# Cretaceous History of Austria

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### Cretaceous of the Eastern Alps

Within the Eastern Alps, a segment of the Alpine fold-and-thrust belt, Cretaceous rocks were identified for the first time in the late 18th century. In the early 19th century detailed investigations and correlations of Cretaceous strata by Sedgewick & Murchison (1832) and Lill von Lilienbach (1830) were undertaken, followed by monographs on various aspects of the Cretaceous from ca. 1850 onwards, e.g., Reuss (1854), Zittel (1866) and Redtenbacher (1873).

The Eastern Alps originated within the northwestern Tethys palaeogeographic belt due to repeated convergence between the European and the African plate and intervening microplates. A Jurassic-Cretaceous, "Eoalpine" orogeny was followed by Meso- and Neoalpine deformational events (e.g. Faupl & Wagreich 2000). The evolution of the orogen, especially Cretaceous geodynamics in the Eastern Alps and the Western Carpathians, are strongly discussed because of polyphase young deformations overprinting Mesozoic structures, the incompleteness of the sedimentary record and the weakly constrained palaeogeographic and palaeotectonic positions of some units. Proposed paleogeographic models differ in the inferred positions and timing of subduction zones and collisions (e.g. Faupl & Wagreich 2000; Von Eynatten & Gaupp 1999; Wortmann *et al.* 2001; Stampfli & Borel 2002).

Three major tectonic units with different types of sedimentary basins and basement units can be distinguished within the Cretaceous Alps (Fig. 1, 2): (1) the Helvetic s.l. European shelf units, platforms and basins on continental crust; today, these units form the northernmost thrust complexes of the orogen and are partly continuous into autochthonous successions of the North Alpine foreland, (2) the Penninic units, partly overthrust onto Helvetic units s.l. and exposed as large tectonic windows below overthrusting units of more internal derivation(3) the Austro-Alpine and the Southern Alpine units which originated from the northern margin of the Adriatic plate (Haubold *et al.* 1999). The Northern Calcareous Alps (NCA) represent a complicated pile of cover nappes including significant Cretaceous to Paleogene strata.

In the segments of the Eastern Alps and the Western Carpathians, Alpine orogeny commenced with the closure of a Triassic Tethys Gulf (Hallstatt-Meliata Ocean, e.g. Channel & Kozur 1997) within the Austro-Alpine domain during the Jurassic to Early Cretaceous. Contemporaneously, the Penninic Ocean (Part of the Liguria-Piemont Oceanic domain; Alpine Tethys of Stampfli et al., 2002) opened by oblique rifting and spreading between the European shelf and the Austroalpine microplate, connected to the opening of the Atlantic Ocean (Frisch 1979;

Stampfli *et al.* 2002). The Penninic-Austroalpine plate boundary changed from transtension to transpression during the mid-Cretaceous (Wagreich 2003). From Early Cretaceous times onwards, the sedimentary cover of the NCA was sheared off from its basement and stacked into a complex nappe pile. Deposition of synorogenic to postorogenic strata followed until renewed orogenesis during the Eocene to Oligocene. A complex history of synorogenic basins with strongly varying geometries and short-lived subsidence and uplift events characterizes the Austro-Alpine unit, especially during mid- and Late Cretaceous (Figs. 2, 3).

**Facies overview**

**Helvetic/Ultrahelvetic Units**

The Helvetic paleogeographic realm represents the depositional area on the southern border of the European continent during Mesozoic-Paleogene times. The Helvetic nappes extend from the western part of the Eastern Alps (Austria and Germany), where they disappear below the Austro-Alpine nappe system to Switzerland. These Helvetic units comprise sedimentary strata deposited on the shelf and upper continental slope of the European continent in a passive margin setting during the Cretaceous. The Early Cretaceous is characterized by a southward-prograding carbonate platform. Following the Cenomanian transgression, basinal hemipelagic to pelagic sediments dominate until Maastrichtian times. Towards the south, hemipelagic to pelagic deeper-water sediments of the Ultrahelvetic Zone, e.g., the Gresten Klippen Zone in eastern Austria, mark the transition into the Rhenodanubian Flysch Basin. The Upper Cretaceous-Paleogene Bunmergelserie, a variegitated successions of pelagic and hemipelagic marls and shales, is present in the Ultrahelvetic Gresten Klippen Zone of the Eastern Alps. Dark grey and black shales and limestone prevail from Aptian to Cenomanian up to a distinct black shale interval at the Cenomanian-Turonian boundary. The following Turonian to Upper Campanian is characterized by red marls and light grey to white limestones (Wagreich & Neuhuber, 2007; Neuhuber et al., 2007). Campanian to Maastrichtian marls again display medium to dark grey colours and increasing input of clay and silt. Upper Campanian ammonites are reported from this interval in Upper Austria (Kennedy & Summesberger 1984, 1999).

**Penninic Units**

The Penninic units comprise different parts of the Ligurian-Piemontais-Penninic-Valais oceanic systems, and include remnants of marginal continental fragments. The opening of these partly oceanic basins was linked to the Jurassic opening of the North Atlantic (Frisch 1979; Stampfli & Borel 2002). Mesozoic to Paleogene parts of the Penninic units are preserved as non-metamorphic cover nappes, comprising mainly turbidite successions in Switzerland and Austria, while other parts occur in various stages of metamorphism within tectonic windows below the overriding Austro-Alpine units.

