated and refigured by REYMENT (1958, p. 34), refigured again by KENNEDY et al. (2000).

**Material:** The lectotype (GBA 1873/01/11) from Grünbach, 10 topotypes from Grünbach. Two specimens from Muthmannsdorf: GBA 1935/01/16, probably from REDTENBACHER's type series (1873, p.107) and listed by BRINKMANN (1935, p.6). An unregistered specimen from the PUNTIGAM collection could be from REDTENBACHER's locality at Muthmannsdorf. A single specimen from Puchberg (Lower Austria), a juvenile one from Gießhübl (Lower Austria). The material from the Gosau Group of the Krappfeld (THIEDIG & WIEDMANN, 1976) was not at our disposal.

**Discussion:** *Pseudokossmaticeras brandti* (REDTENBACHER) was discussed by HANCOCK & KENNEDY (1993). Its stratigraphic range in the Upper Campanian of the Aquitaine basin (France) was discussed by KENNEDY et al. (2000).

**Occurrence:** All specimens of *Pseudokossmaticeras brandti* (REDTENBACHER) are from the basal Piesting Formation, from close to or from the first 'Orbitoidensandstein'. This is below the first occurrence of *Pachydiscus (P.) neubergicus neubergicus* (HAUER) in the Piesting Formation. The stratigraphic range of *P. brandti* in the Upper Campanian *hyatti* Zone of the Aquitaine basin (France) was discussed by KENNEDY et al. (2000). In the Austrian Gosau Group, with its high sedimentation rates, the lithostratigraphic distance between their occurrences might be much larger than the 10–13 m measured at Tercis (WARD & ORR, 1997; COURVILLE & ODIN, 2001; ODIN et al., 2001). In stratigraphically unequivocal localities of the Neue Welt area or Neuberg (Styria), *P. neubergicus* and *P. brandti* do not occur together. At Neuberg (Styria), *P. neubergicus* is accompanied by *P. epiplectus* (REDTENBACHER) and about 10 additional taxa (KENNEDY & SUMMESBERGER, 1986); at Piesting sports field (this paper) *P. neubergicus* is accompanied by 5 taxa. The occurrences of *P. brandti* seem to be stratigraphically isolated and invariably below occurrences of *P. neubergicus* and *P. epiplectus*. The apparent co-occurrence of *P. neubergicus* and *P. brandti* at Grünbach and of *P. epiplectus* and *P. brandti* at Muthmannsdorf seems to have resulted from inaccurate labelling.



Outside Austria and France, *P. brandti* occurs in the Balkans, Spain, Crimea, Caucasus and Tunisia (HANCOCK & KENNEDY, 1993).

Family Pachydiscidae SPATH, 1922  
Genus *Pachydiscus* ZITTEL, 1884  
Subgenus *Pachydiscus* ZITTEL, 1884

Type species: *Ammonites neubergicus* HAUER, 1858:12; pl. 2, figs. 1–4; pl. 3, figs. 1–2, by the subsequent designation of DE GROSSOUVRE, 1894:177.

*Pachydiscus (Pachydiscus) neubergicus neubergicus* (HAUER, 1858)

Plate 1, Figs. 1, 2, 3, 4; Plate 2, Fig. 1

Lectotype: GBA 1858/01/6, the original of HAUER (1858, p. 12, figs. 1,2) subsequently designated by de GROSSOUVRE, 1894, p. 209; from Krampen near Neuberg, Styria (Austria).

#### Synonymy

- 1858 *Ammonites Neubergicus* HAUER, p. 12 (pars), pl. 2, figs. 1–3 (only).  
non 1961 *Pachydiscus (P.) neubergicus* PLÖCHINGER, p. 398 [= *Pseudokossmaticeras brandti* (REDTENBACHER)].  
non 1967 *Pachydiscus (Parapachydiscus) neubergicus* PLÖCHINGER, p. 49, pl. 1, fig. 2 [= *Pseudokossmaticeras brandti* (REDTENBACHER)].
- 1986 *Pachydiscus (Pachydiscus) neubergicus* (HAUER 1858); KENNEDY & SUMMESBERGER, p. 189, pl. 2, figs. 1–2; pl. 3, figs. 1–3; pl. 4, figs. 1–5; pl. 5, figs. 1,4,5; pl. 6, figs. 1,2,5; pl. 15, figs. 7,8; pl. 16, fig. 16. Text-fig.5A,B. (with synonymy).
- 1993 *Pachydiscus (Pachydiscus) neubergicus neubergicus* (HAUER 1858); HANCOCK & KENNEDY, p. 158; pl. 3, figs. 6–7; pl. 9, figs. 5–8; pl. 12, figs. 7–9; pl. 13, figs. 5–7. (with additional synonymy).
- 1993 *Pachydiscus (Pachydiscus) neubergicus neubergicus* (HAUER 1858); WARD & KENNEDY, p. 30, figs. 25.9–12,14, 16–18, 27.3–5, 27.7, 28.1–3, 30.4–6.
- 2001 *Pachydiscus neubergicus*; KENNEDY & ODIN: pl. 1, fig. 8.
- 2001 *Pachydiscus neubergicus*; COURVILLE & ODIN: pl. VI, fig. 48–50.
- 2001 *Pachydiscus neubergicus*; ODIN, COURVILLE, MACHALSKI & COBBAN, pl. 2, fig. 1.

