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# Palynological study of Gosau group deposits (Upper Cretaceous) of the Northern Calcareous Alps (Austria)

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(With 2 textfigures and 6 tables)

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## Abstract

Results of a combined palynological study of the continental to marine deposits of the Upper Cretaceous Gosau Group in the Northern Calcareous Alps (Austria) are presented. A framework for palynostratigraphic correlation based on sporomorphs and dinoflagellate cysts is defined in the composite Gosau section (Upper Turonian-Maastrichtian) and compared to biostratigraphically controlled palynofloral schemes in Europe. The compositional development of the sporomorph assemblages in the Gosau basin is applied for stratigraphical correlation of the basal coal series and transgressional units in adjacent occurrences of the Gosau Group. A pattern of diachronous transgressions in the area studied is supported.


**Key words:** Palynology, Late Cretaceous, Gosau Group, Stratigraphy, Coal.


## Zusammenfassung

Die Ergebnisse palyologischer Untersuchungen in kontinentalen bis marinen Sedimenten der Gosau Gruppe (Oberkreide, Nördliche Kalkalpen, Österreich) werden vorgelegt. Auf der Basis von Sporomorphen und Dinoflagellatenzysten wird in der aus Teilprofilen kombinierten Schichtfolge von Gosau (oberes Turonium - Maastrichtium) ein palynostratigraphischer Korrelationsrahmen erstellt und zu biostratigraphisch kontrollierten Palynoflorenschemata in Europa in Beziehung gesetzt. Die Entwicklung der Zusammensetzung der Sporomorphenspektren wird zur stratigraphischen Korrelation mit kohleführenden Serien und Transgressionsserien in benachbarten Gosauvorkommen eingesetzt. Die diachrone Transgression der Gosau Gruppe im Untersuchungsgebiet wird durch die Ergebnisse gestützt.


## Introduction

During middle Cretaceous Eoalpine deformational phases, an active subduction margin existed along the northern edge of the Austroalpine microplate (WAGREICH 1993). Sediments of the Gosau Group (Late Cretaceous-Eocene) were deposited after middle Cretaceous deformations on the Northern Calcareous Alps (NCA). The oldest sediments of

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the Gosau Group are bauxites and Upper Turonian terrestrial conglomerates which overlie Triassic to Lower Cretaceous deposits. Before and during the marine transgression (Late Turonian) conditions were favorable for paralic to lacustrine peat accumulation (WAGREICH 1988). More open marine environments gradually established in the Coniacian and Santonian. During the most active subsidence phase (Campanian-Maastrichtian) deep-water deposition prevailed. Although the sedimentary development of the Upper Cretacous in the Northern Calcareous Alps is rather uniform, the timing of transgressions and subsequent sedimentation within the the Gosau Group was diachronous due to the tectonic evolution (WAGREICH 1993). Today the Gosau Group occurrences are scattered erosion remnants (WAGREICH & FAUPL 1994), trapped by synsedimentary and subsequent faulting and often obscured by extensive cover of debris and plants.

Chronostratigraphic correlation is based upon a framework of data of micro-, macro- and nannofossils (e.g.: KOLLMANN & SUMMESBERGER 1982; SUMMESBERGER 1985; WAGREICH 1988; WAGREICH 1993; WAGREICH & FAUPL 1994; TRÖGER & SUMMESBERGER 1994; SUMMESBERGER & KENNEDY 1996); for introduction to palynology see SIEGL-FARKAS (1994) and SIEGL-FARKAS & WAGREICH (1996).

Coal series throughout the Gosau Group reflect climatic conditions and subsidence regimes favorable for extensive swamp development. According to VOIGT et al. (1999) the Northern Calcareous Alps did not substantially change their latitudinal position in the Late Cretaceous and remained in the subtropical belt. Since the coals generally occur close to the base of the Late Cretaceous transgressions subsidence rate may be considered to outstrip soon rates of coal accumulation terminating peat accumulation. As a consequence, timing of the basal coal series provides valuable information for reconstructing the tectonic history of the Late Cretaceous NCA.

The present study aims are: (1) giving an palynological inventory of different Gosau Group basins, thus providing a preliminary framework for palynostratigraphic correlation based on dinoflagellates and sporomorphs of primarily continental to restricted marine deposits of the Upper Cretaceous Gosau Group. For this purpose a palynostratigraphical sequence is established in the biostratigraphically well studied Gosau section and compared to European palynofloral schemes. (2) The presented palynofloristic development is applied to correlate basal coal series from several Upper Cretaceous sections in the NCA.

## Stratigraphy and sedimentology

WEIGEL (1937) and KOLLMANN (1982) defined the following lithostratigraphical units in the type area of the Gosau Group around the villages of Gosau and Rußbach from base to top: Kreuzgraben Formation, Streiteck Formation, Grabenbach Formation, Hochmoos Formation, Ressen Formation, Nierental Formation and Zwieselalm Formation. For the palaeoenvironmental interpretation of these deposits see, e.g., WAGREICH (1988) and SANDERS et al. (1997).

The Kreuzgraben Formation, predominantly consisting of alluvial fan conglomerates, forms the basal terrestrial facies of the Upper Cretaceous Gosau Group deposits; to date no stratigraphic assessment of the unit could be established, but sedimentation is considered to start in the Middle? to Late Turonian (TRÖGER & SUMMESBERGER 1994; SIEGL-FARKAS & WAGREICH 1996). The presence of a coal series with fresh water molluscs reflects paralic to lacustrine conditions (STOLICZKA 1860) at the transition from the Kreuzgraben Formation to the Streiteck Formation. The lower part of the Streiteck Fm, comprising marine conglomerates with sandstone intercalations, represents fan delta deposits. Based on marine molluscs the lower part of the formation is correlated to the Upper Turonian (SUMMESBERGER & KENNEDY 1996). The upper part of the Streiteck Fm is mainly composed of shelf marls with occasional sandy storm intercalations; abundant fossil content allowed correlation to the Coniacian-lowermost Santonian (TRÖGER & SUMMESBERGER 1994). The shales with sandy/silty storm layers of the Grabenbach Fm. reflect normal shelf conditions of Early Santonian age (WAGREICH 1992; TRÖGER & SUMMESBERGER 1994). The Upper Santonian Hochmoos Formation (TRÖGER & SUMMESBERGER 1994) consists of fossiliferous shales, sandstones, conglomerates, bioclastic storm layers, rudist bioherms and biostromes, reflecting dynamic sedimentary conditions from low-energy shallow marine to high-energy fan deltas (WAGREICH 1988). On top the characteristic Sandkalkbank Member is consistently present. The Bibereck Formation reflects a transitional facies from shelf marls to bathyal sedimentary conditions of early Early Campanian age. The continuous subsidence is indicated by deep-water turbidites and mass-flow deposits of the overlying Lower Campanian Ressen Formation. Carbonate-rich variegated hemipelagites and pelagites of the Campanian-Maastrichtian Nierental Formation indicate sedimentation under deep water and open marine conditions (WAGREICH 1993).

## Coal accumulation in the Gosau Group and its significance for reconstructing tectonic evolutions

According to MCCABE & PARRISH (1992) accumulation of peat requires a rising water table, but for eventual burial and preservation in the rock record base-level rise is necessary. Base-level fluctuations are determined by the interaction of tectonic subsidence, eustasy and compaction of underlying strata. To form coals, peats must accumulate in active sedimentary basins where both preservation and maturation are possible. Assuming that the basins are within a climatic zone favorable for swamp development, subsidence rates closely match rates of coal accumulation and subsidence is sufficiently rapid that swamps may have enough time to accumulate and preserve thick peats.

The consistent presence of a basal coal series in the Gosau Group transgressive deposits reflects increasing subsidence rates in a compressional tectonic regime during the Late Cretaceous (WAGREICH & DECKER, 2001). In the present study the presumed diachronous Late Cretaceous tectonic evolution of Gosau Group successions will be tested by dating the basal coals in different areas of the Northern Calcareous Alps. SIEGL-FARKAS & WAGREICH (1996) already investigated the base of the Gams section which is also included in the present study. The presumed Late Turonian Subtrudopollis-Complexiopollis Assemblage Zone from the basal part of the Gams section (calibrated by calcareous nannofossil zone CC13 of SISSINGH 1977) suggests already synchronous subsidence for the Gams and Gosau areas.

