Northern Calcareous Alps and Meliata-Zone south of Vienna
Vienna Water Supply

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Short Notes on the Geology of the Northern Calcareous Alps (NCA)

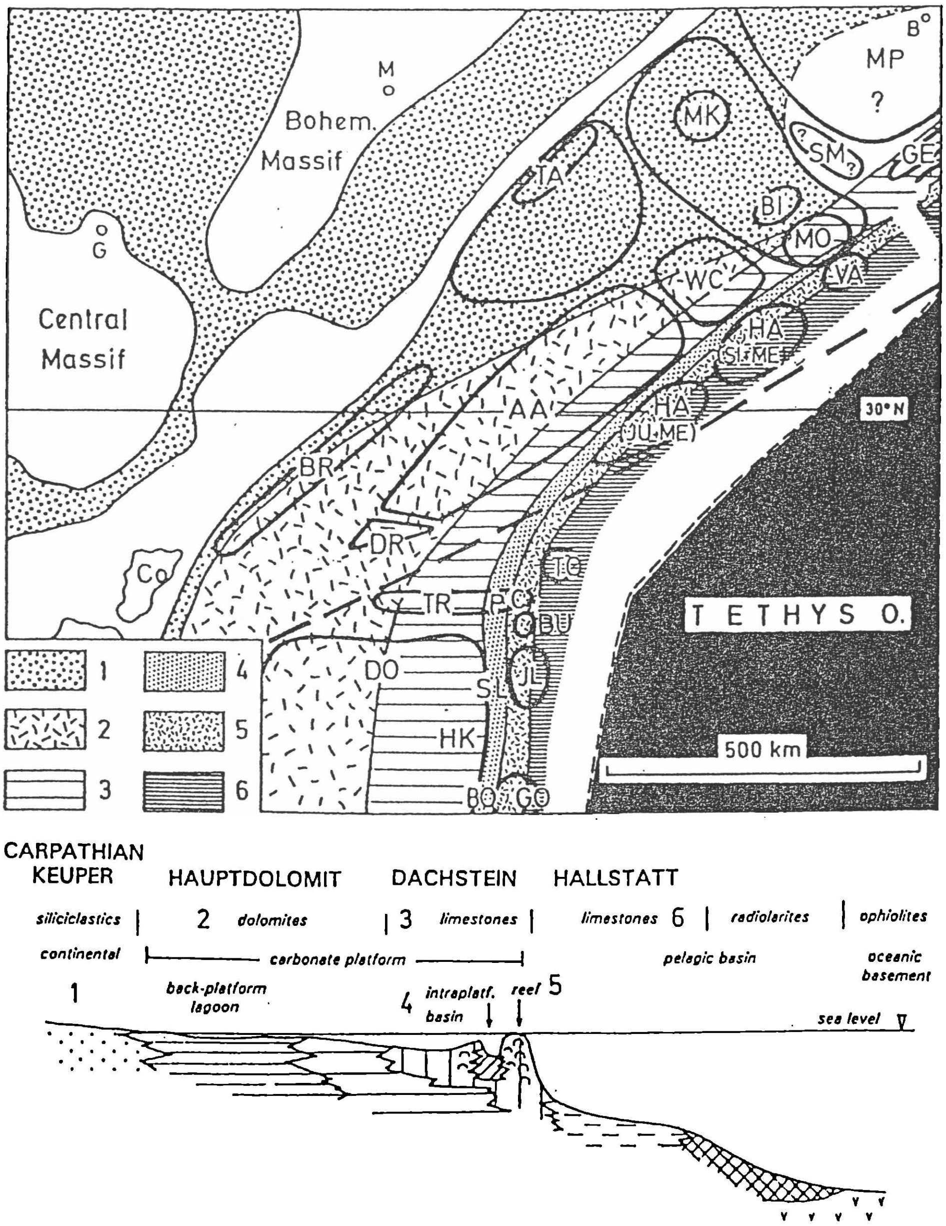
Introduction

One of the most promenent units of the Eastern Alps are the Northern Calcareous Alps, which extend for about 500 kilometers from the Rhine valley in the west to Vienna in the east, forming a 20 to 50 kilometer wide belt. At its eastern end it is bounded by the Vienna Basin, which subsided during Neogene times. In the basement of the Vienna Basin, however, the NCA continue in principle into equivalent units of the Western Carpathians even if the details are still in discussion. For example the uppermost tectonic units of the NCA - the Juvavic Nappe System - end in the Slovakian part of Vienna Basin with a last occurence of Hallstatt Limestone at drillhole Zavod 1. Equivalent units occure again only far in the east of the Western Carpathians (Stratena-, Muran-, Silica-, Aggtelek- and Rudabanya-Mountains) - KOVACS 1984, KOVACS et al. 1989, KOZUR 1991, KOZUR & MOCK 1987, MOCK 1980.

The NCA consist of mountain ranges with considerable plateau mountains, the latter being a remnant of the older Tertiary peneplain, faulted and partly uplifted in the (late) Miocene. In the western and middle part the highest peaks reach altitudes of up to 3.000 meters and are locally glaciated. In the eastern part elevations are up to 2.000 meters - for example Schneeberg (2.076m), Rax (2.007 m), Schneealpe (1.903 m), Veitsch Alpe (1.981 m), Hochschwab (2.277 m).

In the NCA Mesozoic carbonates are predominating, but also clastic sediments are frequent. The sequence begins in the Permian and extends locally into the Paleogene (Gosau Group), but the Triassic rocks are the most prevailing ones, details see below.
Apart from slightly metamorphosed beds at the basis - mainly within the siliciclastic Permo-Skythian rocks - it was assumed that the NCA do not exhibit any metamorphic overprint - see KRALIK et al. 1987 . Investigations of Conodont Color Alteration Index during the last years have reveiled a considerable thermal event in parts of the Juvavic nappes, predating the oldest (Late Jurassic) overthrusts - GAWLICK et al. 1994, KOZUR & MOSTLER 1992 , MANDL 1996.

Today there is a common agreement that the NCA depositional realm during the **Permotriassic** was a passive continental margin between Variscian (=Hercynian) consolidated „Europe" and the Tethys ocean. That part of the ocean that bordered the NCA and the Western Carpathians is also named „Hallstatt-Meliata-Ocean" by KOZUR 1991 and it is thought to be closed by plate tectonics during Jurassic times. The position of this geosutur in the today visible nappe stack as well as the original arrangement of the tectonic mega-units to each others is still a matter of discussion and major disagreement - HAAS, KOVACS, KRYSTYN & LEIN 1995, KOZUR 1991, KOZUR & MOSTLER 1992, SCHWEIGL & NEUBAUER 1997, TOLLMANN 1976, 1981.