**Material:** Three juvenile individuals from the Piesting Formation of the Piesting sports field: NHMW/2001/z/0122/0001, 2, 3; an adult from the Piesting Formation of Grünbach PIUW 1991/1698 (ex coll. WEINFURTER (pl. 1, fig. 4).

**Description and Discussion:** The juvenile individuals and the adult one are preserved as internal moulds, distorted to a certain degree and somewhat elongated to an ellipse. The specimens from the sports field are much smaller than specimens collected elsewhere in the Gosau Group. The general shape is almost identical to that of specimens from the type locality Krampen near Neuberg (KENNEDY & SUMMESBERGER, 1986), differing only in the smaller umbilicus. The typical style of adult ribbing seems to begin at a diameter of 22–25 mm. Inner whorls are smooth or show (NHMW/2001/z/0122/0003) faint ventrolateral ribs only.

**Measurements:**

NHMW/2001/z/0122/0002      D 38              Wh 16.8      U 8.7      U% 22.9

NHMW/2001/z/0122/0001      D 37.0           Wh 15.8      U 8.6      U% 23.2

Measurements of *Pachydiscus (P.) n. neubergicus* (NHMW/2001/z/0122/0001 and 2) from the Piesting sports field. The measurements should be used with caution due to deformation. Nevertheless, the data from the shorter axis give useful information about the relations.

**Occurrence:** *Pachydiscus (P.) n. neubergicus* worldwide indicates basal to middle Maastrichtian. It is present in the Lower Maastrichtian of the Piesting Formation of Piesting (Lower Austria). Further occurrences in Austria are: Neuberg (type-locality; Styria), Lower Maastrichtian of the Piesting Formation of Grünbach (Lower Austria), after BRINKMANN (1935): Gamsbauer near Gloggnitz (Lower Austria).

Suborder Ancyloceratina WIEDMANN, 1966

Superfamily Turrilitaceae GILL, 1871

Family Nostoceratidae HYATT, 1894

Nostoceratidae genus et sp. indet.

Plate 2, Fig. 5

**Material:** A single specimen NHMW/2001/z/0122/0007 from the Piesting Formation of Piesting sports field.

**Description:** NHMW/2001/z/0122/0007 is a 35.3-mm-long fragment of an internal mould with adherent traces of whitish shell. It has about 10 relatively strong, distant, regularly spaced non-bifurcating ribs.

**Discussion:** Due to the poor preservation, the generic and specific identification is left open.

**Occurrence:** Lower Maastrichtian of the Piesting Formation of Piesting (Lower Austria)

Family Diplomoceratinae SPATH, 1926

Subfamily Diplomoceratinae SPATH, 1926

Genus *Diplomoceras* HYATT, 1900

*Diplomoceras* sp. indet.

Plate 2, Fig. 7

**Material:** NHMW/2001/z/0122/0008 fragments of the body chamber of a larger individual.

**Description:** NHMW/2001/z/0122/0008 consists of several irregularly arranged fragments of the body chamber of a larger individual, visible from inside; the shell is partially preserved. The fragments are tightly covered by faint, very narrowly spaced lirae. As no

*Gaudryceras*-like tapering of the lirae is visible, nor is a typical falcooid course present, gaudryceratid ammonites may be excluded from consideration.

**Discussion:** Shell fragments suggest the shell remains are leftovers of a predator's or scavenger's meal. Due to the preservation state open nomenclature is used.

**Occurrence:** Lower Maastrichtian of Piesting Formation of Piesting (Lower Austria). The genus *Diplomoceras* occurs worldwide. As mentioned above, the earliest reports of ammonites from Maastrichtian localities are to be understood now as representatives of the genus *Diplomoceras*. E.g.: CZIZEK (1851, p.122): '*Hamites Hampeanus*' from the church of Grünbach together with inoceramid bivalves; HAUER (1858, p.8) revised his earlier described '*Hamites Hampeanus*' (HAUER, 1847, p.75) from the Maastrichtian of Neuberg (Styria) to *Hamites cylindraceus* DEFRANCE (1816), which is apparently the earliest ammonite mentioned from the Gosau Group.