**The Rhenodanubian Flyschzone**

The Rhenodanubian Flyschzone, which constitutes a 500-km-long imbricated thrust pile, trending ENE-WSW parallel to the northern margin of the Eastern Alps. To the south of Lake Chiemsee (Bavaria) it is interrupted for a short distance and so it has been subdivided into an eastern and western part.

The sedimentary succession of the Rhenodanubian Flyschzone consists of deep-water deposits, which have been considered a lithostratigraphic group (Egger & Schwerd, 2007). This Rhenodanubian Group (RG) consists primarily of siliciclastic and calcareous turbidites of Lower Barremian to Ypresian age. Thin, hemipelagic claystone layers occur in all formations of the RG and indicate a deposition below the local calcite compensation depth, probably at palaeodepths >3000 m (Butt, 1981; Hesse, 1975). Palaeocurrents and the pattern of sedimentation suggest that the deposition occurred on a flat, elongate, weakly inclined abyssal basin plain and was not disturbed by syndepositional tectonic deformation (Hesse, 1982, 1995).

Postdepositional thrusting and wrenching have destroyed the original basin configuration and the relationship to source areas. The RG has been deposited in the Penninic basin to the south of the European Plate, however, the exact palaeogeographic position of its sedimentation area is still a matter of discussion (Butt, 1981; Hesse, 1982; Oberhauser, 1995; Wortmann, 1996; Mattern, 1999; Trautwein, 2000; Egger et al., 2002).

The Cretaceous part of the RG attains a maximum thickness of about 1500m. Lower Cretaceous deposits of the RG recently have been studied biostratigrapically using dinoflagellates (Kirsch 2003): the 11 dinoflagellate zones found indicate the Upper Barremian to Upper Albian. During the major part of this episode, stratigraphically important calcareous nannoplankton species are exceedingly rare, as most of the encountered assemblages consist exclusively of monospecific nannofloras of *Watznaueria barnesiae*, which do not provide significant stratigraphic solution. Species richness is increasing in Upper Albian to lower Cenomanian (calcareous nannoplankton zone CC9) varicoloured marlstone (Untere Bunte Mergel; Egger, 1992; Wagreich et al., 2006).

This varicoloured marlstone is overlain by grey turbiditic marlstone (Ofterschwang Formation) or by the thick-bedded siliciclastic turbidites of the Reiselsberg Formation. Another dearth of turbidite sedimentation is indicated by varicoloured hemipelagic claystone with intercalated thin turbidite beds (Seisenburg Formation) of middle Coniacian to lower Campanian age (Zones CC14-CC18). The formation of these red beds seems to have been an effect of the high sea-level during this period. Another result of this highstand was the formation of the calcareous Röthenbach Subgroup, which is interfingering with the Seisenburg Formation. The calcareous turbidites prograded from the west and form a thickening and coarsening up-ward succession, which is often overlain by the thin-bedded turbidites and red claystone of the Perneck Formation of Late Campanian age (Zones CC21-CC22). The youngest Cretaceous lithostratigraphic unit is the primarily siliciclastic Altlengbach Formation, which comprises the Upper Campanian to Paleocene.

**Austro-Alpine and Southern Alpine basins**

The Austro-Alpine units are a characteristic unit of the Eastern Alps. Based on palaeomagnetic data the Austro-Alpine domain is considered to be a partly independent microplate situated along the northern margin of the Adriatic (Apulian) plate, and represents the northern tip of continental fragments of African affinity during the Cretaceous (e.g. Haubold et al. 1999; see also Stampfli & Borel 2002). Eoalpine deformation strongly influenced Cretaceous sedimentation and the formation of sedimentary basins within of the Austro-Alpine domain. Thus, a complex history of synorogenic basins with strongly varying geometries and short-lived subsidence and uplift events characterizes the Austro-Alpine realm, especially during mid- and Late Cretaceous times.

The best documented Cretaceous successions of the Austro-Alpine domain are preserved within the Northern Calcareous Alps (NCA, Fig. 3). Cretaceous deformation resulted in thrusting and faulting within the NCA. Based upon a restoration of younger faulting (Frisch et al. 1998), the Eastern Alps had about half the length of the present day mountain chain during the Late Cretaceous.

**The Northern Calcareous Alps**

**Pelagic and synorogenic sedimentation in the Early Cretaceous**

Within the Northern Calcareous Alps deep-water carbonate and marls predominate in the Lower Cretaceous. Synorogenic clastic successions and marl facies of the Lower Cretaceous comprises Maiolica-type limestones at their base grading into a shale-limestone cyclic facies. Resedimented clasts of shallow-water Urgonian-type carbonates (e.g. Schlagintweit 1991) give evidence that small carbonate platforms were present in northern parts of the NCA during the Early Cretaceous, but were later completely eroded. The deposits are interpreted as pelagic sedimts of the deep-water shelf to slope of the passive margin of the Austroalpine microplate. The onset of silicilcastic synorogenic strata marked the change to a tectonically active margin due to compression at the Austroalpine-Penninic margin (e.g. von Eynatten & Gaupp 1999; Wagreich 2003).