GENERAL OVERVIEW
(HAAS et al. 1995)

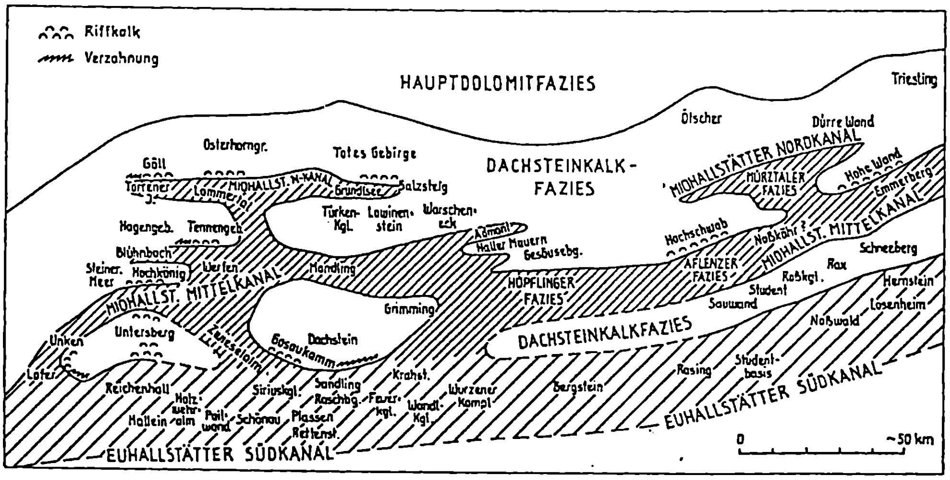
G Geneve
M Munich
B Bucharest

AA Austroalpine
BR Briançonnais
DR Drauzug
HA Hallstatt
JU Juvavicum

TA Tatricum
WC Central Western Carpathians
SI Silicicum
ME Meliaticum
TO Tornaicum
TR Transdanubian Central Range
BU Bükk

DO Dolomites
HK High Karst
SL Slovenian trough
JL Julian Alps
BO Bosnian trough
GO Golia zone

MK Mecsek
BI Bihor
MO Moma unit
VA Vascau unit
MP Moesian platform
SM Serbo-Macedonian unit



PALAEOGEOGRAPHY
OF THE HALLSTATT REALM
(TOLLMANN 1981)

Hauptdolomit facies

Dachstein carbonate platform

Intraplatform Hallstatt facies =
Miohallstatt channels

Isolated Dachstein platforms

Hallstatt facies s.str.=
Euhallstatt channel

Fig.1: Palaeogeographic models of the Austroalpine Realm in Late Triassic time.

Beginning in the **Jurassic** the Austroalpine realm (including the NCA) became separated from its european hinterland by the birth of the transtensional basin of the **Penninic Ocean**, which was linked by large transform faults with the opening of the Northern Atlantic Ocean. Subduction processes at the southern margin of this Penninic Ocean started in the **Cretaceous**, causing heating and deformation within the Austroalpine basement and nappe movements in its sedimentary cover. For details of metamorphic evolution of the Eastern Alps and controversial discussions see FRANK 1987.

Upper Cretaceous clastic sediments of the **Gosau-Group** transgressed after a periode of erosion over the NCA nappe stack. The sediments of the Gosau-Group show a facies change from the south toward the north, from shallow water clastics to flysch-like deep water sediments. The latter ones are also typical for the adjacent Penninic troughs, where beside other structural units the **Rhenodanubian Flysch Zone** originates from.

Ongoing subduction of the Penninic realm toward the south below the Austroalpine units led to the closure of the Penninic Ocean. The sediments of the Rhenodanubian Flyschzone became deformed, lost their oceanic basement (only preserved in form of some Klippen) and became partly overthrusted by the nappes of the NCA, beginning in the late Eocene.

The remaining sea between the alpine orogenic front and the european foreland was during **Oligocene** and **Miocene** the depositional site of the **Molasse Zone**, which one collected the erosional debris of the uplifting Alps. The southernmost part of the Molasse Zone became also incorporated into the alpine orogeny due to the youngest subduction pulses.

The large scale overthrusts of NCA, Flysch Zone and Klippen over Molasse Zone and European Foreland (Crystalline Basement of the Bohemian Massive with autochthonous sedimentary cover) is proved today by several drillings, which reached the basement in depth of about 3.000 to 6.000 meters - see Fig.11.

The uplift of the central part of the Eastern Alps in Miocene was accompanied by large strike slip movements on its northern side (sinistral Salzach-Ennstal- and Mur-Mürz-fault systems; responsible also for the genesis of the Vienna Basin)) and on its southern side (dextral Periadriatic fault system) - see for example DECKER et al. 1994.

Permotriassic Stratigraphy and Facies (Eastern NCA)

The sedimentary sequence of the NCA starts in the **Permian** with continental red beds, conglomerates, sandstones and shales of the **Prebichl Formation**, transgressiv overlaying the Lower Paleozoic rocks of the Greywacke Zone (Noric nappe). The Permian age is assumed due to local intercalations of acid tuffs and pebbles of quartzporphyr, which are widespread in the European Permian (Saalic tectonic phase). A marine facies of Permian sediments is the so called **Haselgebirge**, a sandstone-shale-evaporite association, containing gypsum and salt. This facies is frequent in the Juvavic units, for example in the open pit gypsum mine near Puchberg/Schneeberg, we will pass by between excursion stop 6 and 7. The Upper Permian age is proved paleontologically by pollen/spores at several localities and confirmed by sulfur isotopes.

The **Lower Triassic** is characterized by uniform shallow shelf siliciclastics of the **Werfen Formation**, containing limestone beds in its uppermost part with a poor fauna including Scythian ammonoids.

In the **Middle Triassic** carbonate sedimentation became dominant. The dark **Gutenstein Limestone/Dolomite** is present in most of the NCA nappes. It can be laterally replaced in its upper part by lightgrey dasycladacean bearing carbonates, the **Steinalm Limestone/Dolomite**. During the Middle Anisian a rapid deepening and contemporary blockfaulting of the so called Reifling