### Abbreviations

PIUW Institut für Paläontologie, Universität Wien  
NHMW Naturhistorisches Museum Wien  
GBA Geologische Bundesanstalt Wien

## 7. CONCLUSIONS

The Upper Cretaceous Piesting Formation (Gosau Group, "Neue Welt" area) is newly defined as a several-hundred-meters thick sequence of shelf to deeper marine siliciclastic sediments. The Piesting Formation replaces the *Inoceramenschichten* and *Inoceramemergel* of former authors (e.g. PLÖCHINGER, 1961) and includes the *Orbitoidensandstein* of PLÖCHINGER (1961). Along a section to the south of Piesting the Piesting Formation comprises Campanian to Lower Maastrichtian strata. Three intervals can be distinguished: a lower part of grey marls with tempestites, followed by sandstones and conglomerates, and an upper part comprising sandy marls with rare turbidites.

Within the lower part of the Piesting Formation, in the "Umfahrungsstraße" road cutting, a late Late Campanian age is indicated by *Trochoceras* cf. *morgani* (SORNAY) and *Trochoceras* cf. *dobrovi* PAVLOVA. Nannofossil data indicate standard nannozones CC18–22. Palaeomagnetic data indicate a normal interval, probably Chron 32 N.

Early Maastrichtian is indicated at the type section in the Piesting sports field by *Pachydiscus neubergicus* und inoceramid bivalves of the Muntigl fauna including *Platyceras* *salisburgensis* (FUGGER & KASTNER) and *Trochoceras* cf. *monticuli* (FUGGER & KASTNER) (TRÖGER et al., in press). Although the first occurrence of *Pachydiscus* (*P.*) *neubergicus neubergicus* (HAUER) defines the base of the Maastrichtian, the species ranges up into the late Early Maastrichtian; the age indication for the Piesting sports field section is therefore broad and imprecise. The Early Maastrichtian nannozone CC24 could be recognized, above the last occurrence of *Broinsonia parca parca*. Reversed palaeomagnetic data indicate probably Chron 31 R.

In terms of ammonite stratigraphy the Piesting Formation in the Grünbach – Neue Welt area ranges from the Late Campanian *N. hyatti* Zone to the Early Maastrichtian *P. epiplectus* Zone (WARD & KENNEDY, 1993).

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## Plate 1

All specimens are coated with ammonium chloride; all are × 1.

Fig. 1: *Pachydiscus (Pachydiscus) neubergicus neubergicus* (HAUER 1858); GBA 1858.01.6, the original of HAUER 1858, pl. 2, figs. 1,2; designated lectotype by DE GROSSOUVRE 1894:209 from Neuberg, Styria, Austria.

Fig. 2: *Pachydiscus (Pachydiscus) neubergicus neubergicus* (HAUER 1858); NHMW/2001z0122/0001; a juvenile specimen from the sports field section of the Piesting Formation, S Piesting, Lower Austria.

Fig. 3: *Pachydiscus (Pachydiscus) neubergicus neubergicus* (HAUER 1858); NHMW/2001z0122/0002; a juvenile specimen from the sports field section of the Piesting Formation, S Piesting, Lower Austria.

Fig. 4: *Pachydiscus (Pachydiscus) neubergicus neubergicus* (HAUER 1858); PIUW/1991/1698; coll. Weinfurter; adult specimen from the Piesting Formation of Grünbach, Lower Austria.





## Plate 2

All specimens except No. 2 are from the sports field section of the Piesting Formation, Piesting, Lower Austria; all are x 1 and all are coated with ammonium chloride.

Fig. 1: *Pachydiscus (Pachydiscus) neubergicus neubergicus* (HAUER 1858); NHMW/2001z0122/0003; juvenile individual.

Fig. 2: *Pseudokossmaticeras brandti* (REDTENBACHER) from the Piesting Formation of Muthmannsdorf, Lower Austria; Collection J. PUNTIGAM, Muthmannsdorf, unregistered.

Fig. 3, 3a: *Saghalinites* sp. indet., NHMW/2001z0122/0005.

Fig. 4: *Hauericeras* sp. indet., NHMW/2001z0122/0006.

Fig. 5: Nostoceratidae genus et sp. indet., NHMW/2001z0122/0007.

Fig. 6: *Pseudophyllites* sp. indet., juvenile individual; NHMW/2001z0122/0004.

Fig. 7: *Diplomoceras* sp. indet., NHMW/2001z0122/0008.

