Acta Geologica Polonica, Vol. 57 (2007), No. 4, pp. 443-451

First record of the late Campanian heteromorph ammonite *Nostoceras hyatti* from the Alpine Cretaceous (Grünbach, Gosau Group, Lower Austria)

HERBERT SUMMESBERGER[1], MARCIN MACHALSKI[2] & MICHAEL WAGREICH[3]

[1] *Naturhistorisches Museum Wien, Burgring 7, A-1010 Wien, Austria.*
E-mail: herbert.summesberger@nhm-wien.ac.at
[2] *Institute of Paleobiology, Polish Academy of Sciences, ul. Twarda 51/55, PL-00-818 Warszawa, Poland.*
E-mail: mach@twarda.pan.pl
[3] *Universität Wien, Department für Geodynamik und Sedimentologie, Althanstr., 14, A-1090 Wien, Austria.*
E-mail: Michel.Wagreich@uni.vie.ac.at

ABSTRACT:

SUMMESBERGER, H., MACHALSKI, M. & WAGREICH, M. 2007. First record of the late Campanian heteromorph ammonite *Nostoceras hyatti* from the Alpine Cretaceous (Grünbach, Gosau Group, Lower Austria). *Acta Geologica Polonica*, **57** (4), 443-451. Warszawa.

The heteromorph ammonite *Nostoceras* (*Nostoceras*) *hyatti* is described for the first time from the Piesting Formation (Gosau Group; Upper Cretaceous) at Grünbach along the eastern margin of the Northern Calcareous Alps, Lower Austria. This record significantly extends the geographic range of this late Campanian marker species; it was not previously known from the Alpine Cretaceous. Moreover, it corroborates earlier age assignments as late Campanian of the (lower) part of the Piesting Formation. A matrix sample taken from the specimen studied has yielded taxa whose range covers zones CC20 to CC23, or UC 15^{tp} to UC18, of the standard nannofossil zonation.

Key words: Campanian, Cretaceous, Piesting Formation, Gosau Group, Lower Austria, Ammonites, Calcareous nannofossils.

INTRODUCTION

The heteromorph ammonite *Nostoceras* (*Nostoceras*) *hyatti* STEPHENSON, 1941 is widely recognised as an excellent stratigraphic marker for the latest Campanian, both in terms of the traditional 'boreal' definition of the Campanian/Maastrichtian boundary (KENNEDY & *al.* 1992; HANCOCK & KENNEDY 1993; WARD & ORR 1997) and of new criteria based on the Global Stratotype Section and Point (GSSP) for the base of the Maastrichtian Stage at Tercis, Landes, France (ODIN & LAMAURELLE 2001).

The aim of the present paper is to document *N. hyatti* for the first time from the upper Campanian to lower Maastrichtian Piesting Formation (Gosau Group, eastern margin of the Northern Calcareous Alps, Lower Austria). This record significantly extends the geographic range of the species, as it was not previously known from the Alpine Cretaceous.

PROVENANCE OF THE SPECIMEN

The single specimen of *Nostoceras* (*Nostoceras*) *hyatti* discussed here is registered as NHMW 1935.III.4 (NHMW = Museum of Natural History, Vienna). The label, in Roland BRINKMANN's handwriting, reads "*Anisoceras wernickei* WOLLEM.". The specimen was subsequently assigned to the genus *Hamites* (BRINKMANN 1935, p. 6). According to the label, the specimen was collected from the Upper Cretaceous of the Gosau Group, in the environs of Grünbach, Lower Austria (Text-figs 1, 2). No further data on the locality and horizon of the specimen studied are available.

The matrix of specimen NHMW 1935.III.4 is a fine-grained, dark grey sandstone to coarse siltstone. It allows to conclude that the specimen came from the Piesting Formation of the Gosau Group as defined by SUMMESBERGER & *al*. (2000) and SUMMESBERGER & *al*. (2002) (see Text-fig. 2 for stratigraphic log of the Gosau Group with distribution of the most important fossils).

The carbonate cement of the specimen differs from that of the lower Maastrichtian ammonites in collections from Grünbach (SUMMESBERGER & *al*. 2002, pl. 1, fig. 4), which is coarser and more brownish in colour. A fine specimen of *Pseudokossmaticeras brandti* (REDTENBACHER, 1873) (NHMW 1935.III.5.) from Grünbach, labelled and listed by BRINKMANN (1935, p. 6) as '*Pachydiscus egertoni* FORB.' [= *Pseudokossmaticeras brandti* (REDTENBACHER, 1873)] is preserved in dark grey sandstone similar to that of NHMW 1935.III.4, suggesting identical provenance (Text-fig. 2).