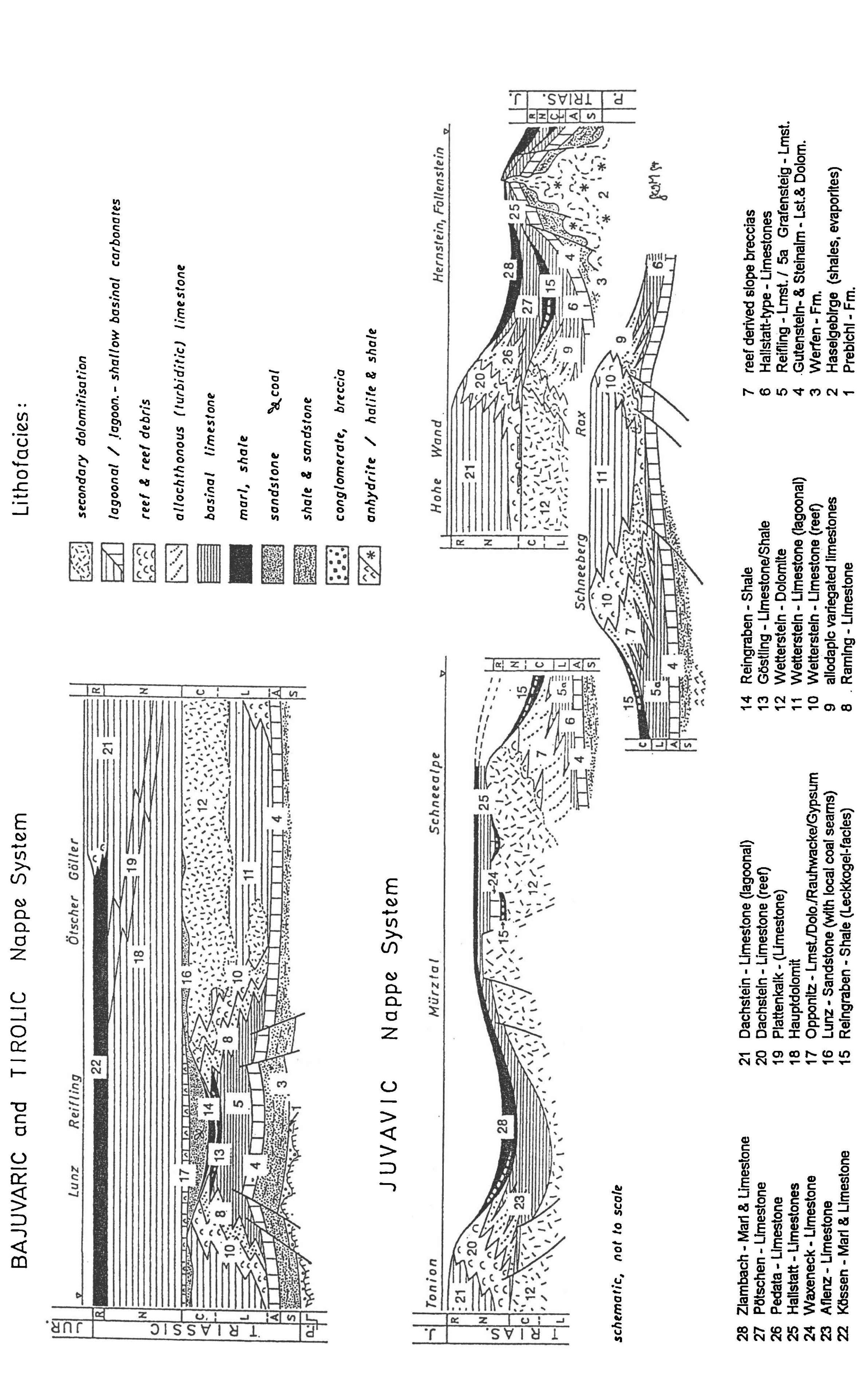


Fig. 2: Triassic Stratigraphy and Depositional Realms of the eastern NCA.

event caused a sea floor relief, responsible for the following differentiation into shallow carbonate platforms (**Wetterstein Formation** and lateral slope sediments) and basinal areas. The latter ones can be distinguished into the **Reifling** Basin, local intraplattform basins of **Grafensteig Limestone** type and the **Hallstatt** basin, bordering the open Tethys. The transition from the Hallstatt deep shelf into oceanic conditions with radiolarites is not preserved in the NCA. We have hints on the existence of such an oceanic realm only in form of olistolites of Ladinian **red radiolarite** in the **Meliata Klippes** at Florianikogel and Ödenhof.

The Wetterstein platforms in general show a platform progradation over the adjacent basinal sediments until the Lowermost Carnian („Cordevolian"). Then carbonate production decreased rapidly due to a sealevel lowstand. The platforms emerged, the remainig basins received siliciclastics from the European hinterland. The Reifling basin has been filled completely by marine black shales (**Reingraben shale**) and marin to ?brackish **Lunz Sandstone**, containing coal seams. The intraplatform basins and the Hallstatt realm toward the south received also finegrained siliciclastics (Reingraben shale) interbedded with dark cherty limestones and local reef debris (**„Leckkogel facies"**), derived from small surviving reef mounds at the basin margins.

As sealevel started rising up again in the Upper Carnian, rather slowly in the beginning, carbonate production increased, locally filling a relief in the drowning platforms with lagoonal limestones (**Waxeneck Limestone**). The relief (several 10th up to about 100 meters) may be caused by erosion during the lowstand time and /or by tectonic movements. More toward the north, in the Lunz - Reifling area, partly hypersalinar conditions led to the deposition of limestones and dolomites with evaporitic (gypsum) intercalations (**Opponitz Formation**).

A transgressive pulse just below the Carnian/Norian boundary caused an onlap of pelagic limestones over the shallow water carbonates and initiated the rapid growth of the Norian carbonate platform. Due to local differences in platform growth conditions we can distinguish two different developments. In the central part of the NCA (Hochkönig, Tennengebirge, Dachstein area etc.) and probably also at the Hohe Wand the pelagic onlap was only a short time interval and became covered by the prograding **Dachstein carbonate platform**. In this areas the Upper Triassic reefs approximately are situated above the Middle Triassic ones. An other situation characterizes the Hochschwab - Mürztal area. There the Uppermost Carnian pelagic transgression continues until the Upper Norian and has been termed Mürztal Type of Hallstatt facies by LEIN 1982. Dachstein reefs are only known from the Upper Norian and this ones are situated above the former platform interior, several kilometers away from the Wetterstein reef front. Such a configuration seems to be also typical for the Slovakian karst and the Aggtelek Mountains. This „backstepped" reefs show transitions into the basinal facies of the black **Aflenz Limestone** at the eastern Hochschwab/Aflenz area and at the Sauwand- and Tonion Mountains. In contrary the „Southern Marginal Reefs" of central NCA are connected by the allodapic **Pedata Limestone** to the **Pötschen Limestone** of the Hallstatt facies s.str. The **Hallstatt-Group** shows a great variability of variegated limestones often with only local sedimentary features due to its mobile basement (diapirism) of Permian evaporites - features like breccias and slumpings, fissure fillings, block tilting, sedimentary gaps, condensed faunas, local extruded and resedimented haselgebirge.

Behind the Dachstein reefs a large lagoonal environment extended all over the NCA with **Dachstein bedded limestones** near to the reefs and the intertidal **Hauptdolomit** in distal parts. An intermediate facies between them is the so called Plattenkalk.

In the Uppermost Triassic („Rhaetian") once again increasing terrigenious influx has reduced the carbonate platforms. The Hauptdolomit area and parts of the Dachstein lagoon became covered by the marly **Kössen Formation**, borderd by Rhaetian reefs.

In the Hallstatt realm as well as in the intraplatform basin of Aflenz Limestone the marly **Zlambach Formation** has been deposited onlapping and interfingering with the Dachstein platform slope.

In the Jurassic the Austroalpine shelf drowned completely, basinal conditions prevailed until the Lower Cretaceous with the only exception of local Plassen carbonate platforms (Upper Malmian) in parts of the realm of the Juvavic nappes. Irregular drowning and synsedimentary faulting caused an complex seafloor topography with red crinoidal and ammonoid limestones on intrabasinal highs and grey marly/cherty limestones in the troughs between. The greatest water depth has been reached in Oxfordian, characterized by widespread radiolarite deposits.

