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347 - 353

THE CALCAREOUS ALPS BELOW THE VIENNA BASIN IN AUSTRIA AND THEIR STRUCTURAL AND FACIAL DEVELOPMENT IN THE ALPINE-CARPATHIAN BORDER ZONE

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Abstract: The bore hole, drilled into the Pre-Neogene floor of the Vienna Basin, brought information about the facies and structure of the Calcareous Alpine units below the Vienna Basin. The Triassic and Jurassic sequences show changes of facies and thickness from north to south similar to the Alpine area. Triassic basin facies turns into a thick platform development toward the south near the frontal part of the Göller Nappe. In the Jurassic period an alternation of narrow longitudinal belts of swells and basin zones took place in the north. Deepening of the basin in the south seems to cause gravitational gliding of Triassic and early Jurassic complexes into allochthonous positions. Neocomian basinal sediments and synclines filled with Albian to Cenomanian sediments are restricted to the northernmost Calcareous Alpine units. The Upper Cretaceous sediments have a typical low thickness in the north (Gießhübl Syncline). The frontal part of the Göller Nappe is characterized by a thick coarse clastic slope development (Prottes). The Glinzendorf Syncline is filled by mostly limnic deposits of probably Coniacian to Maastrichtian age, which cover Pre-Gosau sediments. In the Paleocene period a thick turbiditic sequence in the Gießhübl Syncline points to deep-water sedimentation. The frontal parts of the Göller Nappe advancing at that time, were buried by further Paleocene sedimentary deposition, dating the overthrust event.

The structures of the northern part are narrow, folded and sliced by upthrusting or horizontal displacement. The frontal part of the Göller Nappe shows strong compression, evident by folding and backthrusting of the frontal zone. The southern continuation of the Göller Nappe shows a more rigid style and a relatively flat layering. A deep syncline marks the southernmost part of the Calcareous Alps, and points to strong compressional forces existing also in this part.

Only a few bore holes give information about the extension of Calcareous Alpine nappes downwards. The deep structure and the relationship of some outcropping units to hidden structural elements will be a task for further investigation.

Key words: Calcareous Alpine stratigraphy, Calcareous Alpine structure, Vienna Basin, Alpine-Carpathian correlations.

Introduction

About 220 bore holes, some of them more than 6000 *m* deep, drilled into the Calcareous Alpine base of the Neogene, give evidence of the style, the stratigraphic and facial content of the Alpine-Carpathian units. Some of the bore holes encountered more than 3000 *m* of Calcareous Alpine section and provided a three dimensional view in distinct areas within the basin and lead to a better understanding of the outcropping Calcareous Alpine-Carpathian structure also. Additional information on Alpine-Carpathian geodynamics and timing of the tectonic events was obtained.

An exploration of the deepest part of the Calcareous Alpine section by drilling has not been achieved up to now. Interpretations of deep seismic indications are hypothetical at the moment. For several units of the Calcareous Alps the continuation from one part of the Vienna Basin to the other has been proved (Fig. 1). However, some of them disappear below the basin, and others mapped on surface have not been found or identified till now in bore holes. An important task remains also in correlating the different troughs of Cretaceous and Paleogene sediments: the Gießhübl Syncline, the Prottes Gosau, the Glinzendorf Gosau, the Gosau of the Brezová Depression, the Studienka Gosau.

The Calcareous Alpine floor below the Vienna Basin plays an important role in exploration for hydrocarbons. About 10 partly major gas- and oilfields were found in Austria and Czecho-Slovakia up to now. The opportunity for favourable fracture porosity in generally, a thick carbonate platform and the position of the Calcareous Alpine section just above the large hydrocarbon source potential in the allochthonous floor of the Vienna Basin encourage further geologic and seismic investigations. From this point of view this report has to be seen as a preliminary one, but can be used as a model for further investigations and confirmation of geological ideas.

Stratigraphic overview

In the Triassic a low thickness of all members in the north and an increasing toward the south can be observed (Fig. 2). This is caused by an absence of Permo-Skythian in the north and a more complete development in the south, a southward changing of Middle to lower Upper Triassic basin facies to a thick platform facies, and an integration of the Carnian Lunz Beds into the carbonatic platform sequence in the highest nappes. The thin, in the north terrigenous influenced Hauptdolomite gets considerable thickness toward south and changes to Dachstein Lo-