## Palynology

Previous palynological investigations of Gosau-type deposits have mainly concentrated on sections in Austria, Hungary and Slovenia. GÓCZÁN (1964) introduced a palynostratigraphical zonation primarily based on the ranges of pollen types of the *Normapolles* group for the Hungarian Upper Cretaceous establishing eight palynozones within presumed Upper Santonian to Upper Maastrichtian deposits. In 1990 GÓCZÁN & SIEGL-FARKAS subdivided this scheme into six subzones, but chronostratigraphic correlations remained. According to this scheme the Gosau-type sediments in the Uppony Mts, northern Hungary, were dated as Campanian. SIEGL-FARKAS (1991, 1993) applied the Hungarian standard to the Gosau Group in Austria and Slovenia. SIEGL-FARKAS (1994) reported Late Turonian, Middle Coniacian and Santonian pollen assemblages from six samples of the Austrian Gosau Group: Weisswasser/Unterlaussa, Aussee and the Gosau Basin.

The lowermost samples from the Noth Fm of the Gosau Group of Gams (SIEGL-FARKAS & WAGREICH 1996) were taken from a stratigraphically higher part of the section than those included in the present study. SIEGL-FARKAS & WAGREICH (1996) defined two new palynostratigraphic zones, and correlated them with the Late Turonian-Coniacian calcareous nannofossil zone CC13 of SISSINGH (1977):

(1) the *Subtrudopollis-Complexiopollis* Assemblage Zone, defined in the Noth Formation;

(2) the *Complexiopollis* Dominance Zone, defined in the lower Grabenbach Formation. Successively, the Hungarian standard pollen zones were recognized, of which the lowest (*Oculopollis-Complexiopollis* Dominance Zone) was identified in the upper Grabenbach Formation of the Gams section. It has to be noted that the nannofossil calibrated stratigraphic assessments of the presumed Upper Santonian-Upper Maastrichtian zones originally defined in Hungary profoundly differ from the zones identified in the Austrian Coniacian-Campanian (compare SIEGL-FARKAS 1991, 1993 with SIEGL-FARKAS & WAGREICH 1996). HRADECKÁ et al. (1999) identified also the *Complexiopollis* Dominance Zone and the *Oculopollis-Complexiopollis* Dominance Zone in the Upper Turonian to Santonian Grabenbach Formation of the Weissenbach near Bad Aussee.

For palynostratigraphic correlation two main categories of palynomorphs are of importance, the Normapolles group and the dinoflagellate cysts.

### Normapolles group

The Normapolles group comprises many types of angiosperm pollen which are generally oblate triaperturate with protruding pores and a complex structure in the apertural areas, but of uncertain specific origin. This morphologically characteristic group first appears in the Cenomanian (e.g. DULIC 2002), reaches its acme in Coniacian to Paleocene and declines rapidly in the Eocene. GOCZAN et al. (1967) first defined the Normapolles province featuring the restricted spatial distribution of most representatives to Europe, West Siberia and the eastern part of North America. Later, emphasis was laid on the climatic implications of this spatial distribution, and on the morphological resemblance to pollen from the families *Sapindaceae, Juglandaceae, Myricaceae and Betulaceae* (SRIVASTAVA 1978; BATTEN 1981; HERNGREEN & CHLONOVA 1981; DULIC *2002?)*. It was suggested that Normapolles associations reflect a wide variety of tropical-subtropical vegetation types, from forests to swamps.

The gradual compositional changes of the Normapolles assemblages in time offer a firm tool for stratigraphic correlation within the Normapolles province. This was already shown in excellent initial studies on Normapolles in Central Europe by KRUTZSCH (1966) and GOCZAN et al. (1967). Although those early studies focused on compositional changes in a stratigraphic sense, the biostratigraphic control remained obscure. For example KRUTZSCH (1966) described two of his palynozones of presumed Turonian age ("Zeicher Bild" and "Zatscher Bild") and one of presumed Coniacian age ("Oberlausitzer Bild"), without presenting any accurate biostratigraphic control. The first two palynofloral units are characterized by the presence of *Atlantopollis* and predominance of representatives of *Complexiopollis*, whereas the successive appearances of *Vacuopollis* and *Semioculopollis* species in the assemblage are considered indicative for the Coniacian.

As one of the first ANTONESCU (1973) compared the Turonian Normapolles assemblages in sections from the Upper Cretaceous of the Metaliferi Mountain, Romania, with other fossil groups, *viz*. dinoflagellate cyst and macrofossil data. In later integrated studies (e.g.: MEDUS et al. 1980 and ROBASZYNSKI et al. 1982) on Turonian deposits of Portugal and southern France, the higher resolution pollen zonation was calibrated to standard ammonite stratigraphy. To a large extend this zonation is based on the stratigraphic ranges of *Complexiopollis* (=*Turonipollis*), *Atlantopollis* and *Vacuopollis* species. These taxa predominate Turonian palynofloras and their associated occurrences are characteristic. Species of *Oculopollis*, *Krutzschipollis* and *Trudopollis* first appear in Upper Turonian, but they are rare. In an even more detailed stratigraphic investigation on ammonite calibrated Upper Cretaceous sections in Bulgaria PAVLISHINA (in: PAVLISHINA & MINEV 1996) highlighted the predominance of *Complexiopollis* in Turonian palynofloras, especially *C. christae*. It is associated with *Atlantopollis microreticulatus* in Lower Turonian (*Mammites nodosoides* ammonite zone), while Middle and Upper Turonian palynofloras feature the concurrent presence of *C. christae* and *C. complicatus*. The Coniacian palynoflora could be differentiated based on the presence of *C. complicatus* in combination with representatives of *Semioculopollis*, *Vacuopollis* and *Extratriporopollenites*.

Santonian and Campanian Normapolles assemblages from North Bulgaria were correlated to dinocyst zones identified in the same sections by PAVLISHINA (1994, 1999).

For the higher Upper Cretaceous already in 1972 MEDUS presented a biostratigraphically controlled palynostratigraphical scale for the Santonian - Maastrichtian in Southern France and northeastern Spain. An Upper Santonian - Upper Maastrichtian palynozonation for Hungary was proposed by GOCZAN (1964), and subsequently refined by GOCZAN & SIEGL-FARKAS (1990). The scheme of zones and subzones reflect evolutionary trends within the Normapolles group, but in both papers biostratigraphic control is lacking. Parallel to this zonation a provisional dinoflagellate zonation was established by SIEGL-FARKAS (1995).

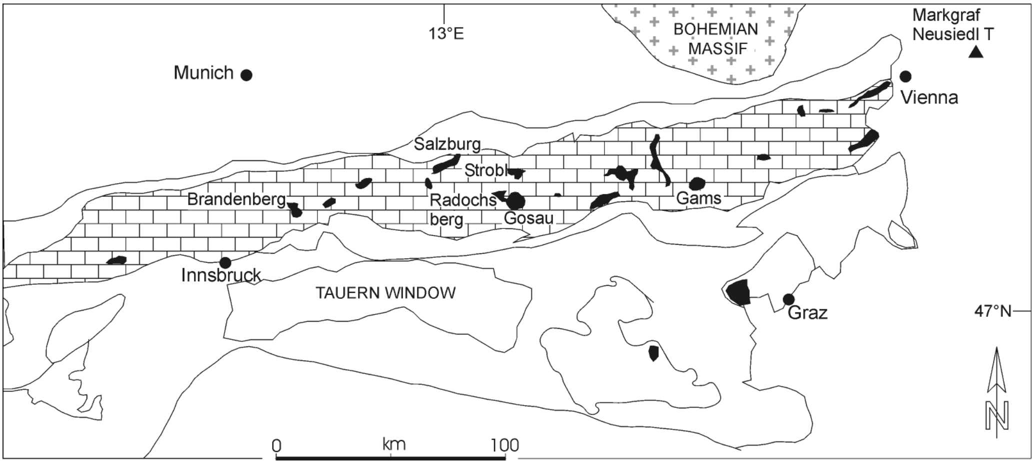



Fig. 1: Schematic tectonic map of the Eastern Alps including major outcrop areas of the Gosau Group (in black) within the Northern Calacreous Alps (brick signature). Localities of the Gosau Group mentioned in the text are indicated.

## Material

The present study is based on sections (Fig. 1) with minor or without stratigraphic continuity, depending on outcrop conditions of the Gosau Group in the Northern Calcareous Alps. Sections and sample positions in the Gosau basin and other areas in the Northern Calcareous Alps are described below.