The Kimmeridgian - Early Berrasian Oberalm Formation represents a pelagic deep-water limestone with grey, cherty, bedded micrites including carbonate turbidites of varying thicknesses. The microfauna is dominated by radiolarians, calpionellids and foraminifera (e.g., Weidich 1990; Reháková *et al.* 1996; Boorová *et al*. 1999). Turbiditic Barmstein Limestone beds within the Oberalm Formation contain a diverse fauna of calcareous algae and foraminifera indicating an Early Berriasian age. The Upper Jurassic to Berriasian carbonate platforms of the Plassen Formation (Schlagintweit & Ebli 1999; Gawlick et al. 2006) can be regarded as the source for the resedimented shallow-water material.

The Oberalm Formation grades into grey micritic limestones and limestones-marl rhytmites of the Schrambach Formation (e.g. Vašíček & Faupl 1999; Rasser *et al.* 2003; Lukeneder, 2003, 2004, 2005; *Aptychus* limestone and Ammergau Formation p.p. of some authors) during the Berriasian. Sandy turbidites are largely absent in the Schrambach Formation, and the amount of marl intercalations increases upwards. Considering different tectonic units of the NCA both the base and especially the top of the Schrambach Formation are diachronous.

In more internal nappe complexes of the NCA (Tirolic units west and south of Salzburg; Reichraming and Lunz nappes further to the east), deep-water limestones graded into synorogenic terrigenous facies of the Rossfeld Formation during Valanginian to Aptian time (Decker *et al*. 1987; Vašíček & Faupl 1998). The Rossfeld basin is interpreted as a deep-water foreland to piggyback trough in front of overthrusting higher NCA-nappes (Decker *et al*. 1987). The Rossfeld Formation comprises a coarsening upward succession of marls and sandstones, grading into deep-water conglomerates/breccias as well as slump deposits sedimented on an active north-facing slope. The sandstones contain considerable amounts of siliciclastic and ophiolitic detritus from southern source terrains, including chrome spinels from ophiolites of the Tethys-Vardar-Hallstatt suture (Pober & Faupl 1988; von Eynatten & Gaupp 1999).

**Lower Cretaceous Formations of the eastern part of the Northern Calcareous Alps**

During the Lower Cretaceous the Mediterranean palaeogeographic domain was characterized by the presence of microplates located in the middle of the Tethyan oceanic corridor between the African and European landmasses. As noted by many authors (for example Cecca, 1997, 1998; Stampfli & Mosar, 1999), the region (Northern Calcareous Alps) on which the investigated areas were situated during the Lower Cretaceous was formed at the eastern border of the Alpine-Carpathian Block, which was located at the western margin of the Tethys.

Lower Cretaceous pelagic sediments are well known to form a major element of the northernmost tectonic units of the Northern Calcareous Alps (e.g., Ternberg-, Reichraming-, Frankenfels-, and Lunz Nappes) (see Lukeneder, 1998, 1999, 2001, 2003, 2003a, 2004; Lukeneder & Harzhauser, 2003). They cover wide areas both within the latter (e.g., Rossfeld, Losenstein, Schneeberg, Anzenbach, Ebenforst, and Flössel Synclines) and in various other European areas (e.g., Vocontian basin, Dolomites, Umbria, Western Carpathians, Gerecse and Mecsek Mountains and others) (Lukeneder & Aspmair 2006).

The Steinmühl Formation (approx. 15 m) is of Early Berriasian to late Early Valanginian age. Its lower part consisting of red (‘Ammonitico rosso’ type) and its upper part of grey (‘Maiolica’ type) condensed pelagic limestones with a few ammonoids, but abundant calpionellids and calcareous dinoflagellates enabling precise biostratigraphic correlations. The brachiopod *Pygope cattuloi* is abundant in the topmost bed (Lukeneder, 2002).

Schrambach Formation (approx. 150 m): Late Valanginian to late Barremian in age, consisting of pale grey, even bedded limestones intercalated with grey to black calcareous marlstones (laminated ‘black shales’), and marls. The beds are intensively bioturbated, and the trace fossils *Zoophycos*, *Chondrites* and *Planolites* occur throughout (Lukeneder, 2001).

The wavy boundary between the Steinmühl and the Schrambach Formation is marked by a primary hardground characterized by fragmented, encrusted, and partly eroded ammonoids and several bored cephalopods (e.g. belemnites; Lukeneder, 1998).

The evolution of marine biota on the southern European shelf was influenced by continuing disintegration of carbonate platforms during the Lower Cretaceous. Their pelagic influence also became more pronounced in former reef and shallow areas. The morphological highs (elevations or swells) in the pelagic environments were characterized by condensed sedimentation of the 'Ammonitico rosso' facies (Cecca et al., 1993, 1994).

Only elevated, firmer parts of the bottom were typically inhabited by benthic micro-organisms at that time. Nannoconid biomicrites prevailed both in the hemipelagic and pelagic environments over the extensive sea floor, formerly (during the Late Jurassic) characterized by diversified sedimentation. Pelagic marine environments were characterized by a uniformly soft unconsolidated muddy bottom. Nannoconids persisted in dominance during the Valanginian and Hauterivian, while the calpionellid share in the microplankton association decreased. Reorganization of the Mediterranean Tethys palaeogeography correlated with a change in current patterns resulted in a new Berriasian - Valanginian 'bloom' in plankton development.