GEOLOGICAL BACKGROUND

The Gosau Group of the Grünbach – Neue Welt area in the eastern part of the Northern Calcareous Alps forms an approximately 14 km long, deformed syncline of Upper Cretaceous to

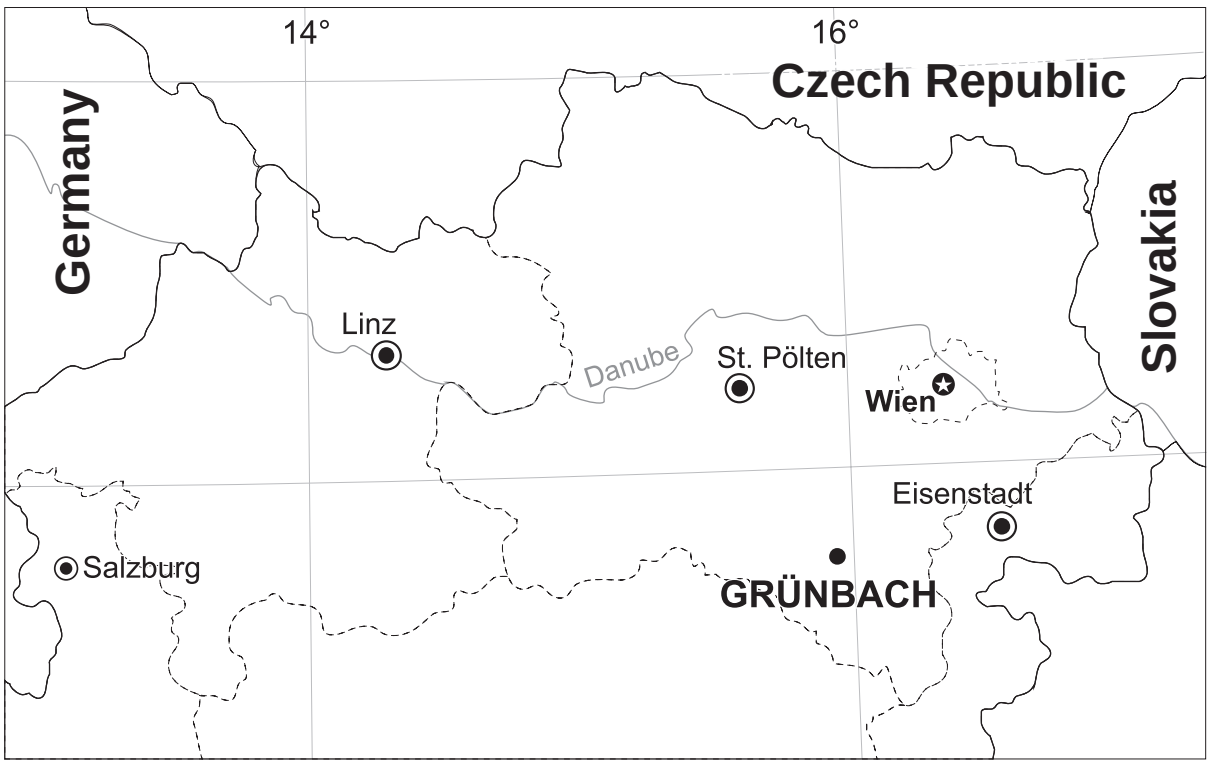

Fig. 1. Location of the Grünbach area in Austria

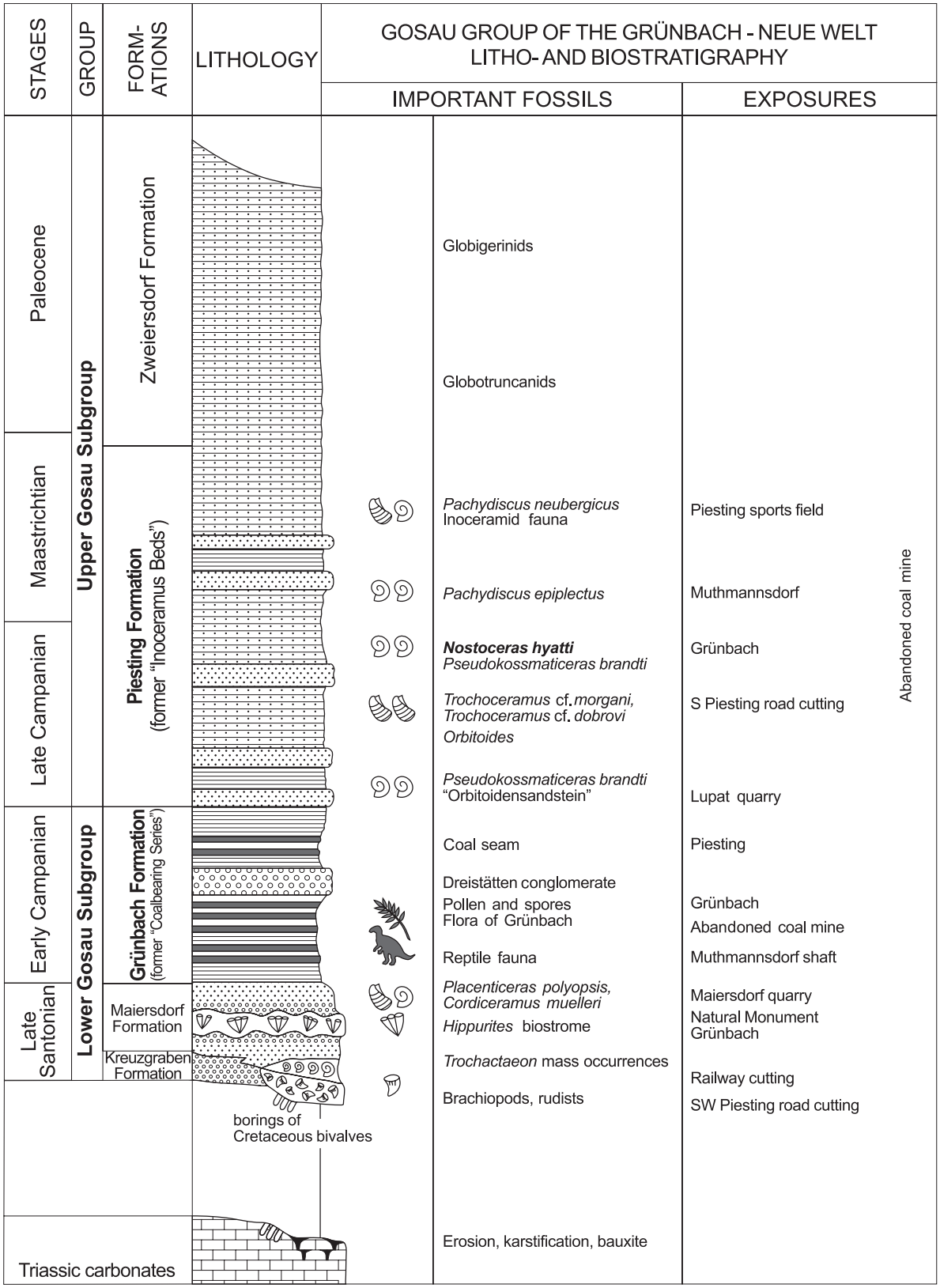

Fig. 2. Compiled section and distribution of more important fossils in the Gosau Group at Grünbach (modified from SUMMESBERGER in PILLER & *al*. 1997; EGGER & *al*. 2000; SUMMESBERGER & *al*. 2002)

Paleogene sediments. In terms of lithostratigraphy, five formations can be distinguished (SUMMESBERGER & *al*. 2000, SUMMESBERGER & *al*. 2002; Text-fig. 2). These are (from bottom to the top): the Kreuzgraben Formation (coarse conglomerate with reddish matrix), the Maiersdorf Formation (limestones, sandstones and marls; rudist bioherms, *Trochactaeon* beds), the Grünbach Formation ("Coalbearing series" of KOLLMANN & SUMMESBERGER 1982), the Piesting Formation (Inoceramenschichten = *Inoceramus* Beds of earlier authors) and the Zweiersdorf Formation (marls and sandy turbidites).

The Piesting Formation is a several hundred metres thick succession of deeper marine siliciclastic sediments. It comprises upper Campanian to lower Maastrichtian strata. Late Campanian age is indicated by foraminifera (OBERHAUSER in PLÖCHINGER 