Tectonic style of the southeastern NCA

The pile of Mesozoic sediments of the NCA has lost its former crustal basement during alpidic orogeny and rests with overthrust contacts in the north on the Rhenodanubian Flysch Zone, in the south on the Greywacke Zone.
The latter contact was matter of long lasting controversial discussions: on the one hand there is a transgressive contact of Permo-Skythian clastics over Lower Palaeozoic rocks of the Greywacke Zone visible, on the other hand the Skythian clastics (Werfen Fm.) are followed by Middle Triassic carbonates. Many authors have seen here an undisturbed sedimentary sequence. Local missing members of the sequence have been explained by only minor thrusting. Other authors - for example TOLLMANN 1976, 1981, 1985 - claimed that this sedimentary contact is only a virtual one. They postulated a major overthrust, separating the Permoskythian of a Tirolic nappe origin from carbonates of the Juvavic nappe system. New mapping of this southern margin during the 1980ies brought the evidence for this tectonic concept. The overthrust plane is marked by slices and small Klippe-like bodies of tectonized rocks of the Hallstatt realm and - at two places - of the Meliata realm, details well be given at excursion stop 1, 5 and 6.

The following nappe scheme can be given today - see also Fig. 11:
The northern (=frontal) part of the eastern NCA is built by the **Bajuvaric** Lunz-Frankenfels nappes, which one show narrow synclines and anticlines. They dip down toward the south below the overthrusted **Tirolic** nappe system of Reisalpen-, Unterberg- and Göller nappes. Due to their widespread dolomitic lithology the Tirolic nappes exhibit internal thrusting and faulting and only minor folding. The **Greywacke Zone** is thought to represent the Palaeozoic sedimentary substratum of the Tirolic nappes, remaining several kilometers in the south during the nappe movements. The **Juvavic** nappes represent the uppermost tectonic element, overlying the Tirolic Mesozoic in the north and the Greywacke Zone with its Tirolic transgressiv Permoskythian in the south. The former used terms „Lower" and „Upper" Juvavicum seem to be not useful anymore. They had a mix facial and tectonic meaning: „Lower" means pelagic Hallstatt facies and a tectonic position below the „Upper"Juvavic carbonat platform of Wetterstein-/Dachstein facies. Recent mapping has shown that just the opposite also is possible and is not rare.

Due to the fact that sediments younger then Triassic are rare in the southeastern NCA it is difficult to reveal the timing of the multiple tectonic events.
The concept of Jurassic gravitational nappe movements, which was developed in the central NCA, seems to be also useful in the eastern NCA - see TOLLMANN 1981. The sequence of the Göller nappe ends with the Jurassic Allgäu Fm. and dips down below the Schneeberg Nappe, also visible in the Hengst- and Ödenhof Window. Transgressiv Upper Jurassic like in the Salzkammergut unfortunately is not preserved, therefore the Jurassic movement is only a hypothesis.
The nappe pile has been covered after a long periode of erosion by the clastics of the Upper Cretaceous to Paleocene Gosau-Group. Additional deformation affected the Gosau rocks in form of overthrusting and backthrusting in post-Paleocene times.

The Water Supply of Vienna

Today 97% of Vienna´s water comes from the two Mountain spring aquaeducts, which carry the water from karstic springs in the Northern Calcareous Alps. The remaining 3% is groundwater (Lobau) or surface water from the Wiental supply line, but this one is used during peak times only.

The Early Times

A first aquaeduct has been built by the Romans to bring about 5,000 cbm water per day to their camp of Vindobona from the Anninger area south of Vienna. In post-Roman times this aquaeduct went to ruin.

Later on until the 16 th century the population drew its drinking water from private wells. After a catastrophic fire in the city in 1525 it was decided to built the first municipal water supply line, the *Hernalser Wasserleitung*. It operated from 1565 onwards, carrying about 1,500 cbm water per day from the today´s 17th district area to a well house in the city. There it was distributed by water sellers.

Additional public water supply lines have been completed in 1804 (*Albertinische Wasserleitung*) and in 1841 (*Kaiser Ferdinand Wasserleitung*). An intricate network of piping was laid to allow water to be brought to the homes.

The First Vienna Mountain Spring Aquaeduct

By the middle of the 19th century, each of the 326.000 inhabitants received as little as 4-5 litres of water per day. Inadequately built tunnels, however, caused pollution to the water. The poor quality gave rise to epedemics of typhoid fever and cholera.

In 1864 the Vienna City Council decided - following proposals by the geologist Eduard Suess - the construction of a water pipeline, tapping springs in the Schneeberg-Rax-area. The *Kaiserbrunnen* spring - the water of which has been brought to the Court of Vienna for many years by horses by special water riders - was donated to the citizens of Vienna by Emperor Franz Joseph I. in 1865.

On December 6th 1869 the project started with blasting operations in the Höllental Valley and was finished with a ceremonial inauguration on October 24th 1873.

At that time the aquaeduct carried 138.000 cbm water per day. The system was designed for a transport capacity of 220.000 qbm per day. Therefore later on additional springs have been incorporated into the system:

1887-1910 the springs „upstreams" of Kaiserbrunn,

1965-1969 the *Siebenquellen*, by means of the Schneealpen tunnel (9.68 km lenght),

1986-1988 the *Pfannbauer Quelle*, by means of the Wetterin tunnel (8,1 km), Lärchstein tunnel (2,6 km) and Scheibling tunnel (1,1 km).

Exampels of spring discharge:

Kaiserbrunn:	max.	3,500 l/sec
	min.	200 l/sec
Siebenquellen:	max.	2,000 l/sec
	min	100 l/sec
Pfannbauer Quelle:	max.	400 l/sec
	min.	240 l/sec

Some technical data of the aquaeduct:

Transport capacity: approx. 220.000 cbm/day
Lenght (Kaiserbrunn - Vienna): 90 km
Height difference: 280 m
Flow time: 16 hours
Extended length (Pfannbauer spring - Vienna): 135 km
Height difference (Pfannbauer spring - Vienna): 545 m

The First VMS Aquaeduct is mainly a gravity flow system, i.e. it uses the natural height difference to carry the water to Vienna. Only the water of the Pfannbauer Spring has to be pumped up to about 80 meters to overcome the peak point of the Wetterin tunnel. The power supply for the pumping station is provided by an electric power plant at Hinternaßwald, driven by the aquaeduct water itself; therefore the system is energy autarkic.
The Water Supply Department holds 600.000 cbm of water ready in reservoirs along the First VMS Aquaeduct. In Vienna itself there are 34 additional reservoirs with a total storage of 1.550.000 cbm.