## Methods

More than 500 palynological samples were investigated and treated according to standard palynological preparation techniques (HCl, HF treatment, sieving, mounting in glycerin-jelly) at the Laboratory of Palaeobotany and Palynology (Utrecht, The Netherlands). The permanent mounts are stored in the collection of the Natural History Museum, Vienna (Austria).

A minority of the investigated samples contains identifiable palynomorphs; these are indicated in the figures by bold arrows. The palynological content was analysed semi-quantitatively with emphasis on sporomorphs and dinoflagellate cysts. Dinoflagellate cyst taxonomy and nomenclature follows citations in LENTIN & WILLIAMS (1993), whereas Normapolles taxonomy accords GÓCZÁN et al. (1967).

## Gosau area

The composite Upper Cretaceous Gosau succession encompasses approximately 2000 m of sediment from Upper Turonian to Eocene. Samples are labeled "Gosau"; their stratigraphic position is indicated in Fig. 2. Subsequently the lithological units are listed in stratigraphical order.

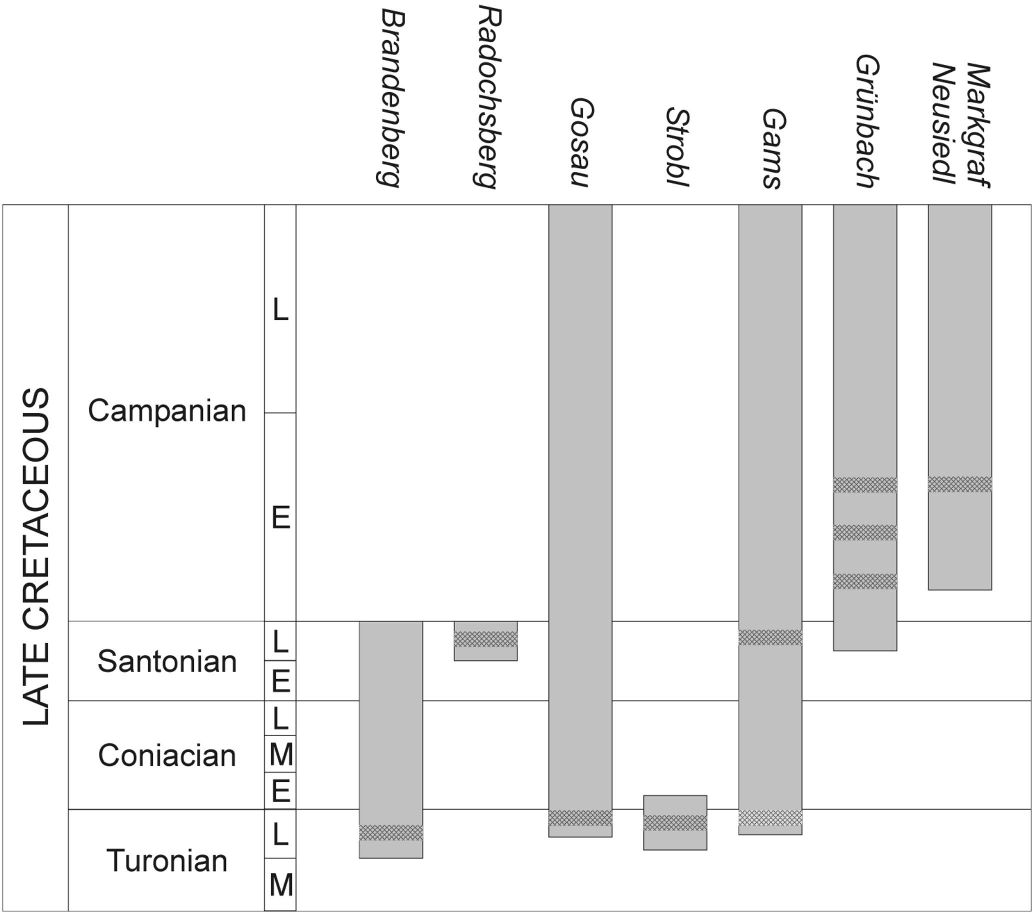



Fig. 2: Stratigraphic interpretation of coal-bearing transgressive successions based on palynological data of this study and published data from SUMMESBERGER & KENNEDY (1996), PILLER et al. (2000) and WAGREICH (this volume).

Kreuzgraben Formation (Upper Turonian: SUMMESBERGER & KENNEDY 1996):

Samples were taken from the Neualpe at the upper course of the Randobach (STOLICZKA 1860, SUMMESBERGER & KENNEDY 1996, fig. 5); Sample Gosau 23 is from a coal seam, Gosau 23a is from the accompanying level with freshwater gastropods (stop 23 KOLLMANN & SUMMESBERGER 1982).

Streiteck Formation (Upper Turonian - basal Santonian: TRÖGER & SUMMESBERGER 1994):

The transition from the Kreuzgraben Formation to the Streiteck Formation was sampled at the Neualpe/Randobach section (samples Gosau 21, 22); Gosau 21 is a marine marl intercalation at the base of the Streiteck Formation, exposed upstream a small tributary of the Randobach. Gosau 22 is from the same level in approximately 100 m distance. The Late Turonian age is controlled by ammonites and inoceramids (SUMMESBERGER & KENNEDY 1996).

Samples from the overlying Streiteck Formation come from:

(1) road-side exposure Paß Gschütt, between Rußbach and Gosau, 2 km W of Gosau (samples Gosau 11, 11a; see WAGREICH 1988); the deposits consisting of conglomerates and thick sandstones and siltstones (ca 0.5-3 m) are dated by inoceramids as Coniacian (TRÖGER & SUMMESBERGER 1994). Gosau 11a is composed of marl with corals. Gosau 11 is taken above Gosau 11a.

(2) the lower part of the Stöcklwaldgraben, a tributary of the Randobach (stop 22 in KOLLMANN & SUMMESBERGER 1982), (sample Gosau 212). Upper Coniacian is indicated by inoceramids (TRÖGER & SUMMESBERGER 1994).

Grabenbach Formation (Santonian; TRÖGER & SUMMESBERGER 1994):

(1) Samples Gosau 213-217 are from the Randobach section. Gosau 216 is from the top of the section, Gosau 213 (stop 26 in KOLLMANN & SUMMESBERGER (1982) is Early Santonian (TRÖGER & SUMMESBERGER 1994); its lithostratigraphic position is 10 m below Gosau 216. Gosau 214 is 2 m below Gosau 213. Gosau 215 is 2 m below Gosau 214. Gosau 217 is from the 15-20 m high escarpment of calcareous sandstone on the left side if the Randobach (footnote at stop 26 in KOLLMANN & SUMMESBERGER 1982).

(2) Samples Gosau 25 – 29; 210, 211 are from the upper part of the Stöcklwaldgraben section (stop 21 in KOLLMANN & SUMMESBERGER 1982). The basal one, Gosau 25 is Coniacian in age (based on inoceramids: TRÖGER & SUMMESBERGER 1994) and is from the forest road a few hundred meters NE of the Schneckenwand locality (see Hochmoos Fm.). Gosau 26 is from 10 m above Gosau 25; Gosau 27 (Santonian: TRÖGER & SUMMESBERGER 1994, figure 4) 5 m higher than Gosau 26; Gosau 28 is 5-10 m above 27, Gosau 29 is 10 m above 28; Gosau 210 again 10-15 m higher; Gosau 211 is from the top of the section and approximately in the same stratigraphic position as sample Gosau 31 from the Grabenbach section.

(3) the Grabenbach section (stop 15 of KOLLMANN & SUMMESBERGER 1982) section along the Grabenbach, a little N of Gosau, starting at the dam; samples Gosau 31-33). Gosau 33 corresponds to the level 20 m above the *inoceramid* level past the wall of the second dam. The position of Gosau 32 is ca 50 m below the second dam, at the *inoceramid* level. Gosau 31 is located 50 m upstream of the first concrete dam, corresponding approximately to the level of sample Gosau 211 from the Stöcklwaldgraben section.

Hochmoos Formation (Upper Santonian: TRÖGER & SUMMESBERGER 1994):

(1) Gosauschmied, road cut in Gosau-Hintertal, half way Gosau-Gosausee (samples Gosau 131, 132, 133). Although the outcropping deposits can not be assigned to a formation with certainty, according to SIEGL-FARKAS (1994, p. 111) it correlates to the Hochmoos Fm. Gosau 131 is derived from thin black clayey siltstones intercalated in sandstones. Gosau 132 is taken from the core of a local syncline, from dark thin bedded shaly sandstones. Gosau 133 approximately coincides with the position of SIEGL-FARKAS' sample: black clayey fine sandstones with a freshwater (or brackish) fauna (*Ampullina*, bivalves, coal fragments).