1961). An early Maastrichtian date for portions of the Piesting Formation is suggested by the ammonites *Pachydiscus neubergicus* (von HAUER, 1858) from Grünbach and *Pachydiscus epiplectus* (REDTENBACHER, 1873) from the nearby village of Muthmannsdorf, although it must be noted that specimens of *P. neubergicus* occur well below the recently accepted Campanian/Maastrichtian boundary at Tercis (MACHALSKI 2005, p. 655) and in the Middle Vistula River section, central Poland (WALASZCZYK 2004, p. 108). Another ammonite recorded from the Piesting Formation, *Pseudokossmaticeras brandti* (REDTENBACHER, 1873), supports late Campanian age (e.g. HANCOCK & KENNEDY 1993).

Late Campanian nannozones CC18-CC22 are documented from the section S Piesting, early Maastrichtian nannozone CC24 from the sports field section (SUMMESBERGER & *al*. 2002). The terrestrial to shallow-marine Grünbach Formation underlying the Piesting Formation is early Campanian, the overlying turbiditic Zweiersdorf Formation is of Paleocene age (PLÖCHINGER 1961; SUMMESBERGER 1997).

SYSTEMATIC PALAEONTOLOGY

Order Ammonoidea VON ZITTEL, 1884
Suborder Ancyloceratina WIEDMANN, 1966
Superfamily Turrilitoidea GILL, 1871
Family Nostoceratidae HYATT, 1894
Genus and Subgenus *Nostoceras* HYATT, 1894

TYPE SPECIES: *Nostoceras stantoni* HYATT, 1894, p. 569, by original designation.