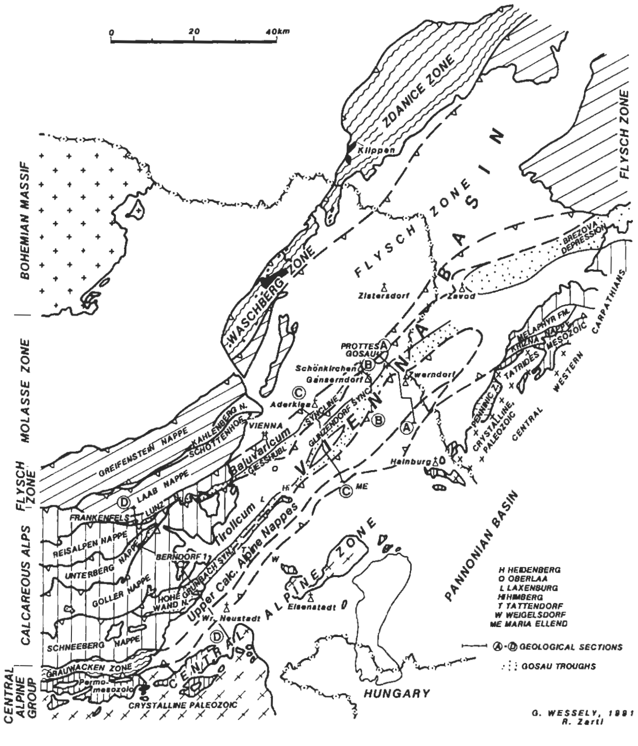

Fig. 1. Alpine-Carpathian tectonic units in the Vienna Basin area.

ferite and reef facies. The basinal Hallstatt facies is only represented by sliding blocks in the Jurassic sequence of the Tirolicum. The Keuper in the Central Alpine Semmering series shows its continental northern position with respect to the Calcareous Alps.

The Jurassic sequences (Fig. 3) of the Frankenfels-Lunz Nappe (Bajuvaricum) differ in many cases from those of the Göller Nappe (Tirolicum). The general feature of the Liassic is a differentiation in facies belts, relatively constant in striking. Upon Rhaetian beds the northernmost belt of the Bajuvaricum contains Liassic basinal facies, which may reach considerable thickness, followed by thin crinoidal limestone. After a transition zone this swell facies passes into a basinal facies. This facies distribution is to be seen in the Aderklaa - Raasdorf area (Fig. 3) as well as in the Schönkirchen area. A further possible belt of crinoidal facies is finally followed by a thick sequence of basinal Allgäu Beds in the Tirolicum

A thin pelagic facies in the Dogger of the Bajuvaricum is replaced in the Tirolicum by breccias and block sedimentation pointing to a Jurassic slope (Wittau ÜT 1, Fig. 5, section C). Large olistolites of Middle Triassic Steinalmkalk, Upper Triassic Hallstatt Limestone, Rhaetian and Liassic marly limestones were encountered in the Jurassic of the Tirolicum of Zwerndorf T1 (Fig. 5, section A).

Radiolarites form a general marker at the base of Malm in all tectonic units, thickenning toward the south.

Thin pelagic variegated Middle and Upper Malm limestones in the Bajuvaricum are represented by thick Oberalm Beds in the Tirolicum.