(2) Schneckenwand exposure, geological monument W of Randobach (stop 20 in KOLLMANN & SUMMESBERGER 1982; sample Gosau 24).

(3) Finstergrabenwandl (stop 11 in KOLLMANN & SUMMESBERGER 1982) along the Zwieselberg forest road (samples Gosau 35 and Gosau 12); both samples are from the Sandkalkbank Member of the Hochmoos Fm, Gosau 35 is from the middle of the exposure, 2 m below bed 12 of the profile of SUMMESBERGER (MS; uppermost Santonian: TRÖGER & SUMMESBERGER 1994).

Ressen Formation (Campanian: WAGREICH 1988):

Samples Gosau 141 and 142 are from the Zwieselberg forest road. No.142 is from stop 12 of KOLLMANN & SUMMESBERGER (1982).

Nierental Formation (uppermost Campanian-Maastrichtian: KOLLMANN 1982):

Sample Gosau 34 is from coarse sandstone on the Zwieselberg forest road close to the Zwiesel Alm skilift.

**Sampled coal-bearing successions in the Gosau Group outside the Gosau area**

Brandenberg (Upper Turonian to Turonian-Coniacian boundary):

The samples were collected from coal seams in the Zöttbach section (sample Brand 3) and the Achen gorge (Brand 19B) of the Brandenberg area. A Late Turonian age was reported by SUMMESBERGER & KENNEDY (1996). Sample Brand 20 was taken from the location Atzlsäge, below the first rudist level (see sections by SANDERS 1998:157).

Radochsberg W of Rußbach (Salzburg):

The samples Radoch 1 – 4 are from a locality north of the road from Pass Gschütt to Abtenau.The exposure of a coalbearing succession is situated in a small ditch close to a bed with large nerineids. No age assignment was reported in the literature.

Strobl/Weißenbach (Salzburg; SUMMESBERGER & KENNEDY 1996: Upper Turonian):

The section is situated about 2 km W of Strobl (N of Gosau) in a small tributary of the Weißenbach creek (SUMMESBERGER & KENNEDY 1996, p. 107 and fig. 8). The palynological samples SWP 1-15 are from a clayey series of about 10 m thickness with interbedded coalseams, On top of the sampled section with freshwater gastropods the conditions changed to fully marine environments with Late Turonian ammonites (e.g.: *Barroisiceras haberfellneri* (HAUER)).

Gams basin (Styria; Akogl section; SIEGL-FARKAS & WAGREICH 1996: Upper Turonian):

Samples Gams 1-21 are from a coalbearing series along the Akogl forest road,in the western part of the Gams basin. The lowest samples of SIEGL-FARKAS & WAGREICH (1996) of Late Turonian age are from a similar stratigraphic level.

Markgraf Neusiedl Tief (borehole):

In the floor of the Neogene Vienna Basin the borehole Markgraf Neusiedl Tief crosses a section of Upper Cretaceous coal-bearing deposits (sample (MT 1/7) of the Glinzendorf syncline being the eastward equivalent of the Grünbach syncline (see: WAGREICH & MARSCHALKO 1995).

## Palynostratigraphical zonations and stratigraphy

A selection of stratigraphically important Normapolles taxa and their biostratigraphic and chronostratigraphic significance is listed below:

*Complexiopollis* spp.: predominate Turonian microfloras in Europe (e.g., MEDUS et al. 1980; ROBASZYNSKI et al. 1982; PAVLISHINA & MINEV 1996).

*Complexiopollis christae*: predominate Turonian microfloras in North Bulgaria (PAVLISHINA & MINEV 1996).

*Emscheripollis* spp.: the stratigraphic range of the genus is from the Middle Turonian to Santonian in Europe (GOCZAN et al. 1967).

*Krutzschipollis crassus*: the taxon is characteristic for the Late Santonian to Maastrichtian palynofloras in Hungary (GOCZAN 1964; GOCZAN & SIEGL-FARKAS 1990). Its first occurrence is well documented in the Lower Santonian in North Bulgaria (PAVLISHINA 1994, 1999).

*Krutzschipollis magnoporus*: although the taxon is restricted to presumed Lower Maastrichtian in Hungary (GOZAN et al. 1967), MEDUS (1972) reports it from Upper Santonian-Maastrichtian in southern France and northeastern Spain. According to MEDUS' zonal scheme the species reaches high abundances in the Upper Santonian.

*Krutzschipollis spatiosus*: the first occurrence of the species is documented in the Middle Santonian in Bulgaria (PAVLISHINA 1994, 1999).

*Longanulipollis*: the first representatives of the taxon are presumed to appear within the Santonian and dominate Campanian palynofloras (GOCZAN & SIEGL-FARKAS 1990; SIEGL-FARKAS & WAGREICH 1996).

*Magnoporopollis*: the stratigraphic distribution of the genus encompasses Santonian-Maastrichtian deposits (GOCZAN et al. 1967; MEDUS 1972).

*Oculopollis*: representatives of *Oculopollis* dominate Santonian assemblages (MEDUS 1972; PAVLISHINA 1994, 1999; SIEGL-FARKAS & WAGREICH 1996).

*Oculopollis orbicularis*: the taxon is characteristic for the Upper Santonian and Campanian palynofloras in Hungary (GOCZAN 1964; GOCZAN & SIEGL-FARKAS 1990), southern France and northeastern Spain (MEDUS 1972). PAVLISHINA (1994) reported its first consistent occurrence in the Lower Santonian (*Dinogymnium denticulatum* dinocyst Zone) in North Bulgaria.

*Oculopollis concentus:* representatives of the taxon are known from Coniacian to Lower Maastrichtian in Europe (GOCZAN et al. 1967).

*Oculopollis parvoculus*: predominate Santonian and Campanian palynofloras in Hungary (Goczan 1964) and Bulgaria (PAVLISHINA 1999).

*Semioculopollis* ?*minimus*: representatives of the taxon are known from Coniacian to Maastrichtian in Europe (GOCZAN et al. 1967).

*Triangulipollis* spp: the genus is known from the Upper Turonian in Germany (KRUTZSCH in GOCZAN et al. 1967).

*Trudopollis* spp.: the stratigraphic distribution of the genus is from the Upper Turonian to Lower Eocene in Europe (GOCZAN et al. 1967; MEDUS et al. 1980).

**Dinoflagellate cysts**

Biostratigraphically controlled Late Cretaceous dinocysts in the Alpine region were described by KIRSCH (1991) from the German-Austrian border from Turonian to Maastrichtian. For the stratigraphic distribution of the encountered dinocyst taxa see the charts of WILLIAMS & BUJAK (1985), COSTA & DAVEY (1992), HARDENBOL et al. (1998).

*Canningia reticulata*: KIRSCH (1991) reports the first occurrence of the species in the Coniacian (*primitiva* Zone). The upper range limit is Middle Campanian (*ventricosa* Zone).

*Cannosphaeropsis utinensis*: According to HARDENBOL et al. (1998: chart 5, dinocyst data by FOUCHER) the base of the widely distributed taxon extends into the upper Santonian *asymetrica* Zone. In SE Germany its first occurrence is reported from the Campanian (*elevata* Zone; KIRSCH 1991). The last occurrence of *C. utinensis* is in the Upper Maastrichtian (e.g. WILSON 1974).

*Dinogymnium acuminatum* ranges from the uppermost Turonian or the base of the Coniacian to the top of the Maastrichtian (e.g. COSTA & DAVEY 1992; HABIB & DRUGG 1987). According to the charts of WILLIAMS & BUJAK (1985) its range is restricted to the Santonian - Maastrichtian interval. In Bulgaria its first occurrence is in the Santonian (PAVLISHINA 1999).

*Dinogymnium denticulatum* is characteristic for the Santonian to Maastrichtian interval in Europe (CLARKE & VERDIER 1967; WILLIAMS & BUJAK 1985). Its first occurrence is reported from the Santonian in Bulgaria (PAVLISHINA 1999).

*Hystrichodinium pulchrum*: This long-ranging Jurassic/Cretaceous taxon has a last common occurrence at the top of the Campanian and becomes extinct in the Lower Maastrichtian.

*Isabelidinium* spp.: This genus ranges from the Upper Cenomanian to the top Maastrichtian.