Nostoceras (*Nostoceras*) *hyatti* STEPHENSON, 1941 (Text-fig. 3.1-3.3)

1935. *Hamites wernickei* WOLLEMANN; BRINKMANN, p. 6.
1941. *Nostoceras hyatti* STEPHENSON, p. 410, pl. 81, fig. 9-12.
1974. *Nostoceras hyatti* STEPHENSON; COBBAN, p. 10, pl. 5, fig. 1-21; pl. l. 6, fig. 1-12; pl. 7, fig. 1-10; pl. 8, fig. 1-30, text-fig. 12 (with synonymy).
1980. *Nostoceras pozaryskii* BŁASZKIEWICZ, p. 26 (*partim*), pl. 10, fig. 8, 9, 12.
1993. *Nostoceras* (*Nostoceras*) *hyatti* STEPHENSON, 1941; HANCOCK & KENNEDY, p. 162, pl. 9, fig. 1, 4; pl. 14, fig. 2-4; pl. 16, fig. 2, 3; pl. 17, fig. 10, 11; pl. 18, fig. 2-4, 6,7; pl. 19, fig. 1-4, 8-10 (with synonymy).
2000. *Nostoceras* (*Nostoceras*) *hyatti* STEPHENSON, 1941; KENNEDY & *al*., p. 12, text-fig. 6.
2000. *Nostoceras* (*Nostoceras*) *hyatti* STEPHENSON; KÜCHLER, p. 480, pl. 17, fig. 2-6.
2001. *Nostoceras* (*N.*) *hyatti* STEPHENSON, 1941 I subsp. nov.; KÜCHLER & ODIN, p. 516, pl. 3, fig. 4; pl. 4, fig. 11, 13.
2001. *Nostoceras* (*N.*) *hyatti* STEPHENSON, 1941 II; KÜCHLER & ODIN, p. 517, pl. 3, figs 1-3, 6-7, 10, 11-12, 13; pl. 4, figs 3-5.
2001. *Nostoceras* (*N.*) *hyatti*; KÜCHLER & *al*; p. 739, pl. 5, fig. 3, 6, 7. pl. 6, fig. 1.

TYPE: Holotype, by original designation, is USNM77258, the original of STEPHENSON (1941, p. 410, pl. 81, fig. 9) from the upper Campanian Nacatoch Sand on Postoak Creek on the north edge of Corsicana, Navarro County, Texas.

MATERIAL: A single specimen, NHMW 1935.III.4, from the Piesting Formation of the Gosau Group at Grünbach (exact locality and horizon unknown).

DESCRIPTION: Specimen NHMW 1935.III.4 is an internal mould with adherent whitish shell remnants. It is a U-shaped body chamber with a half of the last whorl of the helix of an adult, dextrally coiled individual. The earlier whorls of the helix are missing, and its preserved part is still in contact with the body chamber but displaced to a certain degree by a large crack reducing the original

angle between helix and body chamber. The whole specimen is slightly crushed. Both shafts of the body chamber are parallel, the terminal part bringing the aperture again in close proximity of about 25 mm to the helix.

The specimen is 90 mm in length. The preserved part of the helix is the last half whorl, now flattened and stretched by deformation of its curvature. The apical angle is unknown. The length of the body chamber is 80 mm, and that of the terminal shaft about 52 mm. The aperture is indicated by crowding of ribs. Both shafts are more or less straight. The section of the last whorl of the helix may have been rounded with a dorsal concavity. Whorl height (intercostally) is approximately 15.8 mm. The section of the body chamber is high oval, enhanced by lateral compaction. Whorl height of the body chamber is about 26 mm, and whorl breadth is about 16.5 mm (both measurements intercostally).

Ornament consists of strong ribs and a differentiated tuberculation. There are about 15 or more sharp and narrow ribs on the last half whorl of the helix with narrowly rounded and faintly crenulated crests. Ribs bifurcate irregularly or zig-zag on venter and flanks of the helix, the junctions are marked by distinct sharp tubercles which are arranged in two parallel rows. The ribs are spaced in relatively wide distances (9 per 30 mm). On the ventrolateral edge rib junctions are without tubercles.

The dorsum of the helix is similarly ribbed but somewhat finer and narrower and non-tuberculated. Ornament changes abruptly after the juvenile stage: there are about 24 sharp and undivided, widely spaced ribs on the entire body chamber (6-7 per 30 mm). They are entire and sharply crested without crenulation. Perhaps due to deformation ribbing seems to begin rursiradiate on the entire body chamber, becoming straight and slightly falcoid at the curvature, being straight and rursiradiate again at the terminal part of the body chamber. Each rib is decorated by two narrow bullae, changing into 9 pairs of distinct clavi at the curvature, finally changing again into weak bullate rib edges on the terminal portion of the shaft. In general, ribs are strengthening around the venter and weakening on the dorsum.