The different Jurassic facies types are represented by charac-

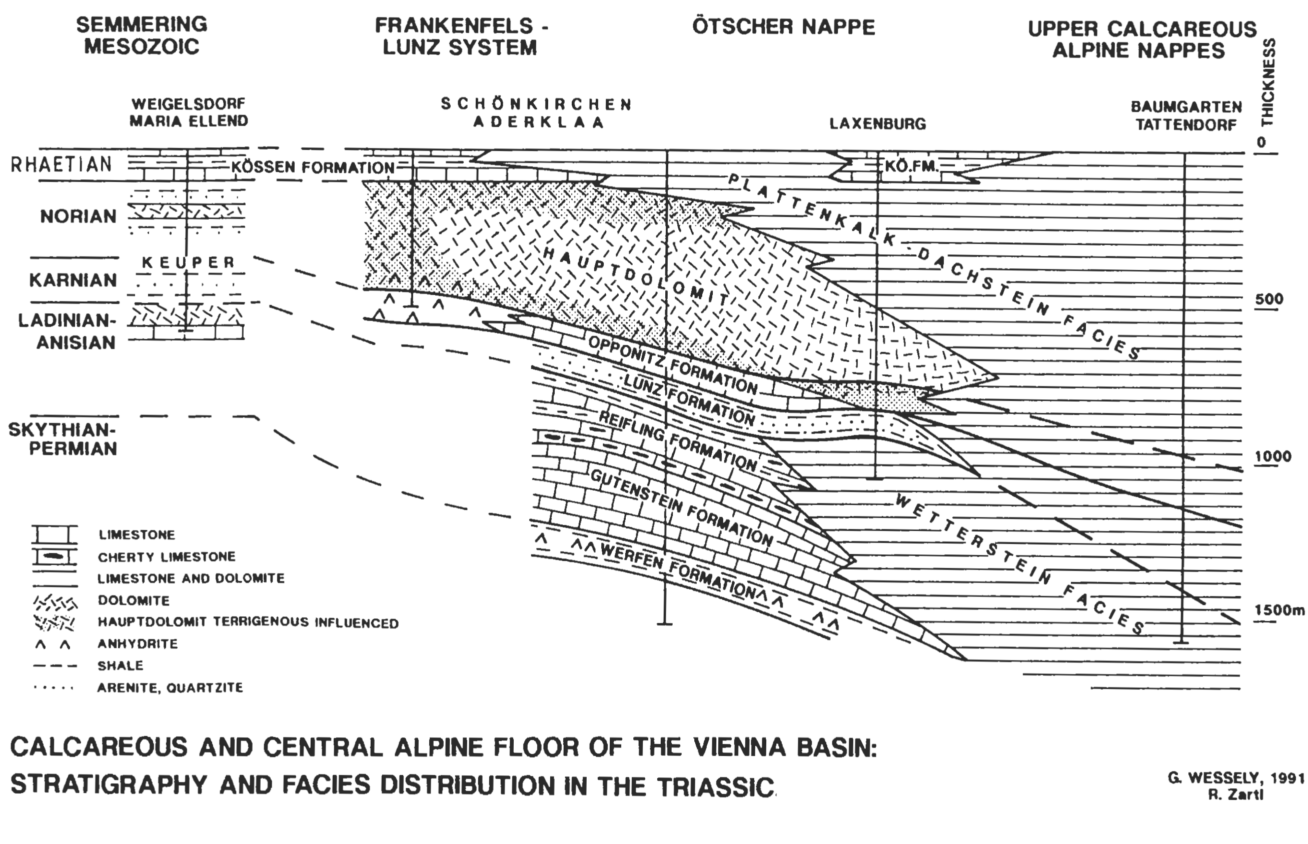

Fig. 2. Calcareous and Central Alpine floor of the Vienna Basin: stratigraphy and facies distribution in the Triassic.

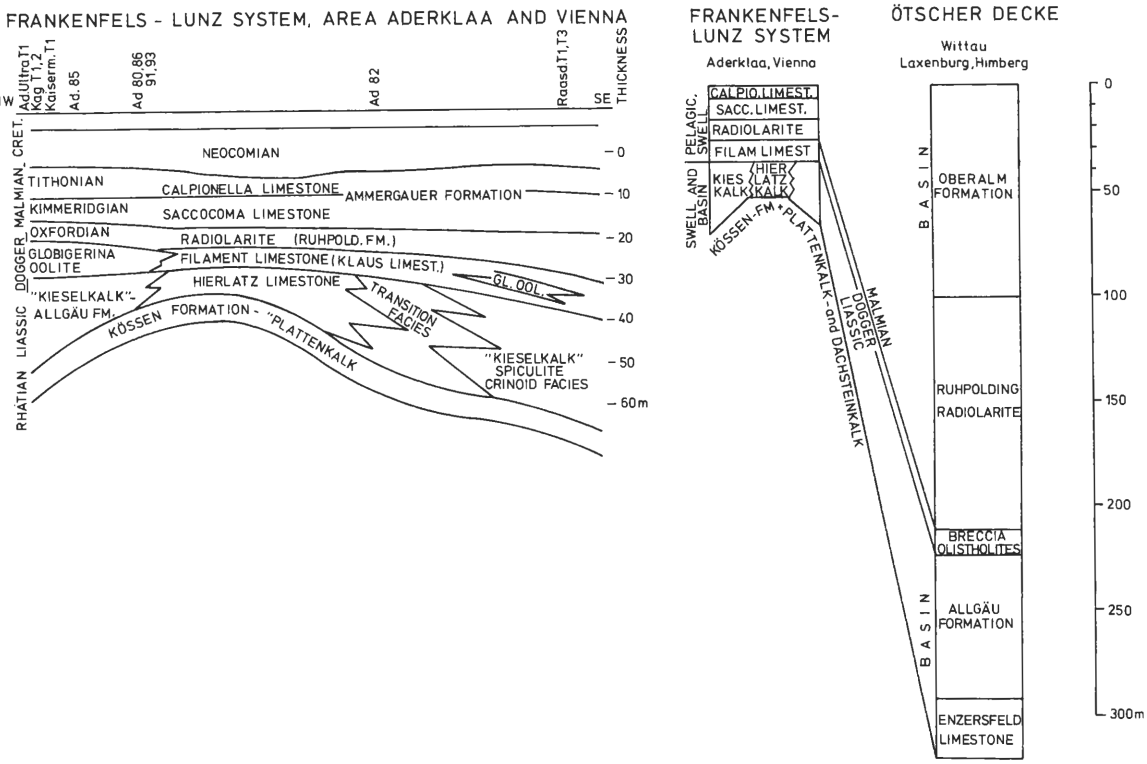

Fig. 3. Calcareous Alpine floor in the Vienna Basin: stratigraphy and facies distribution in the Jurassic.