The biostratigraphic data on the transition between the Schrambach and the Tannheim Formation of the northeastern Northern Calcareous Alps (Upper Austroalpine) are remarkable scarce (Weidich, 1990; Wagreich 2003). This fact reflects the absence of identifiable ammonoid macrofossil fauna as well as the absence or bad preservation of relevant microfossils. The corresponding boundary however has an extraordinary importance for the reconstruction of Austroalpine geodynamics as marking the initial siliciclastic input into the basin reflecting the starting point of the Penninic Ocean subduction beneath the Upper Austroalpine (Wagreich, 2003). Newly discovered outcrops in the Wienerwald (Vienna Woods), should now fill that gap. In these sections the critical interval has been found for the first time in an environment comprising extraordinarily rich accumulations of planktonic foraminifera.

**Synorogenic mid-Cretaceous of the Northern Calcareous Alps**

With the termination of the Rossfeld sedimentary cycle in the Barremian-Early Aptian, synorogenic basin subsidence shifted to tectonically lower (northern) zones of the NCA, the Frankenfels-Ternberg-Allgäu nappe system. Piggyback basins evolved in front of north to northwestward propagating thrusts, such as the Tannheim-Losenstein basin (Late Aptian to Early Cenomanian; Wagreich 2003). Deposits of the Tannheim-Losenstein basin (Fig. 2) form the core of faulted and partly overturned, narrow synclines. Within these units the Schrambach Formation is overlain by a few metres of marlstones and calcareous shales of the Tannheim Formation followed by a 100 - 350 m thick coarsening-upward clastic cycle of the Losenstein Formation.

The Tannheim Formation comprises grey and minor red and black shales and marlstones of Late Aptian to Middle/Late Albian age (Weidich, 1990). The marlstones and calcareous shales of the Tannheim Formation can be classified as hemipelagites, being a mixture of an autochthonous biogenic carbonate fraction, mainly planktonic foraminifera and calcareous nannoplankton, a terrigenous siliciclastic fine silt and clay fraction, and organic carbon. Bathyal depositional depth of at least a few hundred meters have been estimated based on the high content of planktonic foraminifera and the lack of shallow water foraminifera (Weidich 1990). Black shales with organic carbon up to 2% (Wagreich & Sachsenhofer 1999) are present in the Lower Albian, inlcuding OAE 1b with ammonites such as *Leymeriella tardefurcata* (Kennedy & Kollmann 1979; Kennedy *et al.* 2000).

The Tannheim Formation is overlain by the up to 350 m thick coarsening-upward cycle of the Losenstein Formation (Middle Albian - lowermost Cenomanian; Kollmann 1968; Weidich 1990), comprising turbidites, deep-water conglomerates and slump horizons. In the lower part of the Losenstein Formation, thin sandy turbidites and laminated siltstone-shale intervals prevail. Sandstone beds are up to 30 cm thick and show grading and both complete and partly incomplete Bouma-cycles. The amount of conglomeratic layers increases upsection. Both normal and inversly graded clast-supported conglomerates and matrix-supported pebbly mudstones and pebbly sandstone are found. Overall, the thickness of pebbly mudstones and slump intervals increases in the upper part of the Losenstein Formation. Slump intervals comprise folded beds of laminated siltstone-shale intervals with only minor sandstone intercalations. The uppermost preserved facies type includes thick slump intervals and olistostromes. The facies association was interpreted as a coarse-grained deep-water slope apron along the active northern margin of the Austroalpine microplate (Wagreich 2001, 2003).

The synorogenic Branderfleck Formation (Cenomanian-Turonian; up to Early Campanian in the western NCA) unconfomably overlies faulted and folded older NCA strata. (Gaupp 1982). Basal breccias and shallow-water sandstones containing orbitolinids pass into tens of metres of deep-water hemipelagic and turbiditic deposits, including olistoliths of Triassic to Jurassic carbonates (Schlagintweit & Wagreich, 2006).

**Upper Cretaceous Gosau Group**

In the Turonian, as a consequence of the Eoalpine orogeny, most of the deformed Austroalpine domain was elevated above sea level. In front of the Austroalpine microplate, an accretionary wedge existed as a result of subduction of the Penninic Ocean under a dextral transpressional regime (comp. Fig. 2). This wedge comprised tectonic slices of Austroalpine units and obducted ophiolite remnants. The NCA, which had probably already been sheared off from their metamorphic basement, were situated during this time at this tectonically active continental margin.

In Late Turonian time, a new sedimentary cycle started with the deposition of the Gosau Group, which rests unconfomably upon the Eoalpine deformed pre-Gosau strata and also on metamorphic Austroalpine basement south of the NCA. As unconformable Upper Cretaceous strata are widespread in the Alpine-Carpathian mountain chain, the term Gosau has been used from the NCA to Slovakia, Hungary and Romania for such deposits (e.g. Willingshofer *et al.* 1999). Basin formation is still discussed as a result of a complex interplay of sedimentation and tectonism during the Late Cretaceous history of the whole Austroalpine block, and several basin types were recently interpreted for these basins, e.g. compressional piggy back and synthrust basin models (e.g. Ortner 2001) or extensional and pull-apart basin models (e.g. Willingshofer *et al.* 1999; Wagreich & Decker 2001).

Recent data on the biostratigraphy, lithostratigraphy and isotope stratigraphy of the Gosau Group can be found, among others, in Summesberger (1985), Wagreich (1992), Tröger & Summesberger, Summesberger & Kennedy (1996), Summesberger *et al.* (1999), Steuber (2001), Wagreich et al. (2003), Hradecka et al. (2005).