DISCUSSION: According to KENNEDY & *al*. (2000, p. 12, fig. 6 A-F), *Nostoceras* (*Nostoceras*) *hyatti* appears to occur as a pair of dimorphs, the smaller microconch (fig. 6 A-C therein) and the larger macroconch (fig. 6 D-F therein). When compared with material described by KENNEDY & *al*. (2000), the Grünbach specimen may be tentatively classified as a macroconch.

Differences between *Nostoceras* (*N.*) *hyatti* and other species of the genus (subgenus) have been discussed at length by COBBAN (1974), KENNEDY & COBBAN (1993), HANCOCK & KENNEDY (1993),

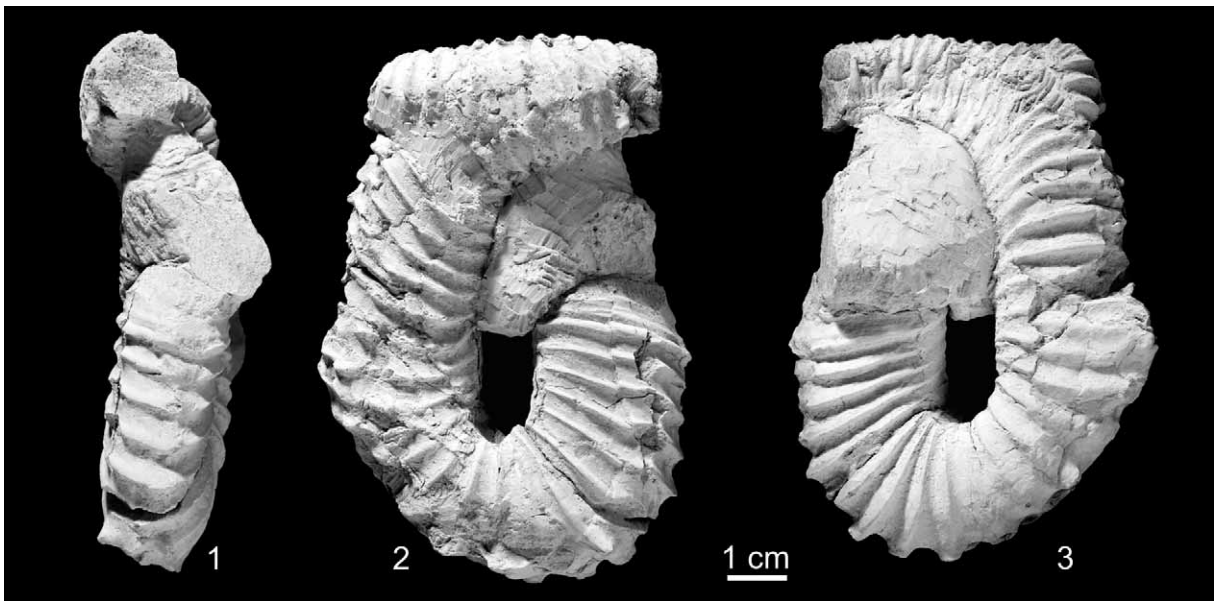

Fig. 3. *Nostoceras* (*Nostoceras*) *hyatti* SEPHENSON, 1941; specimen NHMW 1935.III.4, upper Campanian, Piesting Formation, Gosau Group, Grünbach, Lower Austria; × 1

and KENNEDY & *al*. (2000). *Nostoceras pozaryskii* BŁASZKIEWICZ, 1980, was described from the siliceous chalk (opoka) as exposed at Piotrawin quarry, Middle Vistula River section (Piotrawin Opoka *sensu* WALASZCZYK 2004). Its partial synonymy with *N.* (*N.*) *hyatti* was suggested by HANCOCK & KENNEDY (1993, p. 162), a view accepted herein.

KÜCHLER & ODIN (2001, p. 517) introduced *Nostoceras (Nostoceras*) *hyatti* STEPHENSON I, as a new subspecies from a stratigraphically earlier horizon, whereas *Nostoceras* (*Nostoceras*) *hyatti* STEPHENSON II is based upon STEPHENSON's holotype (1941, pl. 81, fig. 9). Only microconchs are described of *N.* (*N.) hyatti* STEPHENSON I (KÜCHLER & ODIN 2001). It differs in its larger size and distant ribbing of the body chamber from the stratigraphically younger nominate subspecies. The subspecies concept introduced by KÜCHLER & ODIN (2001) is based on material from Tercis, Landes, France, and has to be tested on American materials from continuous sections (*ibidem*, p. 525). Until then we leave the species undivided and are content to state that the specimen from Grünbach is closer to *Nostoceras* (*N.*) *hyatti* STEPHENSON II *sensu* KÜCHLER & ODIN (2001).