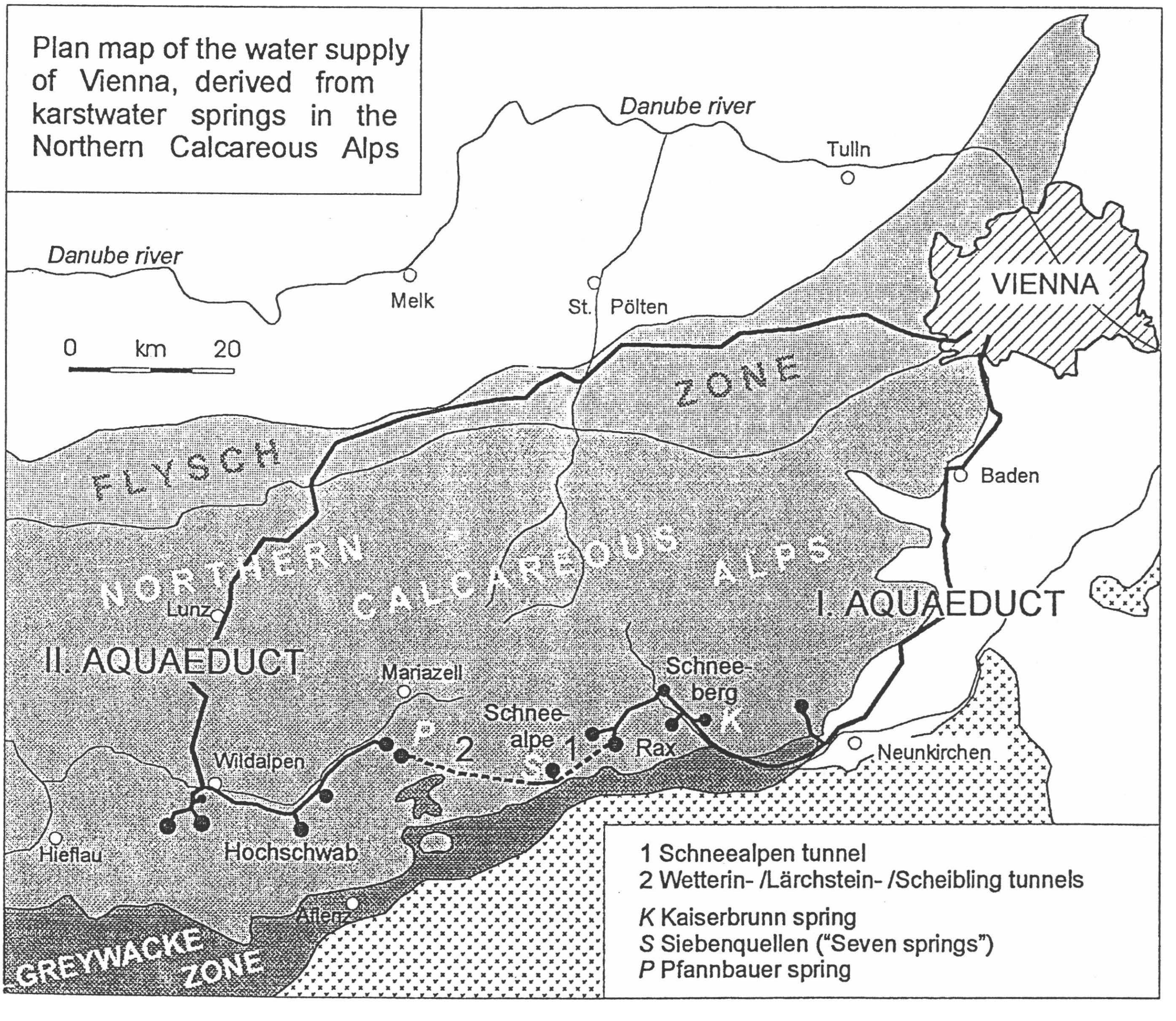


Fig. 3: The System of Vienna Water Supply Aquaeducts.

The Second Vienna Mountain Spring Aquaeduct

The rapid demographic growth of Vienna after 1890 made it necessary to open up new water ressources. Several large karstic springs in the Hochschwab mountains have been selected for that purpose. In 1900 the construction of the second aquaeduct system started. At times as many as tenthousend workmen were employed on the site. On December 1910 the Second Vienna Mountain Spring Aquaeduct was inaugurated.

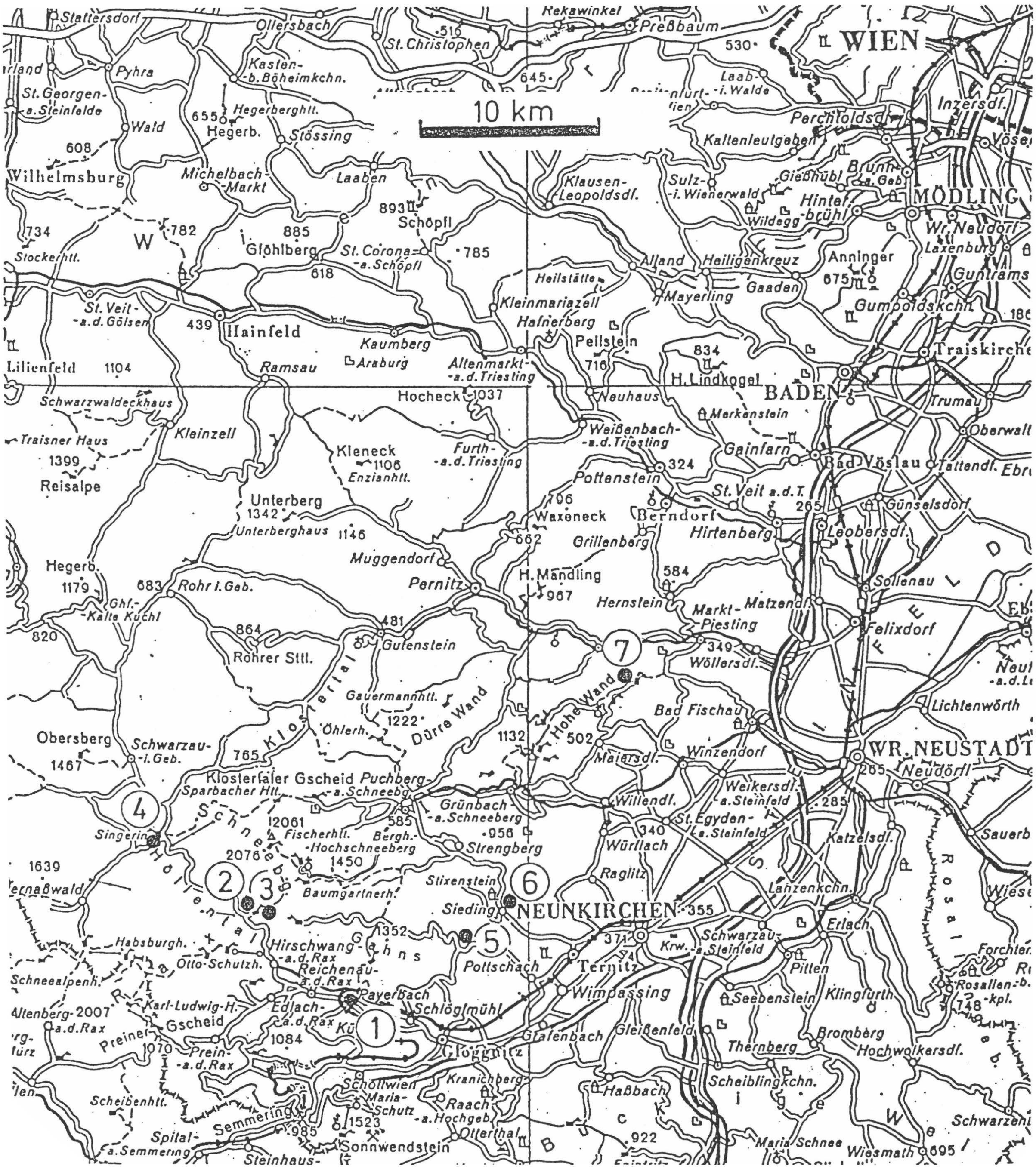
Some technical data:
Transport capacity: approx. 230.000 cbm/day
Total Lenght (Brunngraben - Vienna): 190 km
Height difference (Schreier spring - Vienna): ~ 630 m
Flow time: 36 hours