The Gosau Group of the NCA can be divided into two subgroups as a consequence of different basin geometries and subsidence histories (Wagreich 1993, 1995; Wagreich & Faupl 1994). The lower Gosau Subgroup (Upper Turonian - Campanian; Maastrichtian-Paleogene only in the southeastern NCA) consists of diachronous terrestrial deposits at the base and passes gradationally into shallow-marine successions (Fig. 3). At the base, karst bauxites of probably Turonian age are present (Mindszenty & D'Argenio 1987), giving evidence for pronounced subaerial exposure of at least parts of the NCA during this time. Sandstones and sandy limestones together with rudist-bearing limestones, storm-influenced inner and outer shelf facies and shelf/slope transitional facies are the main facies of the lower Gosau Subgroup (Wagreich & Faupl 1994, Sanders *et al*. 1997; Sanders & Pons 1999). Locally, high contents of ophiolitic detritus are a conspicous feature of sandstones of this subgroup. The lower Gosau Subgroup was deposited mainly in small strike-slip basins (Wagreich & Decker 2001) which originated due to extension or transtension after mid-Cretaceous thrusting and transpression along the Penninic-Austroalpine boundary (Wagreich & Faupl 1994).

The upper Gosau Subgroup comprises deep-water deposits (Fig. 7), such as hemipealgic and pelagic slope marls (Nierental Formation; Butt 1981; Wagreich & Krenmayr 1993; Krenmayr, 1996) and a broad variety of deep-water clastics, deposited above and below the calcite compensation level (Fig.3). Facies distribution and palaeocurrent data indicate a pronounced fault-controlled relief of a generally north-facing palaeoslope (Faupl & Wagreich 1994). A conspicuous unconformity separates the lower from the upper subgroup, and parts of the lower Gosau Subgroup have been eroded at this unconformity. In contrast to the lower Subgroup, the terrigenous material of the deep-water successions comprises predominantly metamorphic detritus. Shallow-water components, such as corallinacea, orbitoid foraminifera, bryozoa etc., point to the existenece of a coeval carbonate platform in the south of the NCA (Wagreich & Faupl 1994).

The subsidence event into bathyal depths shifted diachronously from the Santonian/Campanian from the northwest towards the southeast of the NCA. The easternmost parts of the NCA were involved as late as Maastrichtian to Paleocene times. This strong subsidence pulse has been explained by subcrustal tectonic erosion, eliminating parts of the accretionary wedge along the northern margin of the Austroalpine plate (Wagreich 1993, 1995).

Several sites with a fairly complete record of the Cretaceous/Paleogene boundary were found within the Gosau Group of the NCA at Gosau (Elendgraben section), at Gams (Knappengraben section) and near Berchtesgaden/Lattengebirge (Herm *et al.* 1981; Preisinger *et al*. 1986; Peryt *et al.* 1993). A detailed biostratigraphy and magnetostratigraphy was established for these sites and several impact-related features were reported from the deep-water boundary clays of the Gosau Group, e.g. iridium enrichment, shocked quartz crystals, etc. (Preisinger *et al.* 1986).

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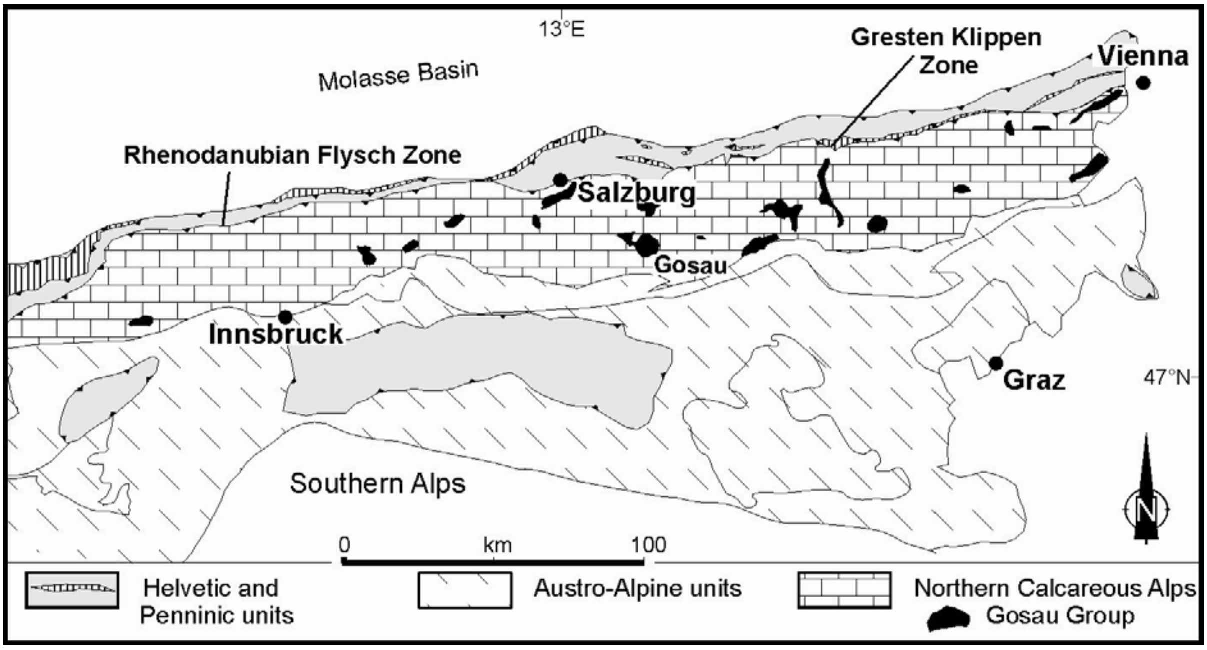