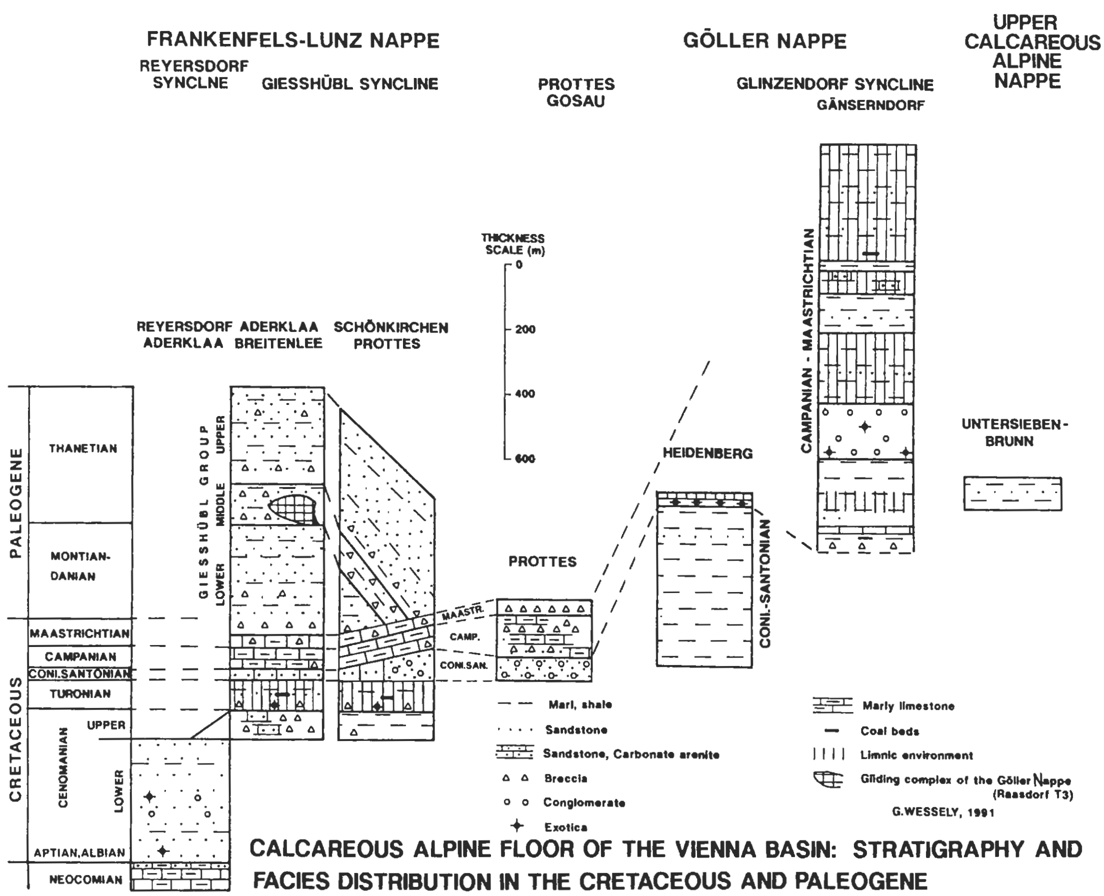

Fig. 4. Calcareous Alpine floor in the Vienna Basin: stratigraphy and facies distribution in the Cretaceous and Paleogene.