Geology, Water Quality and Protection

The drinking water of Vienna originates from springs in the Northern Calcareous Alps. The catchment areas are large plateau mountains (Hochschwab, Rax, Schneeberg, Schneealpe) built up mainly by about 1000 meters thick karstified limestones and dolomites of Middle to Upper Triassic age. Underlying siliciclastic shales of Palaeozoic to Lower Triassic age act as a downward barrier. This seemingly simple geometry is complicated by alpine tectonics with large scale overthrusts, folding, block faulting and strike slip faults.
Tectonic stress provided an interconnected network of fractures which became enlarged by karstic solution - especially during tropic climate conditions at Tertiary times. The mountain massives contain a network of solution openings that extends from plateaus and uppermost slopes with large sinkholes to an intervening system of cavities, caves and tubular openings that transmit the surface-water runoff to the valleys below - as for example at Kaiserbrunn. Tracer tests have shown a very rapid flow from sinkholes at the eastern Schneeberg plateau to the Kaiserbrunn Spring - shorter then 16 hours.
Areas with predominance of dolomitic rocks have lower percolation rates, better filtering and storage capacity and a more regular discharge - for example the Pfannbauer Spring.

To minimize the pollution potential the catchment areas of Vienna´s water supply springs have been declared as protected areas in 1965. But it became visible that nature protection is not identical with karst water protection. The complex system climate - vegetation - soil - rock - water may develop under nature protection conditions into a direction which do not meet the requirements of water protection.
Due to this difficulties and additionaly stimulated by the radioactive pollution caused by Tschernobyl in 1986 the Departments for Water Supply and Environment of the Government of Vienna initiated a Karst Research Programm in the 1990ies which is still going on. The research is done by the Geological Survey of Austria, the Speleological Department of the Museum of Nature History, Joanneum Research Graz (Hydrogeology), Versuchs- und Forschungsanstalt Arsenal (Isotope chemistry), various University Institutes (Vegetation, Soil, Water quality) in cooperation with various Departments of the Government of Vienna.

Excursion Program PRE 4



Excursion Route   Stop 1 - 7

Departure Saturday, 29th August 8.00 a.m.
at Vienna , Bus station at City Air Terminal of the Vienna Hilton Hotel
near S-Bahn-/ Underground-Station (Line U3, U4) „Wien-Mitte/Landstraße"

Return to Vienna, University - Althanstraße 14 / GEO-Center at about 18.30.

Possibility for check in at the Congress registration desk (open until 19.00).

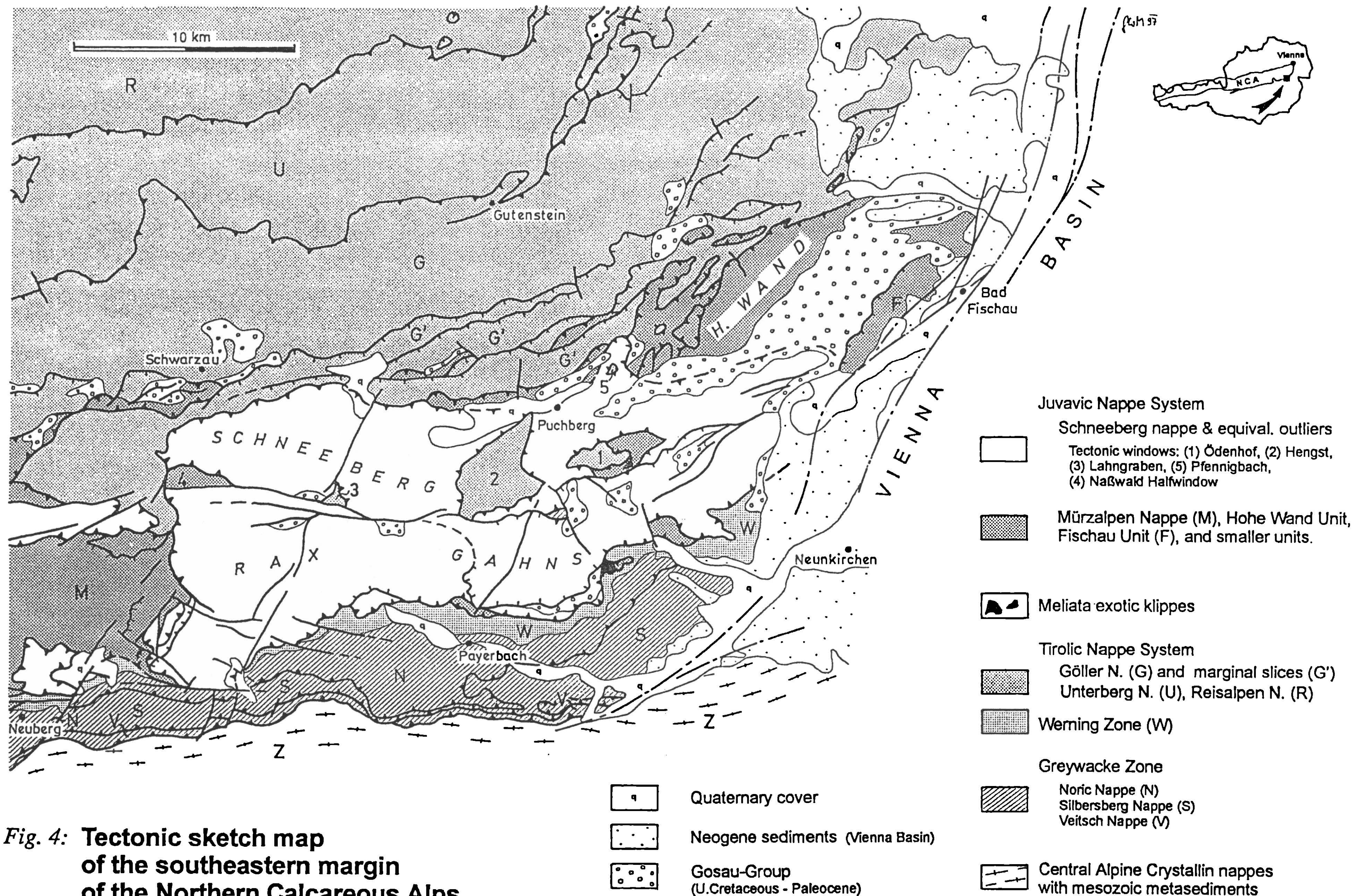


Fig. 4: **Tectonic sketch map of the southeastern margin of the Northern Calcareous Alps**

Travel of about 100 km by bus to the first stop at the village Payerbach, south of Vienna.

Stop 1: Roadside at Payerbach, viewpoint.

Explanation of the geological situation at the southern margin of NCA - see Fig.4.