**Fig. 1**. Schematic geological map of the Eastern Alps including major tectonic zones and Gosau Group localities.

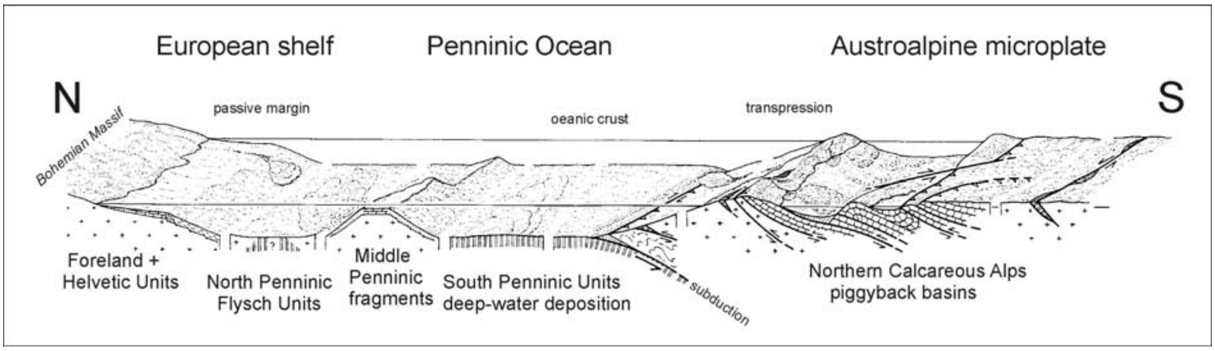



**Fig. 2.** Palaeogeographic sketch for the Cenomanian of the Eastern Alps

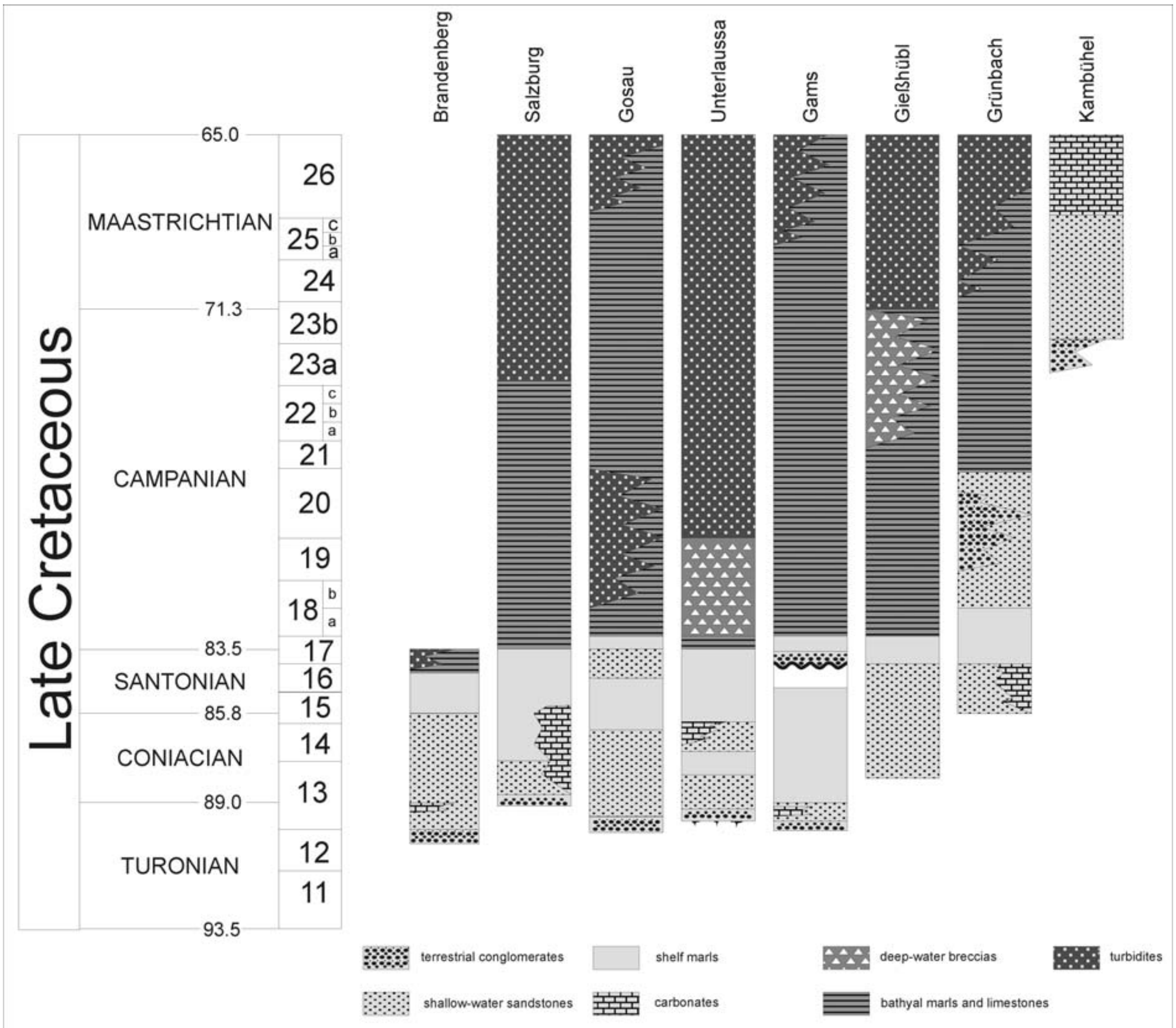



**Fig. 3.** Chronostratigraphy, nannoplankton zonation and facies of the Gosau Group of the Northern Calcareous Alps (Wagreich & Faupl 1994; Faupl & Wagreich 2000)