*Odontochitina operculata*: The widely accepted range of *O. operculata* is from the lower Barremian to the top of the Campanian, although WILSON (1974) reported this type in Denmark from the lowermost Maastrichtian *lanceolata* Zone.

*Pervosphaeridium intervelum*: In SE Germany the species is restricted to the Lower and Middle Campanian (KIRSCH 1991).

*Raphidodinium fucatum*: This type has a last occurrence at the top of Middle Campanian (e.g., COSTA & DAVEY 1992).

*Subtilisphaera pirnaensis* is reported only from the Turonian (ALBERTI 1959; JAIN & MILLEPIED 1973; LENTIM & WILLIAMS 1975).

## Results and palynostratigraphical evaluation

In most of the sections studied reworked Triassic and Late Permian palynomorphs were observed as already previously documented from the Gosau Group (e.g., SIEGL-FARKAS & WAGREICH 1996). The subsequently listed semi-quantitative palynological inventory of the Gosau sequence (Upper Austria) allows stratigraphic correlations from the type area of the Upper Cretaceous Gosau Group to occurrences in different areas in the NCA.

## *Gosau area* (Table I)

### Kreuzgraben Formation

Two samples from the Kreuzgraben Formation are extremely poor in palynomorphs. Extremely rare and poorly preserved ?*Semioculopollis* spp. were identified while dinocysts are absent. The dominance of *Semioculopollis*, although questionably identified makes an Late Turonian to earliest Coniacian age most probable following the palynological zonation of KRUTZSCH (1966) for Northern Europe.

### Streiteck Formation

The palynological assemblages at the base of the Streiteck Formation are rich in both sporomorphs and dinocysts. The former are dominated by *Araucariacites* spp., the latter by *Achomosphaera* spp. Rare Normapolles representatives include *Oculopollis* spp. (with *O. concentus*) and unspecified *Semioculopollis*. The presence of *Oculopollis concentus* suggests the position in the Lower Coniacian. Typical long-ranging Upper Cretaceous dinocysts like *Palaeohystrichophora infusorioides* and *Xenascus ceratioides* are present; however, the presence of the diagnostic taxon *Canningia reticulata* supports correlation with the Coniacian rather than with the Turonian. Reworking from the Triassic, notably from the Rhaetian, is fairly common (e.g. *Rhaetogonyaulax rhaetica, Riccisporites tuberculatus*). The age assessment based on palynomorphs is not in accordance to the finds of *Barroisiceras haberfellneri* (HAUER) by SUMMESBERGER & KENNEDY (1996) which indicates a Late Turonian age.

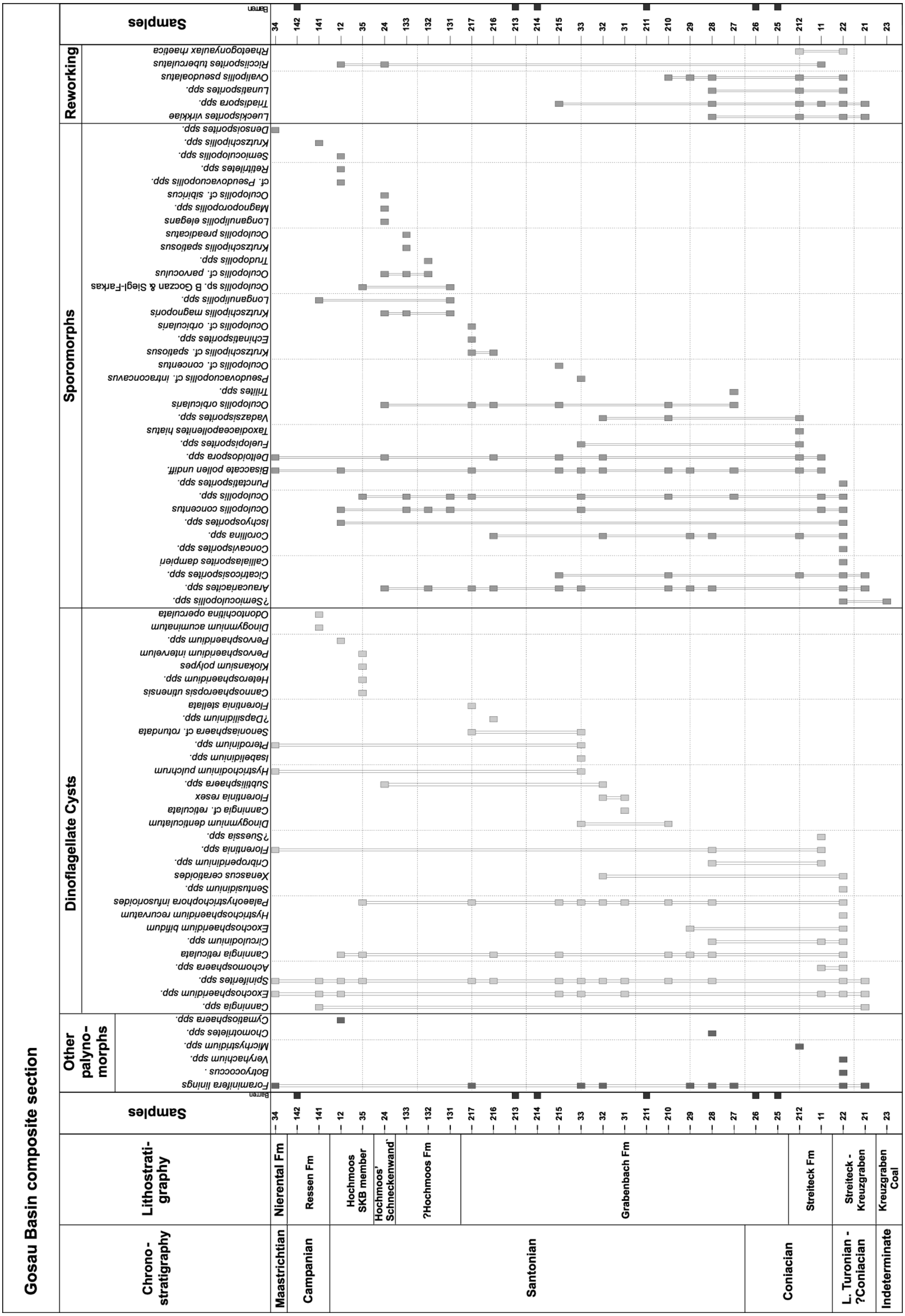
In general the samples from the other outcrops of the Streiteck Formation show common bisaccoid pollen grains and *Corollina* spp., with a relatively rich spore association; representatives of Normapolles and dinocysts are relatively rare. The Normapolles assemblage consists exclusively of *Oculopollis* spp. (with *Oculopollis concentus*). The absence of characteristic Turonian Normapolles markers and the presence of *Oculopollis concentus* suggests the larger part of the formation to correlate with the Coniacian. This is supported by the dinocyst association which is similar to the one in the transition interval with the Kreuzgraben Fm. This coincides with the occurrence of *Volviceramus involutus* (SOW.) in the Streiteck Fm. (TRÖGER & SUMMESBERGER 1994: 22)

### Grabenbach Formation

In general the palynological content from the Grabenbach Fm. is poorer than expected. The sporomorph association is poorly diversified throughout the entire section, with frequent Normapolles. *Pseudovacuopollis* cf. *intraconcavus* and *Krutzschipollis* cf. *spatiosus* are characteristic constituents. Bisaccoid pollen grains remain present throughout the formation and *Corollina* spp. is gradually replaced by *Araucariacites* spp., which is abundantly present in the upper part of the formation.

Common element in the lower part of the Grabenbach Fm. (upper Stöcklwaldgraben section, samples Gosau 27, 28, 29, 210, 211; Grabenbach section, samples Gosau 31, 32) is *Oculopollis orbicularis*, but characteristically present is also *Oculopollis concentus*. Sporomorph assemblages from the higher part of the Grabenbach Fm. (Randobach section, samples Gosau 215, 216, 217) are dominated by *Oculopollis* (mainly represented by *O. orbicularis*).

Tab. I (following page): Palynostratigraphy of the Gosau basin.