STRATIGRAPHIC AND GEOGRAPHIC RANGE: In stratigraphic terms, the first occurrence of *Nostoceras* (*N*.) *hyatti* in the Saratoga Chalk of Arkansas (USA) was introduced as a marker indicating the base of the *N.* (*N.*) *hyatti* assemblage zone of the late Campanian by KENNEDY & COBBAN (1993, p. 404). Subsequently, it was introduced by KENNEDY & *al*. (1992) and HANCOCK & KENNEDY (1993) as an index fossil for the uppermost zone of the Campanian at Tercis and in the Middle Vistula River section. In the latter case, however, the base of the zone was defined on the appearance of a scaphitid, *Jeletzkytes nodosus* (OWEN), with *N*. (*N*.) *hyatti* (= *N*. *pozaryskii* of BŁASZKIEWICZ 1980, *in part*) appearing some way above the base of this zone (KENNEDY & *al*. 1992).

The concept of the *Nostoceras hyatti* Zone as defined by KENNEDY & *al*. (1992) was stated to be unclear by WARD & ORR (1997, p. 417), who proposed the definition of its base 'by the first occurrence of the zonal index, rather than any of its associated fauna, and that the top of the zone be defined by the base of the overlying zone of *Pachydiscus neubergicus* or its equivalent outside the biogeographic range of *P. neubergicus*'.

Whatever the definition of the *Nostoceras hyatti* Zone zone should be, it is clear that *Nostoceras* (*N.*) *hyatti* is a typically late Campanian species. The records of this species from strata traditionally assigned to the lower Maastrichtian in northern Spain (KÜCHLER 2000, 2001) and in the Middle Vistula River section (MACHALSKI, in preparation), fall within the upper Campanian, following the new definition of the Campanian/Maastrichtian boundary (ODIN & LAMAURELLE 2001; see also comments in WALASZCZYK 2004 and MACHALSKI 2005).

In geographic terms, the species occurs in Poland [see reinterpretation of data of BŁASZKIEWICZ (1980) by HANCOCK & KENNEDY (1993)], France (HANCOCK & KENNEDY 1993; KÜCHLER & ODIN 2001), northern Spain (KÜCHLER 2000, KÜCHLER & *al*. 2001), in several areas of the U.S.A. (STEPHENSON 1941; COBBAN 1974; KENNEDY & *al*. 1993; KENNEDY & COBBAN 1993), Angola (HOWARTH 1965), Madagascar (COLLIGNON 1970), Israel (LEWY 1967) and Austria (this paper).

NANNOFOSSIL ANALYSIS

A nannofossil sample was taken from the matrix of specimen NHMW 1935.III.4 to check the age of the fossil and establish its position within the Gosau Group of the Grünbach area. Due to the sandy to silty character of the sediment the nannofossil sample was rather low in abundance (0.5 to 1 specimen per field of view in light microscope, magnification 1000x) and preservation was poor. Therefore, the results of nannofossil investigations are rather disappointing and yield no further information on correlations to other fossil localities in the area. The following species of nannoflora were identified:

Arkhangelskiella cymbiformis VEKSHINA, 1959
Biscutum constans (GÓRKA, 1957) BLACK, 1959
Biscutum cf. *magnum* WIND & WISE, 1977
Braarudosphaera bigelowi (GRAN & BRAARUD, 1935) DEFLANDRE, 1947
Ceratolithoides cf. *aculeus* (STRADNER, 1961) PRINS & SISSINGH in SISSINGH, 1977
Chiastozygus litterarius (GÓRKA, 1957)

MANIVIT, 1971
Cribrosphaerella ehrenbergii (ARKHANGELSKY, 1912) DEFLANDRE, 1952
Cyclagelosphaera sp.
Eiffellithus turriseiffelii (DEFLANDRE & FERT, 1954) REINHARDT, 1965
Heteromarginatus sp.
Lithraphidites carniolensis DEFLANDRE, 1963
Lucianorhabdus cayeuxii DEFLANDRE, 1959
Micula decussata VEKSHINA, 1959
Prediscosphaera cretacea (ARKHANGELSKY, 1912) GARTNER, 1968
Rucinolithus sp.
Stradneria crenulata (BRAMLETTE & MARTINI, 1964) NOEL, 1970
Quadrum (*Uniplanarius*) cf. *gothicum* (DEFLANDRE, 1959) HATTNER & WISE, 1980
Watznaueria barnesae (BLACK, 1959) PERCH-NIELSEN, 1968
Zygodiscus sp.