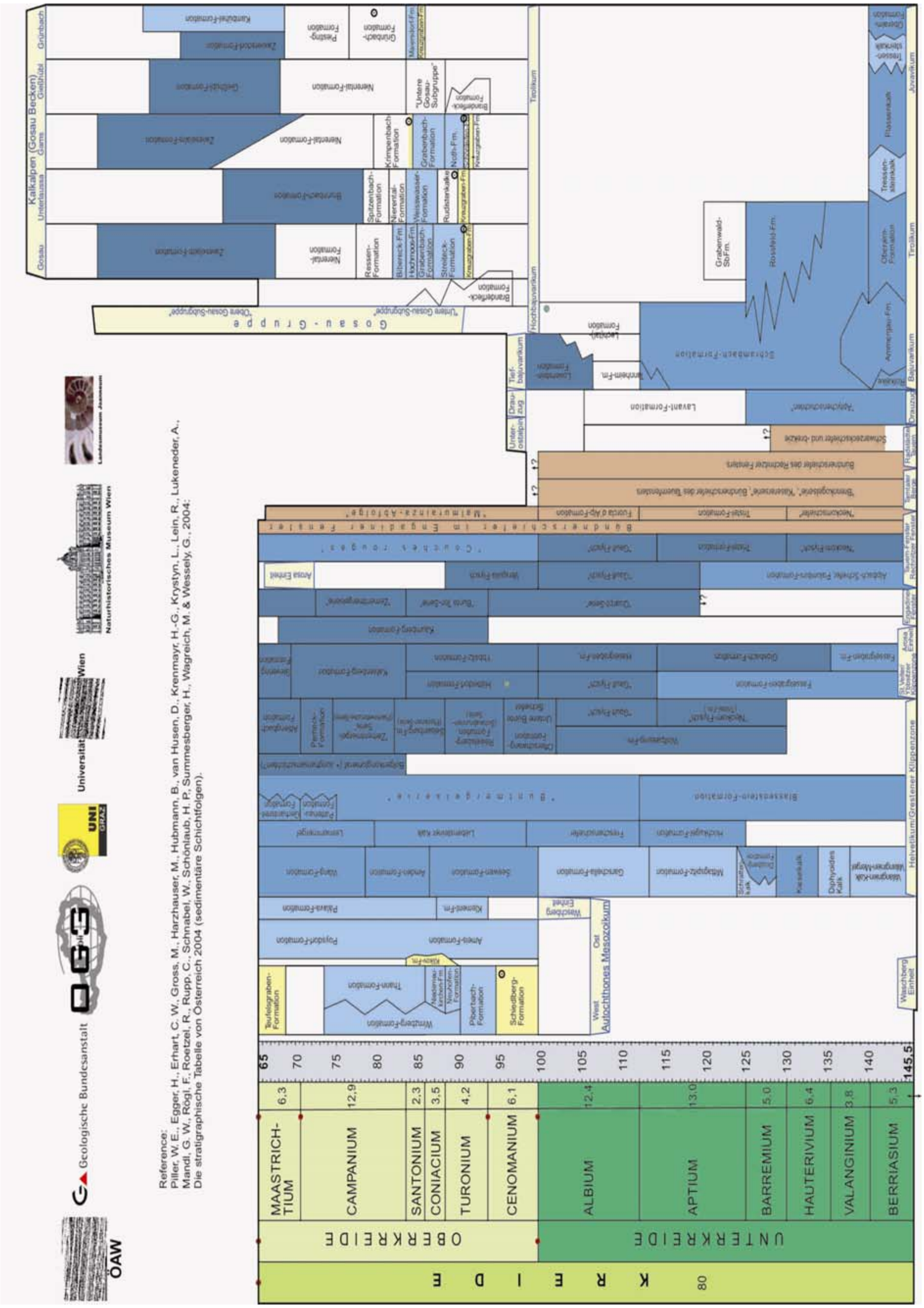
| STAGES | | ZONES | SUBZONES | HORIZONS |
|---|---|---|---|---|
| HAUTERIVIAN | Upper | *Pseudothurmannia ohmi* | *Pseudothurmannia picteti* | |
| | | | *Pseudothurmannia catulloi* | |
| | | | *P. ohmi* | |
| | | *Balearites balearis* | | |
| | | *Plesiospitidiscus ligatus* | | |
| | | *Subsaynella sayni* | | *Cruasiceras cruasense* |
| | Lower | *Lyticoceras nodosoplicatum* | | |
| | | | | *Olcostephanus (O.) variegatus* |
| | | *Crioceratites loryi* | *Olcostephanus (Jeannoticeras) jeannoti* | |
| | | | *C. loryi* | |
| | | *Acanthodicus radiatus* | | *Breistrofferella castellanensis* |
| VALANGINIAN | Upper | *Criosarasinella furcillata* | *Teschenites callidiscus* | |
| | | | *C. furcillata* | |
| | | *Neocomites peregrinus* | *Olcostephanus (O.) nicklesi* | |
| | | | *N. peregrinus* | |
| | | *Saynoceras verrucosum* | *Karakaschiceras pronecostatum* | |
| | | | *S. verrucosum* | |
| | Lower | *Busnardoites campylotoxus* | *Karakaschiceras biassalense* | *Neocomites platycostatus* |
| | | | | *Saynoceras fuhri* |
| | | | *B. campylotoxus* | |
| | | *Tirnovella pertransiens* | | |
| BERRIASIAN | Upper | *Subthurmannia boissieri* | *Thurmanniceras otopeta* | |
| | | | *Tirnovella alpillensis* | |
| | | | *Berriasella picteti* | |
| | | | *Malbosiceras paramimounum* | |
| | Middle | *Subthurmannia occitanica* | *Dalmasiceras dalmasi* | |
| | | | *Berriasella privasensis* | |
| | | | *Subthurmannia subalpina* | |
| | Lower | *Berriasella jacobi* | | |