Gosau Basin composite section
Chrono-stratigraphy
Lithostrati-graphy
Samples
Other palyno-morphs
Dinoflagellate Cysts
Sporomorphs
Reworking
Barren
Foraminifera linings
Botryococcus .
Veryhachium spp.
Michrystridium spp.
Chomotriletes spp.
Cymatiosphaera spp.
Canningia spp.
Exochosphaeridium spp.
Spiniferites spp.
Achomosphaera spp.
Canningia reticulata
Circulodinium spp.
Exochosphaeridium bifidum
Hystrichosphaeridium recurvatum
Palaeohystrichophora infusorioides
Sentusidinium spp.
Xenascus ceratioides
Cribroperidinium spp.
Florentinia spp.
?Suessia spp.
Dinogymnium denticulatum
Canningia cf. reticulata
Florentinia resex
Subtilisphaera spp.
Hystrichodinium pulchrum
Isabelidinium spp.
Pterodinium spp.
Senoniasphaera cf. rotundata
?Dapsilidinium spp.
Florentinia stellata
Cannosphaeropsis utinensis
Heterosphaeridium spp.
Kiokansium polypes
Pervosphaeridium intervelum
Pervosphaeridium spp.
Dinogymnium acuminatum
Odontochitina operculata
?Semioculopollis spp.
Araucariacites spp.
Cicatricosisporites spp.
Callialasporites dampieri
Concavisporites spp.
Corollina spp.
Ischyosporites spp.
Oculopollis concentus
Oculopollis spp.
Punctatisporites spp.
Bisaccate pollen undiff.
Deltoidospora spp.
Fuelopisporites spp.
Taxodiaceaepollenites hiatus
Vadazisporites spp.
Oculopollis orbicularis
Triliites spp.
Pseudovacuopollis cf. intraconcavus
Oculopollis cf. concentus
Krutzschipollis cf. spatiosus
Echinatisporites spp.
Oculopollis cf. orbicularis
Krutzschipollis magnoporis
Longanulipollis spp.
Oculopollis sp. B Goczan & Siegl-Farkas
Oculopollis cf. parvoculus
Trudopollis spp.
Krutzschipollis spatiosus
Oculopollis preadicatus
Longanulipollis elegans
Magnoporopollis spp.
Oculopollis cf. sibiricus
cf. Pseudovacuopollis spp.
Retitriletes spp.
Semioculopollis spp.
Krutzschipollis spp.
Densoisporites spp.
Lueckisporites virkkiae
Triadispora spp.
Lunatisporites spp.
Ovalipollis pseudoalatus
Ricciisporites tuberculatus
Rhaetogonyaulax rhaetica
34
142
141
12
35
24
133
132
131
217
216
213
214
215
33
32
31
211
210
29
28
27
26
25
212
11
22
21
23
Maastrichtian
Campanian
Santonian
Coniacian
L. Turonian - ?Coniacian
Indeterminate
Nierental Fm
Ressen Fm
Hochmoos SKB member
Hochmoos' Schneckenwand`
?Hochmoos Fm
Grabenbach Fm
Streiteck Fm
Streiteck - Kreuzgraben
Kreuzgraben Coal

As a consequence the Grabenbach Formation is suggested to correlate to the uppermost Coniacian-Middle Santonian.

The dinocyst assemblages in this formation are very poor and monotonous. *Spiniferites* is most abundant, *Palaeohystrichophora infusorioides* and *Canningia reticulata* are often present. One sample (Gosau 33) yields a more diverse assemblage, including *Isabelidinium* spp., *Senoniasphaera* cf. *rotunda* and *Hystrichodinium pulchrum*. *Dinogymnium denticulatum* is present in sample Gosau 210.

This dinocyst assemblage confirms a latest Coniacian-Middle Santonian age for the Grabenbach Formation, which is largely in accordance to macrofossil and nannofossil data (WAGREICH 1992).

Hochmoos Formation

In general the palynological assemblages are poor in dinocysts and rich in sporomorphs. The sporomorph assemblages are rich in Normapolles types but *Araucariacites* spp. may be the dominant type also, while fern spores are frequently present. Diagnostic feature is the dominance of representatives of *Oculopollis*, in particular *Oculopollis orbicularis, O. praedicatus*, *O. sibiricus* and *O. concentus*. Successively additional elements appear: *Krutzschipollis magnoporus, Longanulipollis* spp., *Magnoporopollis* spp. and *Krutzschipollis spatiosus*.

The sample from the Sandkalkbank Member (top Hochmoos Formation) yields pollen assemblages with frequent *Magnoporopollis* spp., *Semioculopollis* spp. are present, and *Longanulipollis elegans* and *Krutzschipollis magnoporus* are characteristic constituents. The assemblages indicates a Late Santonian-earliest Campanian age for this part of the Hochmoos Formation.

The dinocyst assemblages are poorly preserved and of low diversity. Representatives of *Spiniferites* dominate the assemblages, but *Exochosphaeridium* is occasionally abundant as well. Sample Gosau 35 from the Sandkalkbank Member yields a few stratigraphically important taxa, such as *Cannosphaeropsis utinensis* and *Pervosphaeridium intervelum*. Based on the dinocyst record of KIRSCH (1991) this would suggest a correlation with the Lower Campanian contradicting the well established macrofossil evidence for a Late Santonian age (e.g.: SUMMESBERGER 1979, 1980, TRÖGER & SUMMESBERGER 1994, KOLLMANN et al. 2000). Given the scarcity of well calibrated dinocyst data for the Alpine region, a Late Santonian age seems likely.

Ressen Formation

The only productive sample Gosau 141 is rather poor in palynomorphs. The sporomorph assemblage mainly consists of Normapolles types, viz. *Krutzschipollis* spp. and *Longanulipollis* spp. Age-diagnostic sporomorphs are absent. In the poor dinocyst assemblage *Odontochitina operculata* occurs, indicating that the formation is not younger than Campanian.

Nierental Formation

The palynological assemblage of sample Gosau 34 differs markedly from the underlying Ressen Formation. The sporomorph assemblage is dominated by fern spores and the rich dinocyst assemblage is characterized by the frequent *Spiniferites* spp. and *Exo-*

*chosphaeridium* spp. In addition, the dinocyst *Hystrichodinium pulchrum* is present, indicating an age not younger than Early Maastrichtian.

## Coal successions in the Gosau Group outside the Gosau area (W to E)

### Brandenberg (Tyrol, Tab. IV)

The palynoflora of samples Brand 3, 19B, 20 from Brandenberg is composed of abundant *Taxodiaceaepollenites hiatus* and *Araucariacites* spp. with frequent bisaccoid pollengrains, and *Appendicisporites* spp. (including A. *tricuspidatus*). The Normapolles group is poorly diversified, and dinocysts are extremely rare. Characteristic is the presence of *Complexiopollis* spp. (including *C. helmigii* and C. *christae*). The sporomorphs indicate Turonian, most probably Late Turonian suggesting to be derived from an interval preceding the Kreuzgraben Formation in the Gosau Basin. Ammonites of the Late Turonian *Deverianum* – Zone from below the coal-bearing series of Brandenberg support this age indication.

### Radochsberg (Salzburg, Tab. II)

Sample Radoch 4 from the Radochsberg area (Salzburg) yields an assemblage containing *Araucariacites* spp., bisaccoid pollengrains, *Deltoidospora* spp. and *Oculopollis orbicularis*; but no dinocysts. Diagnostic feature is the presence of *Oculipollis orbicularis* suggesting Santonian, most probably Upper Santonian age. The sporomorph assemblage is similar to those from the Hochmoos Formation (excluding its top) of the nearby Gosau Basin.