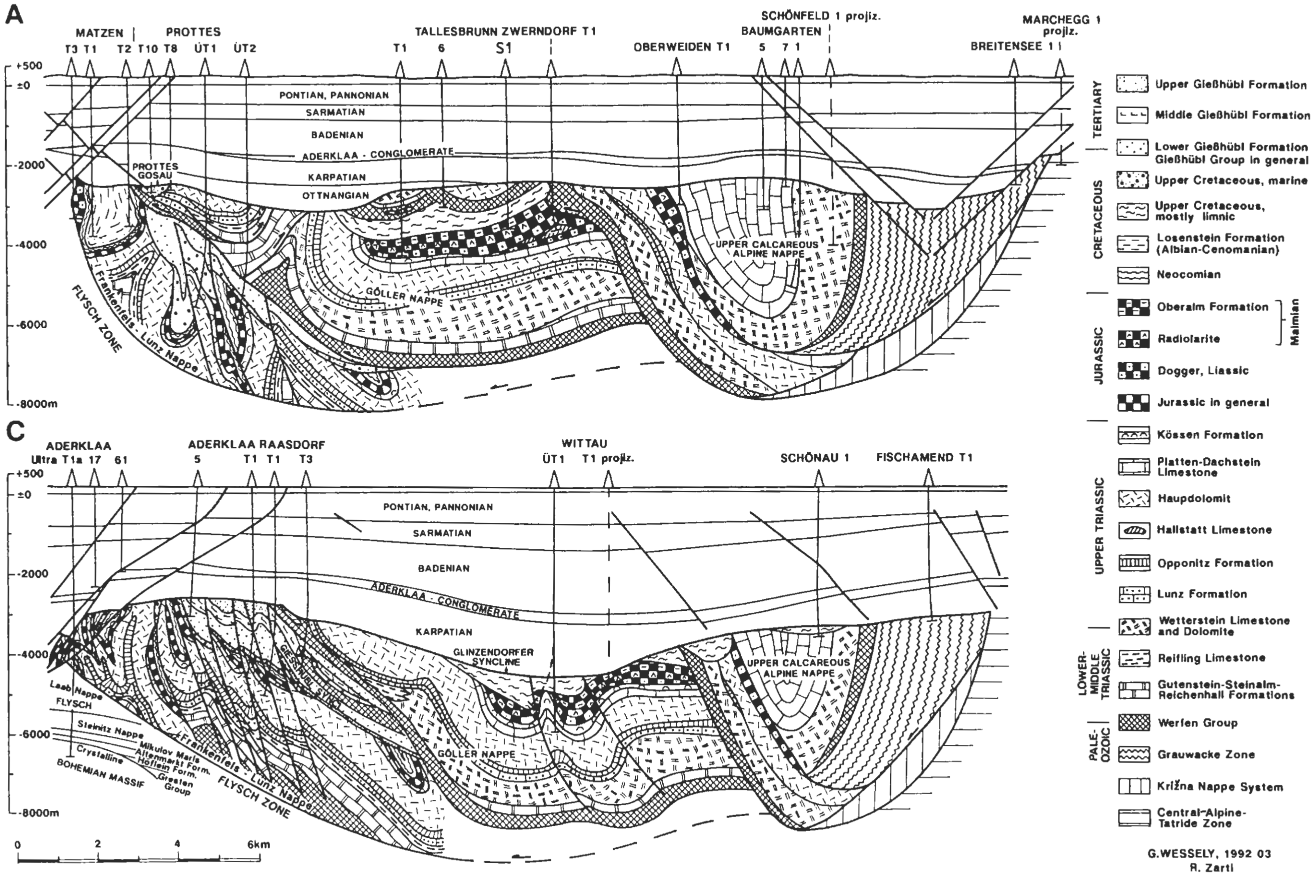

Fig. 5. Geological section Prottes - Marchegg (A). Geological section Wittau - Fischamed (C).

teristic microfacies assemblages. Spiculites (Allgäu Beds, Kieselkalk) and concentrations of crinoids (Hierlatzkalk) occur in the Liassic, filament limestones of Globigerina oolites in the pelagic Dogger, cherty limestones with abundant Radiolaria in the lowermost Malm, Saccocoma- and Calpionella limestone in the middle and upper pelagic Malm and a radiolaria-spicules assemblage with typical rounded rhaxa in the Oberalm Beds.

Neocomian marly spotted limestones, typical in the Bajuvaricum are not really known in the Tirolicum.

Considering the Cretaceous sections of the different tectonic units (Fig. 4) Albian - Cenomanian frontal synclines were filled with clastic sediments including exotic components. It seems, that the late Cenomanian sedimentation lasted longer in the southern pars of the Bajuvaricum and formed a transgression there. No interruption is to be seen towards the Upper Cretaceous. In the Gießhübl Syncline limnic Turonian, thin Coniacian to Santonian carbonatic biodetritic sandstones and finally thin pelagic Campanian variegated marly limestones, poor in clastics, with abundant Globotruncana, follow.

Upon the front of the Göller Nappe, the Coniacian, Santonian and Campanian show a more coarse clastic habit, in connection with an increasing thickness. This points to a slope character and differs therefore from the Gießhübl Gosau.

Marine grey marls of Coniacian to Santonian age were encountered by the bore hole Heidenberg 1 most probably in the northernmost position of the Glinzendorf Syncline

The main area occupied by thick Gosau sediments of the Glinzendorf Syncline is the middle and southern part of the Tirolicum. The sediments show a mostly limnic facies. Sporen and pollen point to Santonian to Maastrichtian age. Some marine ingressions give further stratigraphic hints in the form of foraminifers (assemblages of Globotruncana) and nannofossils. it seems, that a lower complex of grey sediments is overlain by a mainly variegated sequence. At the base of the lower complex, conglomerates, coal-beds, shales and thin limestones were deposited. Grey shales and some sandstones form the main part of this lower sequence. The higher, mainly variegated sequence starts in some bore holes (Gänserndorf ÜT 3) with conglomerates, rich in exotic components (mainly quartz porphyre) in a reddish matrix, followed by variegated and grey sections of marls and some sandstone. A marine intercalation within this section in Gänserndorf ÜT 3 contains Maastrichtian Globotruncanas.