The age of this nannofossil assemblage is middle/late Campanian to early Maastrichtian according to the presence of a few marker species such as *Ceratolithoides* cf. *aculeus* and *Quadrum* (*Uniplanarius*) cf. *gothicum*. According to standard nannofossil zonations, the sample ranges from CC20 to CC23 (sensu PERCH-NIELSEN 1985) or UC 15^{tp} to UC18 (sensu BURNETT 1998). A more detailed zonal attribution was not possible because several important marker species such as *Broinsonia parca parca* or *Quadrum* (*Uniplanarius*) *trifidum* are missing; whether this is due to diagenesis and the low abundances of nannofossils in the samples or due to the stratigraphic position could not be determined. A comparison with nannofossil data from the *Nostoceras hyatti* Zone in northern Spain by KÜCHLER & *al*. (2001) indicates a position of this ammonite zone within CC22 to CC23a/ UC15de^{tp} to UC16 which does not contradict the results from the Grünbach specimen.

SUMMARY AND CONCLUSIONS

The present paper records *Nostoceras* (*Nostoceras*) *hyatti* from the Piesting Formation of the Gosau Group at Grünbach, along the eastern margin of the Northern Calcareous Alps, Lower Austria. The species was previously known from various regions of the world, but not from the Alpine Cretaceous. Thus, the Grünbach record markedly extends the geographical range of this stratigraphically important species.

Outside the Grünbach area, *N.* (*N.*) *hyatti* occurs in upper Campanian strata. Thus, its occurrence in the Piesting Formation confirms earlier dating of the (lower) part of this formation as of the late Campanian, based on micro- and macrofossil evidence. New nannofossil data, gained from the analysis of the matrix of the Grünbach specimen, are consistent with the latter conclusion.

Acknowledgements

MACHALSKI's trip to Vienna was supported by the Institute of Paleobiology of Polish Academy of Sciences and by the Naturhistorisches Museum Wien. Photographic work was done by Alice SCHUMACHER and technical work by Franz TOPKA (both Naturhistorisches Museum Wien). Agnieszka KAPUŚCIŃSKA (Nefryt Studio, Warszawa) is acknowledged for computer processing of the figures. John W.M. JAGT is thanked for linguistic correction of the text. Critical reviews of the typescript by William A. COBBAN (Lakewood, Colorado) and an anonymous reviewer are greatly appreciated.

REFERENCES

BŁASZKIEWICZ, A. 1980. Campanian and Maastrichtian ammonites of the middle Vistula River Valley, Poland: a stratigraphic-paleontological study. *Prace Instytutu Geologicznego*, **92**, 5-63.

BRINKMANN, R. 1935. Die Ammoniten der Gosau und des Flysch in den nördlichen Ostalpen. *Mitteilungen aus dem Geologischen Staatsinstitut Hamburg*, **15**, 1-14.

BURNETT, J. 1998. Upper Cretaceous. *In:* P.R. BOWN (*Ed*.), Calcareous Nannofosil Biostratigraphy, 132-199. *Chapman & Hall*; Cambridge.

COBBAN, W.A. 1974. Ammonites from the Navesink Formation at Atlantic Highlands, New Jersey. *United States Geological Survey, Professional Paper*, **845**, 1-21.

COLLIGNON, M. 1970. Atlas des fossiles caractéristiques de Madagascar (Ammonites) **16**, Campanien moyen et Campanien supérieur, iv + 1-82. *Service Géologique*; Tananarive.

EGGER, J., KOLLMANN, H.A., SANDERS, D., SUMMESBERGER, H. & WAGREICH, M. 2000. Cretaceous of

Eastern Austria. 6th International Cretaceous Symposium, Vienna 2000, Field Trip guide, 56 pp.

HANCOCK, J.M. & KENNEDY, W.J. 1993. The high Cretaceous ammonite fauna from Tercis, Landes, France. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre*, **63**, 149-209.

HOWARTH, M.K. 1965. Cretaceous ammonites and nautiloids from Angola. *British Museum (Natural History) Bulletin*, *Geology*, **10**, 335-412.

KENNEDY, W.J., COBBAN, W.A., SCOTT, G.R. 1992. Ammonite correlation of the uppermost Campanian of Western Europe, the U.S. Gulf Coast, Atlantic Seabord and Western Interior, and the numerical age of the base of the Maastrichtian. *Geological Magazine*, **129**, 497-500.

KENNEDY, W.J. & COBBAN, W.A. 1993. Ammonites from the Saratoga Chalk (Upper Cretaceous), Arkansas. *Journal of Paleontology*, **67**, 404-434.

KENNEDY, W.J., LANDMAN, N.H, COBBAN, W.A. &. JOHNSON, R.O. 2000. Additions to the Ammonite Fauna of the Upper Cretaceous Navesink Formation of New Jersey. *American Museum Novitates*, **3306**, 1-30.

KOLLMANN, H.A. & SUMMESBERGER, H. 1982. Excursions to Coniacian – Maastrichtian in the Austrian Alps. 4. Meeting, Working Group Coniacian – Maastrichtian Stages, 1-105. Vienna.

KÜCHLER, T. 2000. Upper Cretaceous of the Barranca (Navarra, northern Spain); integrated litho-, bio- and event stratigraphy. Part II: Campanian and Maastrichtian. *Acta Geologica Polonica*, **50**, 441-499.