The village Payerbach is situated within the Palaeozoic rocks of the Greywacke Zone. This zone can be separated into three nappes:

1) the lower Veitsch Nappe, built by Carboniferous conglomerates, sandstones and dark shales and small bodies of magnesite;
2) the intermediate Silbersberg Nappe with remnants of a crystalline basement („Vöstenhof-Crystalline") and transgreding siliciclastics of probably Permian age - the sequence is tectonically overturned; a very characteristic element are small intercalated bodies of Riebeckit-gneiss;
3) the upper Noric Nappe, built by grey shales, greenschists and sandy shales with lydites of probably Lower Palaeozoic age. Above follow with transgressive contact the Permo-Skythian Prebichl-Fm and Werfen-Fm.

The transgressive siliciclastics are shown in Fig.4 as Werning Zone and are assigned to the Tirolic units.

Above follows with overthrust contact a zone of tectonized narrow slices with Middle to Upper Triassic pelagic carbonates - the Juvavic Geyerstein-Sieding Slices in a basinal facies. In the same tectonic position we will see the Meliata-Klippe at Florianikogel.

The uppermost tectonic element is represented by the Schneeberg Nappe. It is part of a mainly Middle Triassic carbonate platform (Wetterstein Limestone). Its southern margin has been affected by Post-Gosauic backthrusting, which has created a complex pattern of small slices of Werfen Shales, Wetterstein Limestone and associated pelagic limestones, as well as of rocks of the Gosau-Group - see also Figs. 5, 7.

The Juvavic units below the Schneeberg Nappe, as there are the Mürzalpen Nappe, Hohe Wand Unit, Geyerstein-Sieding Slices and numerous smaller units, are not the erosional remnants of a former continuous nappe. They have different palaeogeographic origins - see Fig.2. Their today arrangement to each other is thought to be a product of the Upper Jurassic gravitational tectonics.

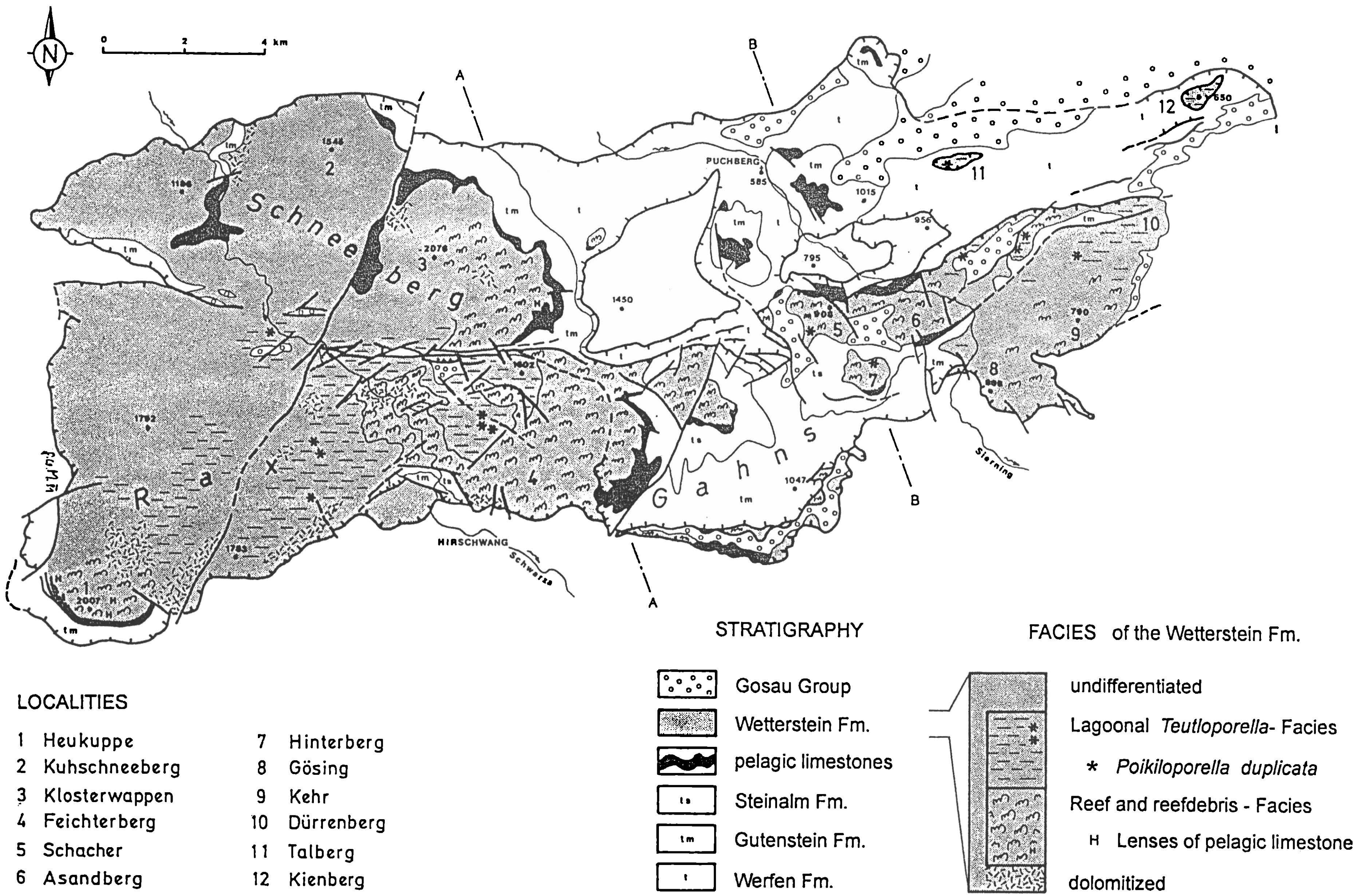
For the reconstruction of the pre-tectonic arrangement of the Juvavic units the facies trends within them can be used.
For example the Schneeberg Nappe shows a platform to basin transition (Grafensteig Limestone) toward the north with onlapping Reingraben Shales in the Carnian - Figs.2 and 6. A similar trend is visible in the northeastern part of the Mürzalpen Nappe (Schneealpen area) - Fig.2. Therefore the two nappes may belong to the same northern margin of a larger carbonate platform. On the other hand there is also a platform margin preserved at the southern slope of Rax Mountain, which one shows a transition from reef to allodapic slope sediments and to variegated limestones of Hallstatt-type. Middle Triassic Hallstatt Limestones today can be found in the Geyerstein-Sieding Slices, within the Ödenhof Window and north of the Hohe Wand. Their depositional area can be assigned to an area „south" of the Wetterstein platform of the Schneeberg Nappe.

Stop 2: Kaiserbrunn, Vienna Water Supply.

Visit of the tapping of Kaiserbrunn Spring.
For some datas see chapter „The Water Supply of Vienna".

FACIES DISTRIBUTION within the WETTERSTEIN LIMESTONE (Ladinian - L.Carnian) of the SCHNEEBERG NAPPE

(After LOBITZER, MANDL, MAZZULLO & MELLO 1990)



Stop 3: Kaiserbrunn - short walk into the Krummbach valley.

Wetterstein Limestone of the Schneeberg Nappe.
Ladinian to Lower Carnian platform carbonates; reef /reefdebris facies.

Published data on the facies distribution in the Wetterstein carbonate platforms of the eastern NCA are scarce and have been summarized by LOBITZER et al. 1990. The Schneeberg Nappe as part of the uppermost Juvavic Nappes provides excellent exposures on large karstified mountain plateaus and deep incised valleys between. Equivalents of the Schneeberg Nappe have been cored also in the subsurface of the Vienna Basin (e.g. Tattendorf drillhole).