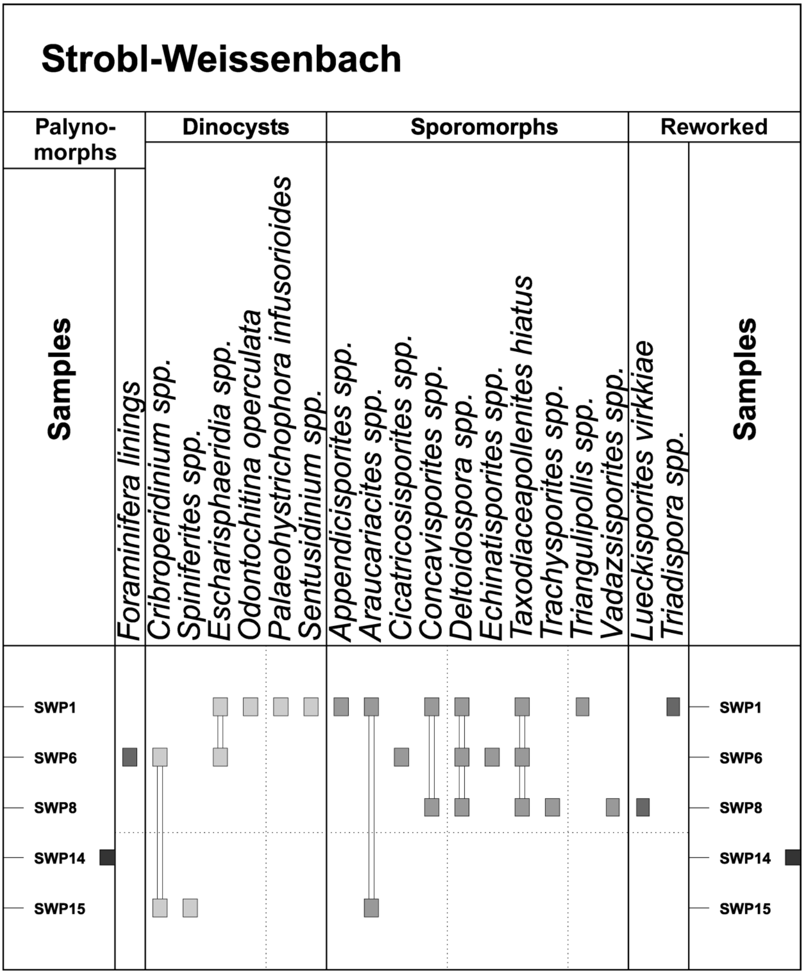
Tab. II: Results of the semi-quantitative palynological analysis of one sample in the Radochsberg area.

| Radochsberg area | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Sporomorphs | | | | | | |
| Samples | *Araucariacites spp.* | *Bisaccate pollen undiff.* | *Deltoidospora spp.* | *Oculopollis orbicularis* | *Oculopollis cf. orbicularis* | *Taxodiaceapollenites hiatus* | Samples |
| RADOCH 4 | ■ | ■ | ■ | ■ | ■ | ■ | RADOCH 4 |

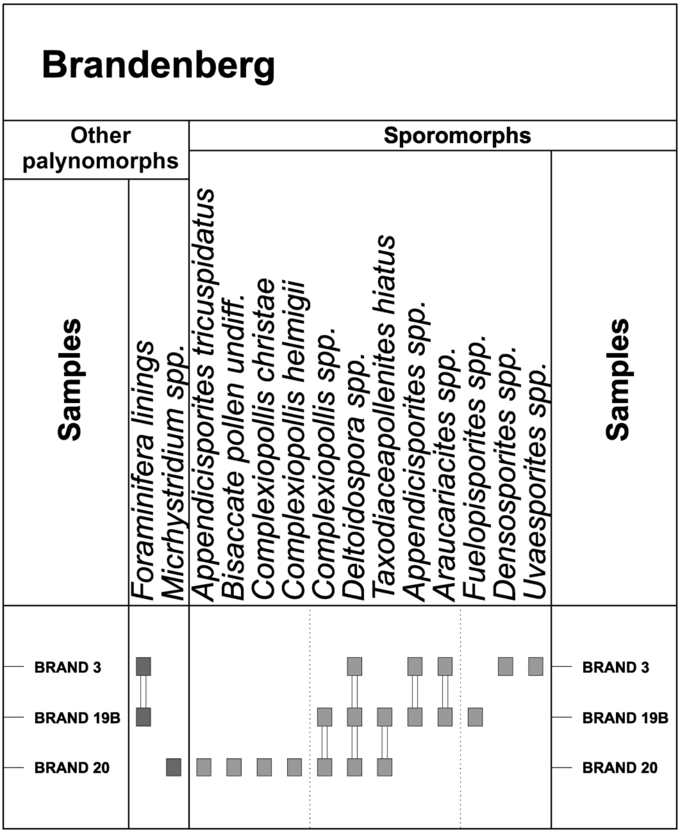
Strobl/Weissenbachtal (Salzburg, Tab. III)

Samples SWP 1, 6, 8, 15 from the Strobl/Weissenbachtal section are rich in spores with *Deltoidospora* spp. occasionally dominating and fluctuating abundances of *Taxodiaceaepollenites hiatus*, rare Normapolles types and dinocysts. The only diagnostic taxon is *Triangulipollis* spp. (sample SWP1). The genus occurs in the German LateTuronian (KRUTZSCH in GOCZAN et al. 1967); diagnostic dinocysts are absent. The typical Turonian sporomorph assemblages suggest their origin from an interval preceding the Kreuzgraben Formation in the Gosau Basin.

Tab. III: Results of the semi-quantitative palynological analysis from the Strobl/Weissenbachtal section.



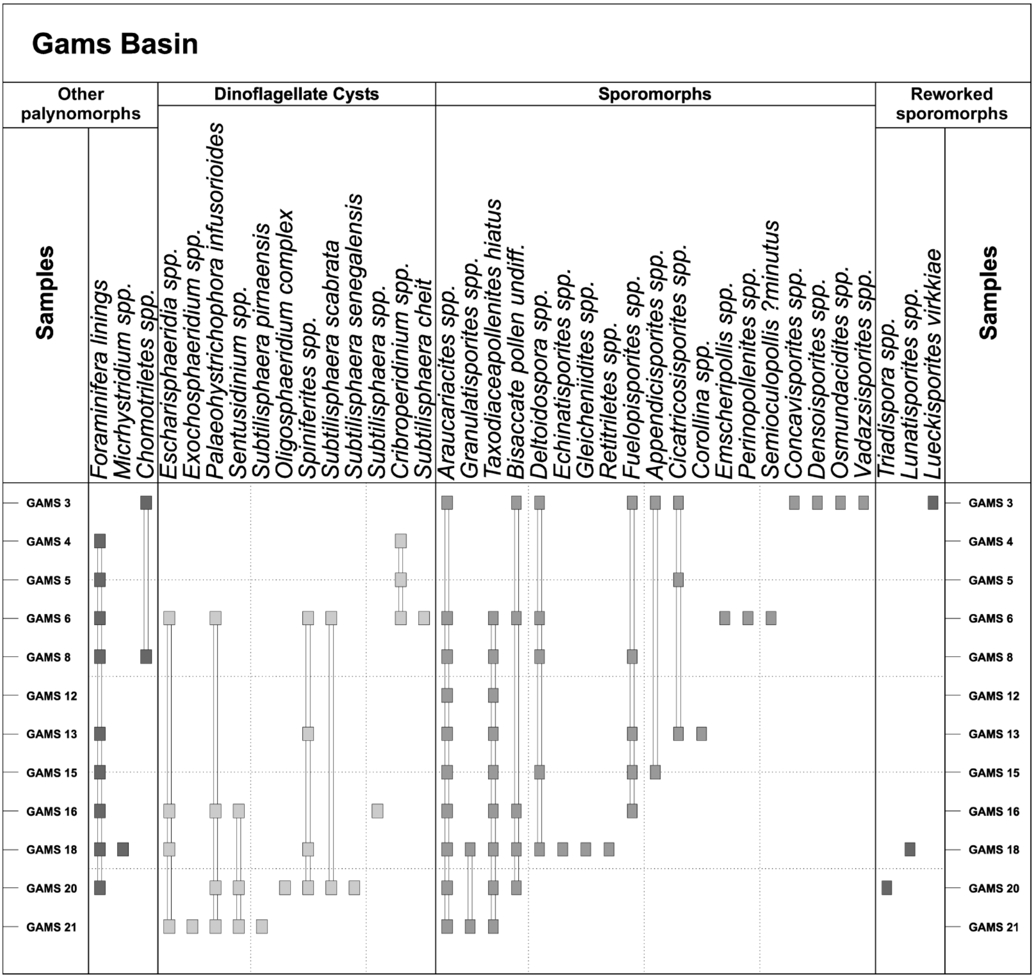
Tab IV: Results of the semi-quantitative palynological analysis in the Brandenberg section.




Gams, Akogl section (Styria; Tab. V)

The samples Gams 3, 4, 5, 6, 7, 8, 12, 13, 15, 16, 18, 20, 21 from the coal-bearing Akogl section show a rich spore association (*Deltoidospora* spp. may be dominant ) with high abundances of *Taxodiaceaepollenites hiatus*. Dinocysts are present in fluctuating abundances with common *Spiniferites* spp. and occasional high frequency of *Palaeohystrichophora infusorioides*. Diagnostic Normapolles taxa *Emscheripollis* spp. and *Semioculopollis* ?*minimus* occurring in the upper part of the section (Gams 6) point to a Coniacian age. The dinoflagellate cyst *Subtilisphaera pirnaensis* in the lower part of the section (Gams 21) suggests Turonian age. According to SIEGL-FARKAS & WAGREICH (1996) the investigated interval apparently ranges from Upper Turonian to Coniacian and is comparable to the Kreuzgraben and Streiteck Formations of the Gosau Basin.