KÜCHLER, T., KUTZ, A. & WAGREICH, M. 2001. The Campanian – Maastrichtian boundary in northern Spain (Navarra province): the Imiscoz and Erro sections. *In*: G.S. ODIN (*Ed.*), The Campanian-Maastrichtian boundary. Characterisation at Tercis les Bains (France) and correlation with Europe and other continents. *Developments in Palaeontology and Stratigraphy*, **19**, 724-744. *Elsevier*; Amsterdam.

KÜCHLER, T. & ODIN, G.S. 2001. Upper Campanian-Maastrichtian ammonites (Nostoceratidae, Diplomoceratidae) from Tercis les Bains (Landes, France). *In*: G.S. ODIN (*Ed.*), The Campanian-Maastrichtian boundary. Characterisation at Tercis les Bains (France) and correlation with Europe and other continents. *Developments in Palaeontology and Stratigraphy*, **19**, 500-528. *Elsevier*; Amsterdam.

LEWY, Z. 1967. Some late Campanian nostoceratid ammonites from southern Israel. *Israel Journal of Earth Sciences*, **16**, 165-173.

MACHALSKI, M. 2005. Late Maastrichtian and earliest Danian scaphitid ammonites from central Europe: Taxonomy, evolution, and extinction. *Acta Palaeontologica Polonica*, **50**, 653-696.

ODIN, G.S. & LAMAURELLE, M.A. 2001. The global Campanian – Maastrichtian stage boundary. *Episodes*, **24** (4), 229-238.

PERCH-NIELSEN, K. 1985. *Mesozoic calcareous nannofossils*. *In*: H.M. BOLLI, J.B., SAUNDERS & K. PERCH-NIELSEN (*Eds*), Plankton Stratigraphy, 329-426. *Cambridge University Press*.

PILLER, W.E, SUMMESBERGER, H., DRAXLER, I., HARZHAUSER, M. & MANDIC, O. 1997. Meso- to Cenozoic tropical/subtropical climates – Selected examples from the northern Calcareous Alps and the Vienna Basin. *In*: H. KOLLMANN & B. HUBMANN (*Eds*), Second European Palaeontological Congress, Vienna Climates: Past, Present and Future, Excursion guides, 111 pp.

PLÖCHINGER, B. 1961. Die Gosaumulde von Grünbach und der Neuen Welt (Niederösterreich). *Jahrbuch der Geologischen Bundesanstalt*, **104**, 359-441.

STEPHENSON, L.W. 1941. The larger invertebrates of the Navarro Group of Texas (exclusive of corals and crustaceans and exclusive of the fauna of the Escondido Formation). *University of Texas Bulletin*, **4101**, 1-641.

SUMMESBERGER, H. 1997. The Cretaceous of the Grünbach – Neue Welt Basin. *In*: W.E. PILLER, H., SUMMESBERGER, I., DRAXLER, M., HARZHAUSER, & O. MANDIC, Meso- to Cenozoic tropical/subtropical climates – Selected examples from the northern Calcareous Alps and the Vienna Basin. *In*: H.A. KOLLMANN, & B. HUBMANN (*Eds*), Second European Palaeontological Congress, Climates: Past, Present and Future, Vienna; Excursion guides, 77-89. Vienna.

SUMMESBERGER, H., WAGREICH M., TRÖGER, K.-A. & SCHOLGER, R. 2000. Piesting-Formation, Grünbach-Formation und Maiersdorf-Formation – drei neue lithostratigraphische Termini in der Gosau Gruppe (Oberkreide) von Grünbach und der Neuen Welt (Niederösterreich). *Berichte des Instituts für Geologie und Paläontologie der Karl-Franzens Universität Graz*, **2**, 23.

SUMMESBERGER, H., WAGREICH, M., TRÖGER, K.-A. & SCHOLGER, R. 2002. The Upper Cretaceous of Piesting (Austria): Integrated stratigraphy of the Piesting Formation (Gosau Group). *In*: M. WAGREICH (*Ed.*), Aspects of Cretaceous Stratigraphy and Paleobiogeography, Proceedings 6th Internatio-

nal Cretaceous Symposium Vienna 2000. *Österreichische Akademie der Wissenschaften, Schriftenreihe der Erdwissenschaftlichen Kommissionen*, **15**, 373-399.

WALASZCZYK, I. 2004. Inoceramids and inoceramid biostratigraphy of the Upper Campanian to basal Maastrichtian of the Middle Vistula River section, central Poland. *Acta Geologica Polonica*, **54**, 95-168.

WARD, P. & ORR, W. 1997. Campanian-Maastrichtian ammonite and planktonic foraminiferal biostratigraphy from Tercis, France: implications for defining the stage boundary. *Journal of Paleontology*, **71**, 407-418.

Manuscript submitted: 15th May 2007
Revised version accepted: 25th October 2007