In the Upper Maastrichtian of the Gießhübl Syncline the deposition of the turbiditic Gießhübl Formation started with basal breccias. The sequences comprise lower, middle and upper Gießhübl Formations, which last until Thanetian. In the middle Gießhübl Formation breccias rich in Lithothamnium are intercalated. Gliding complexes of the northward advancing Göller Nappe are embedded and sealed by the Upper Gießhübl Formation.

Tectonics

In general the Calcareous Alps turned out to be a rootless mass above the Flysch and Central Alpine Tatride Zone (Fig. 5). Aderklaa ÜT 1 showed them above Flysch. In the southern Vienna Basin they were found above Grauwacke Zone and

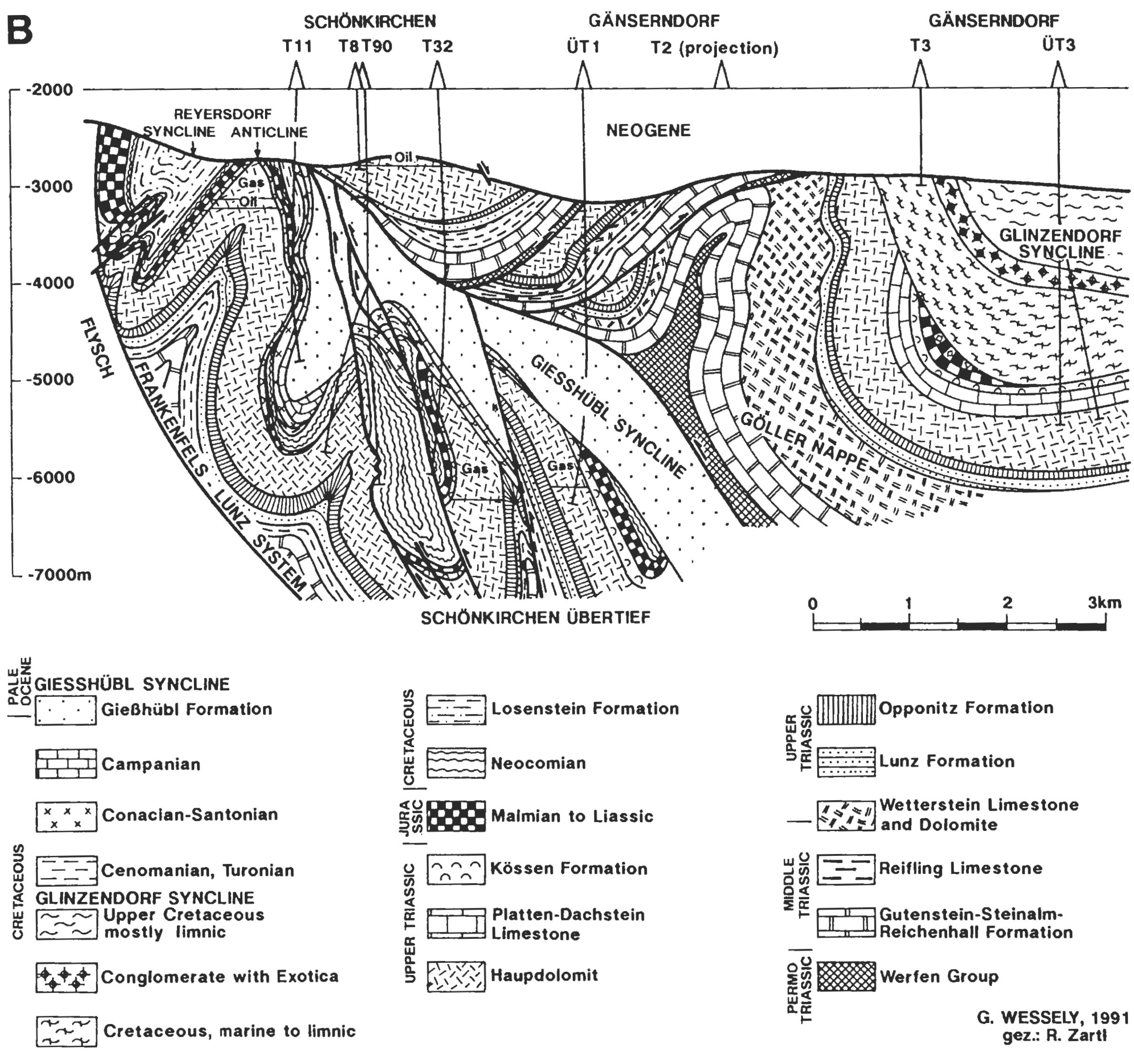

Fig. 6. Geological section Schönkirchen - Gänserndorf (B).