Tab. V: Results of the semi-quantitative palynological analysis in the Akogl section.




Borehole Markgraf Neusiedl Tief (Lower Austria; Tab. VI)

The single sample from the borehole Markgraf Neusiedl Tief (MT1/7) is dominated by dinocysts with frequent Normapolles types. The sporomorphs are represented by *Krutzschipollis crassis*, *Oculopollis parvoculus* and *Trudopollis* spp.; characteristic dinocysts are *Cannosphaeropsis utinensis*, *Hystrichosphaeridium tubiferum, Raphidodinium fucatum* and *Florentinia resex*.

This assemblage is indicative for Santonian-Maastrichtian, without further precision. The co-occurrence of the dinocysts *Cannosphaeropsis utinensis* and *Raphidodinium fucatum* suggests Early to Middle Campanian in accordance to recent age data for the coal-bearing Grünbach Formation of the Grünbach – Piesting area (SUMMESBERGER et al. 2002).

Tab. VI: Results of the semi-quantitative palynological analysis of one sample from the borehole Markgraf Neusiedl Tief.

**Markgraf Neusiedl Tief**

| | Dinoflagellate Cysts | | | | | | | | | | | Sporomorphs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Samples** | *Apteodinium? deflandrei* | *Cannosphaeropsis utinensis* | *Chatangiella spp.* | *Exochosphaeridium bifidum* | *Florentinia resex* | *Hystrichosphaeridium tubiferum* | *Isabelidinium magnum* | *Isabelidinium spp.* | *Palaeohystrichophora infusorioides* | *Raphidodinium fucatum* | *Spiniferites spp.* | *Krutzschipollis crassis* | *Oculopollis parvoculus* | *Trudopollis spp.* | **Samples** |
| MT 1/7 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | MT 1/7 |

## Discussion and conclusions

Remarkably however, the semi-quantitative data of SIEGL-FARKAS & WAGREICH (1996) do not correspond with those presented herein. After personal communication with A. SIEGL-FARKAS it is concluded that this is probably due to: (1) differences in sample position, (2) differences in palynological processing methods, or, (3) a combination of these. Expecting additional results in the future, the presented palynological development of the Austrian Upper Cretaceous is considered a working hypothesis.

The semi-quantitative compositional development of the Normapolles assemblages provides an additional tool for stratigraphic correlation of the Gosau Group with biostratigraphically calibrated successions in Europe. Dinoflagellate cysts can often be used as an additional biostratigraphic control in most of the Gosau Group deposits and can be integrated with macrofossil and microfossil zonations.

Sporomorph assemblages of the Late Cretaceous Gosau Basin can be applied for correlation with Gosau Group deposits in adjacent basins. Simultaneously with the pronounced Turonian-Maastrichtian diversification within Normapolles, relative abundances of this angiospermoid pollen group gradually increase to consistently form the dominant component in Campanian and Maastrichtian sporomorph assemblages. Parallel changes occur in *Taxodiaceaepollenites hiatus* which is dominant in presumed Turonian, rare to absent in higher intervals, bisaccoid pollengrains, common in Coniacian, *Corollina* spp., common in Lower Coniacian, rare to absent in higher intervals, and *Araucariacites* spp., often dominating Santonian assemblages.

The chronostratigraphic assessments of the basal coal series in basins outside of the type locality of the Gosau Group reflects a dynamic pattern of the effects of extensional and compressional tectonics in the Late Cretaceous Northern Calcareous Alps. Subsidence rates and transgressions resulting in peat formation and preservation existed during several time intervals within the Gosau basins (Fig. 2):

- probably contemporaneously in Middle/Late Turonian, coal deposition started in the Brandenberg area (Tyrol) and Strobl/Weissenbachtal area (N of Gosau);
- in Late Turonian coals were deposited in the Gosau Basin proper and the Gams Basin;
- in the Radochsberg area (Salzburg) a new transgression including coal layers probably started in Late Santonian
- in the Markgraf Neusiedl area (NE of Vienna) transgression probably started in Early-Middle Campanian.

This pattern is in accordance with WAGREICH (1993) who inferred that differential and diachronous tectonic subsidence took place in the NCA during the Late Cretaceous. Largely similar results based on molluscs were reported by SUMMESBERGER & KENNEDY (1996).

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# Appendix: **TAXONOMY**

Spores

*Appendicisporites tricuspidatus* WEYLAND & GREIFELD, 1953
*Chomotriletes* sp.
*Cicatricosisporites* sp.
*Concavisporites* sp.
*Deltoidospora* sp.
*Densosporites* sp.
*Echinatisporites* sp.
*Fuelopisporites* sp.
*Gleichenidites* sp.
*Ischyosporites* sp.
*Osmundacidites* sp.
*Punctatisporites* sp.
*Retitriletes* sp.
*Uvaesporites* sp.
*Vadaszisporites* sp.

Gymnosperm pollen

*Araucariacites australis* COOKSON, 1947
*Callialasporites* sp.
*Corollina* sp.
*Lueckisporites virkkiae* POTONIE & KLAUS, 1954
*Ovalipollis pseudoalatus* (TIERGART, 1949) SCHUURMAN, 1976
*Taxodiaceaepollenites hiatus* (POTONIE, 1931) KREMP, 1949

Normapolles Group

*Complexiopollis christae* (VAN AMEROM, 1965) KEDVES, 1980
*Complexiopollis helmigii* (VAN AMEROM, 1965) SOLE DE PORTA, 1977
*Emscheripollis* sp.
*Krutzschipollis crassus* (GÓCZÁN, 1964) GÓCZÁN, 1967
*Krutzschipollis magnoporus* GÓCZÁN, 1967
*Krutzschipollis spatiosus* GÓCZÁN, 1967
*Krutzschipollis* cf. *spatiosus* GÓCZÁN, 1967
*Longanulipollis elegans* (GÓCZÁN, 1964) GÓCZÁN, 1967
*Longanulipollis* sp.
*Magnoporopollis* sp.
*Oculopollis concentus* PFLUG, 1953
*Oculopollis* cf. *concentus* PFLUG, 1953
*Oculopollis orbicularis* GÓCZÁN, 1964
*Oculopollis* cf. *orbicularis* GÓCZÁN, 1964
*Oculopollis parvoculus* GÓCZÁN, 1964
*Oculopollis preadicatus* WEYLAND & KRIEGER, 1953
*Oculopollis* cf. *sibiricus* ZAKLINSKAYA, 1963
*Oculopollis* sp.B GÓCZÁN & SIEGL-FARKAS, 1990
*Pseudovacuopollis* sp.
*Semioculopollis* sp.
*Trudopollis* sp.

**Dinoflagellate cysts**

*Achomosphaera* sp.
*Canningia reticulata* COOKSON & EISENACK, 1960
*Canningia* sp.
*Circulodinium* sp.
*Dinogymnium acuminatum* EVITT et al., 1967
*Dinogymnium denticulatum* (ALBERTI, 1961) EVITT et al., 1967
*Exochosphaeridium bifidum* (CLARKE & VERDIER, 1967) CLARKE et al., 1968
*Florentinia resex* DAVEY & VERDIER, 1976
*Florentinia stellata* (MAIER, 1959) BELOW, 1982
*Hystrichodinium pulchrum* DEFLANDRE, 1935
*Hystrichosphaeridium recurvatum* (WHITE, 1842) LEJEUNE – CARPENTIER, 1940
*Odontochitina operculata* (O. WETZEL, 1933) DEFLANDRE & COOKSON, 1955
*Palaeohystrichophora infusorioides* DEFLANDRE, 1935
*Pervosphaeridium intervelum* KIRSCH, 1991
*Pervosphaeridium* sp.
*Senoniasphaera* cf. *rotundata* CLARKE & VERDIER, 1967
*Spiniferites* sp.
*Rhaetogonyaulax rhaetica* (SARJEANT, 1963) LOEBLICH & LOEBLICH, 1968
*Xenascus ceratioides* (DEFLANDRE, 1937) LENTIN & WILLIAMS, 1973