**Table 1.** Ammonite zonation of the Berriasian-Hauterivian stages.

| STAGES | | ZONES | SUBZONES | HORIZONS |
|---|---|---|---|---|
| ALBIAN | Upper | *Stoliczkaia (S.) dispar* | *S. (S.) dispar* | |
| ALBIAN | Upper | *Stoliczkaia (S.) dispar* | *Stoliczkaia (Faraudiella) blancheti* | |
| ALBIAN | Upper | *Mortoniceras inflatum* | | |
| ALBIAN | Upper | *Mortoniceras inflatum* | *Diploceras cristatum* | |
| ALBIAN | Middle | *Euhoplites lautus* | | |
| ALBIAN | Middle | *Euhoplites loricatus* | | |
| ALBIAN | Middle | *Hoplites dentatus* | *Hoplites spathi* | |
| ALBIAN | Middle | *Hoplites dentatus* | *Lyelliceras lyelli* | |
| ALBIAN | Lower | *Douvilleiceras mammillatum* | | |
| ALBIAN | Lower | *Leymeriella tardefurcata* | | |
| APTIAN | Upper | *Hypacanthoplites jacobi* | | |
| APTIAN | Upper | *Acanthohoplites nolani* | | |
| APTIAN | Upper | *Acanthohoplites nolani* | *Diadochoceras nodosocostatum* | |
| APTIAN | Middle | *Parahoplites melchioris* | | |
| APTIAN | Middle | *Epicheloniceras martini* | *Epicheloniceras buxtorfi* | |
| APTIAN | Middle | *Epicheloniceras martini* | *Epicheloniceras gracile* | |
| APTIAN | Middle | *Epicheloniceras martini* | *Epicheloniceras debile* | |
| APTIAN | Lower | *Dufrenoyia furcata* | | |
| APTIAN | Lower | *Deshayesites deshayesi* | *Deshayesites grandis* | |
| APTIAN | Lower | *Deshayesites deshayesi* | | |
| APTIAN | Lower | *Deshayesites weissi* | | |
| APTIAN | Lower | *Deshayesites oglanlensis* | | |
| BARREMIAN | Upper | *Martelites sarasini* | *Pseudocrioceras waagenoides* | |
| BARREMIAN | Upper | *Martelites sarasini* | | |
| BARREMIAN | Upper | *Martelites sarasini* | | *Leptoceratoides puzosianum* |
| BARREMIAN | Upper | *Imerites giraudi* | | |
| BARREMIAN | Upper | *Imerites giraudi* | | *Heteroceras emerici* |
| BARREMIAN | Upper | *Imerites giraudi* | | *I. giraudi* |
| BARREMIAN | Upper | *Hemihoplites feraudianus* | | |
| BARREMIAN | Upper | *Gerhardtia sartousiana* | *Gerhardtia provincialis* | |
| BARREMIAN | Upper | *Gerhardtia sartousiana* | *G. sartousiana* | |
| BARREMIAN | Upper | *Toxancyloceras vandenheckii* | *Barrancyloceras barremense* | |
| BARREMIAN | Upper | *Toxancyloceras vandenheckii* | *Heinzia sayni* | |
| BARREMIAN | Upper | *Holcodiscus uhligi* | | |
| BARREMIAN | Lower | *Coronites darsi* | | |
| BARREMIAN | Lower | *Kotetishvilia compressissima* | | |
| BARREMIAN | Lower | *Nicklesia pulchella* | | |
| BARREMIAN | Lower | *Kotetishvilia nicklesi* | | |
| BARREMIAN | Lower | *Taveraidiscus hugii* auctorum | | |

**Table 2.** Ammonite zonation of the Barremian-Albian stages.

Tables from REBOULET, ST., HOEDEMAEKER, P.J., AGUIRRE-URRETA, M., ALSEN, P. & al. (20 other authors) 2006. Report on the 2nd meeting of the IUGS lower Cretaceous Ammonite Working Group, the 'Kilian Group' (Neuchatel, Switzerland, 8 September 2005). *Cretaceous Research*, **27**, 712-715.




**Stratigraphic chart** of the Cretaceous sediments of Austria