Grauwacke Zone was found above Semmering Mesozoic.

In particular all sections between the western border of the Vienna Basin and the Austrian Czecho-Slovak boundary (Figs. 5, 6) illustrate the internal structural subdivision into a nappe system consisting of Bajuvaricum (Frankenfels-Lunz Nappe), Tirolicum (Göller Nappe) and the highest Calcareous Alpine nappe (Kröll & Wessely 1973; Wessely 1973, 1974, 1984).

The Bajuvaricum generally shows a strong folded and sliced structure as characterized by Hamilton et al. (1990). A significant feature, especially in the Schönkirchen area, is the deep trough of the Albian - Lower Cenomanian, Losenstein Formation exclusively developed in the frontal zone of the Calcareous Alps. An intra to Pre-Cenomanian movement led to this deformation.

These strongly deformed structures are discordantly overlain by Upper Cretaceous and Paleocene (Fig. 6). The main unconformity seems to be located in the Cenomanian. Although gaps in the following Upper Cretaceous - Paleogene sections are locally common, this sequence shows no significant interruption. Steep upthrust affects the whole section of the Bajuvaricum. They do not continue into the Göller Nappe. Most probably they have a strike slip component indicated by facial reasons. In the Aderklaa region, the interference between thrusting of the Göller Nappe and sedimentation of the Gießhübl Formation is documented (Fig. 5, section C), pointing to a syn-Paleocene overthrust of the Göller Nappe: an advancing gliding complex of Permo-Scythian and Middle Triassic beds and some Gosau of the Göller Nappe advanced over lower Gießhübl Beds and was covered again by upper Gießhübl Beds which were overthrusted later by the main complex of the Göller Nappe.

Upon the front of the Göller Nappe, in the Prottes area, the trangression of Gosau is preserved showing a slope facies, with a thickness diverging against the frontal thrustline (Fig. 5, section A).

Anywhere in the south this Coniacian to Campanian member may be connected with the Gießhübl Gosau.

The overthrust of the Göller Nappe in its frontal part mostly shows complicated deformations, partly duplications. Strong compression in the Schönkirchen - Prottes area caused backthrusting and backslicing, in which the Hauptdolomite syncline of Schönkirchen Tief is involved (Fig. 6). The backthrusting happened along a steep anticline with Permo-Trassic and Middle Triassic in its core, proved by the bore hole Gänserndorf T 2. The fold, which may act as a buffer, coincides with the change of Middle Triassic basin facies (Reifling Formation) to the thick, rigid Wetterstein Formation.

Southward flatening and even a southward rise of layers and more undisturbed conditions are observed, and also a deposition of thick Jurassic sediments covered by the Upper Cretaceous Gosau of the Glinzendorf Syncline. The Glinzendorf Syncline, which seems to have a very differentiated structure and which may be compared with the Grünbach Syncline is delineated by several bore holes, at least by Gänserndorf ÜT 3 (Fig. 6).

Olistolites of Triassic southern facies of the northern Calcareous Alps are signs of the Jurassic event, perhaps in connection with halokinesis of Permo-Triassic evaporites. They were found in Zwerndorf T 1 (Fig. 5, section A).

The tectonic relationship between the Tirolicum and the highest Calcareous Alpine part is not completely clear. Most probably between the northern, main part of the Tirolicum, and the upper Calcareous Alpine nappe a thrust slice exists (Fig. 5). The bore hole Oberweiden T 1 found Jurassic below Lunz Beds, which could be roof of this thrust slice. Its base forms the outlier of Tallesbrunn, consisting of Permo-Skythian beds and Upper and Middle Triassic platform carbonates.

The uppermost Calcareous Alpine nappe is a deep syncline of thick Dachstein Limestone and Wetterstein Dolomite encountered mainly by the Baumgarten bore holes. As well as pre-Gosau tectonics, a strong post-Gosau compression must be assumed, if we consider the outlier of Tallebrunn which has been thrust over the Glinzendorf Gosau a nd the steeply folded syncline of Baumgerten.

The deeper geological sections have to be drawn, the more hypothetical is their construction. A triangle zone is assumed to exist approximately below Zwerndorf T 1 (Fig. 5), because of the southward rise of the Tirolicum and the proven deep position of the Baumgarten Syncline. It seems, that this deep seated buffer forms a ramp, which has been overwhelmed by the Tirolicum. The southern Calcareous Aline units were stopped by the ramp. A continuous connection of the lowermost Calcareous Alpine units, which form the northernmost frontal part (Frankenfels-Lunz Nappe) and southermost zone (Krížna Nappe) is not probable. In the Berndorf bore hole at the western basin border no Bajuvaricum exists (Fig. 7). If we combine the Austrian Grauwacke Zone with the highest Calcareous Alpine units into one stratigraphic sequence, it must cover deeper Calcareous Alpine-Carpathian units.

Correlation of the Austrian and Czecho-Slovak sections

Camparing the Austrian sections with the Czecho-Slovak sections (Wessely 1975; Jiříček 1984; Kysela 1988; Hamilton et al. 1990), we find a distinct similarity in the style.

The facial indications suggest, that the Subtatric units, appearing in the Malé Karpaty Mts as the Krížna Nappe system (Plašienka et al. 1991) and the Bajuvaricum, represented by the Frankenfels-Lunz Nappe belong to the same tectonic system. According to the more continental Keuper facies in the Krížna Nappe system and the lagoonal facies (mostly Hauptdolomite) in the Frankenfes-Lunz system, it seems, that the Krížna Nappe system in the Malé Karpaty Mts. is the former frontal part of the Bajuvaricum, which has been left behind during Alpine thrusting.

The Tirolicum below the Vienna Basin forms the main complex in a similar behaviour in both regions: flattening and even inclining toward north. The position of the highest nappes is also similar in both regions. The Alpine type of the Grauwacke Zone is not found in the Carpathians, it may disappear within the Vienna Basin.

The Paleozoic of the Melaphyr series shows another facies than the eastern Grauwacke Zone.

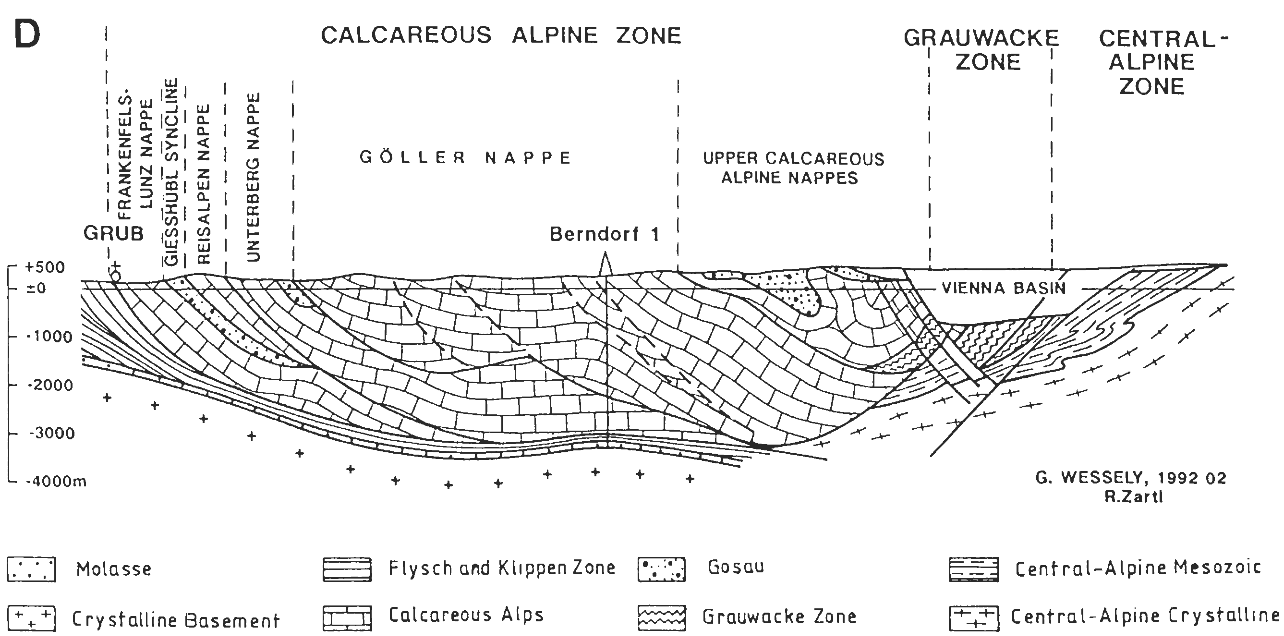

Fig. 7. Geological section Berndorf (D).

A comparison of Gosau focusing on facies may lead to a correlation of the Prottes Goasu with the Brezová Gosau.

'The Gießhübl Syncline may be expected perhaps in a rudimentary form below the middle Calcareous Alpine units in the Slovak region. A correlations of the Gießhübl Gosau with the Brezová Depression and Gosau Beds encountered in the Slovak part of the Vienna Basin (Studienka, Závod) would require a drastic change in facies and thickness of the upper Cretaceous and, to a distinct degree, also the Paleocene sections, along the striking of equivalent tectonic units.

Continued integrated investigation of logs, cores and outcrops will enable further correlations in this instructive part of the Alpine-Carpathian thrustbelt.

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