Three depositional facies can be recognized in the platform carbonates of the Wetterstein Limestone of the Rax/Schneeberg area:

Lagoonal facies. Rocks of this facies are generally massive to thick bedded, locally bioturbated limestones with a diverse biota of various dasycladacean, solenoporacean and codiacean algae, molluscs (mainly gastropods), echinoderms, rare framebuilding organisms, brachiopods, foraminifers and ostracodes. Textures vary from wackestones to grainstones. Patch reefs inside the lagoon are very rare. The immediate transitional area behind the reef - the near-reef lagoon - is often characterized by boundstones or birdseye-limestones with mixed biota consisting of reef debris and the dasycladacean *Teutloporella herculea*, which one is the dominant algal species in the Rax-Schneeberg area. In the uppermost part of the lagoon additionally *Poikiloporella duplicata* occurs and indicates an Lower Carinan age.

Reef facies. The most intensely studied part of the Wetterstein Limestone is by far the reefal facies. These builtups are composed of diverse biotic assemblages of sphinctozoan and other calcisponges, corals („Thecosmilia", „Montlivaltia", „Thamnasteria"), tubiphytes, bryozoans, codiacean and solenoporacean algae, brachiopods, molluscs and rather rare foraminifers. Rock textures of reefal deposits generally are wackestones and packstones. Boundstones resulting mainly from syndepositional marine cementation are also very common. It seems that a biogenic reef framework in the sense of a wave-breaking structure did not exist in the Wetterstein reefs of the eastern NCA. Practically all reef-organisms are of small dimensions of several centimeters only. Coral-buildups of large dimensions are missing as well as other potential wave-breaking organisms. It seems that a rigid framework could have been constructed by a combination of pervasive submarine early diagenetic cementation and various encrusting organisms. The fact of immediate interfingering of the „reef" with lagoonal birdseye limestones is considered as a prove for platform-edge reefs and not an upper slope situation. Typical assemblages of a deeper water slope (ammonites, radiolarians, silicisponges) are missing. Such biota occures only in very rare small lenses of Hallstatt-type within the reef of Heukuppe (summit of Rax-plateau).

Grossoolite facies. A conspicuous feature of platform-edge facies in the Wetterstein Limestone is the development of coarse breccias. The term „Grossoolite" refers to thick, laminated, isopachous coatings of radiaxial-fibrous calcite cement and calcite-replacive dolomite around lithoclasts and skeletal particles. Although initially interpreted as being of organic origin, this coatings are now regarded as inorganic cements. The component clasts are commonly angular and often poorly sorted, ranging in size from a few centimeters to several decimeters in diameter. They are mainly composed of reefal lithologies. In places the grossoolitic breccias are the only remaining evidence of the former existence of in-situ shelf-margin reefs. Syndepositional tectonism, oversteepening of the platform margin, slope instability, or a combination of these processes must have been causative factors in the formation of such widespread breccia deposits.

← *Fig. 5: Facies of Wetterstein Limestone of the Schneeberg Nappe.*

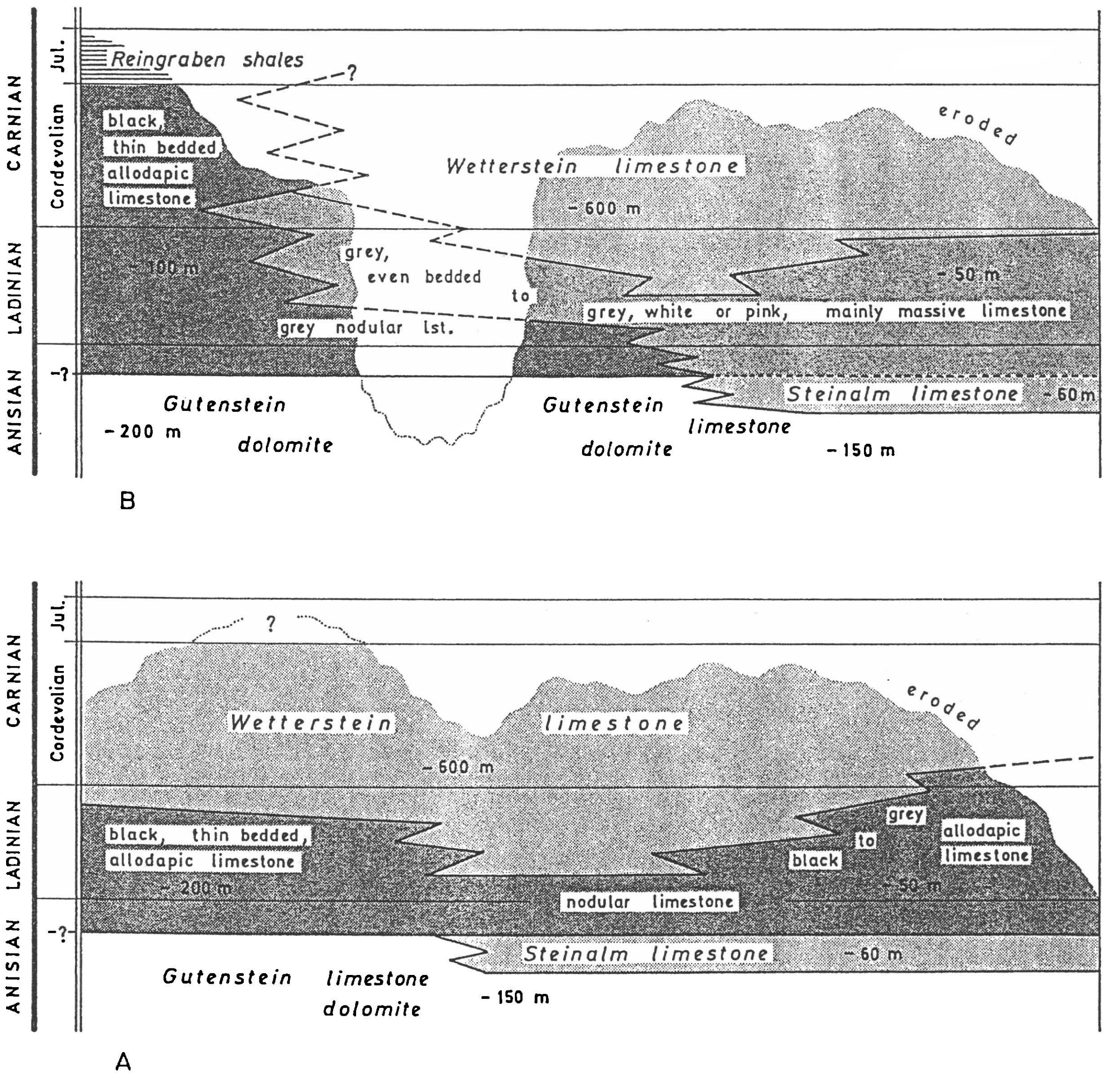


Fig. 6: Stratigraphic scheme (Anisian to Lower Carnian) of the Schneeberg Nappe, after LOBITZER et al 1990. Note lateral variability of platform to basin transitions. Approx. location of cross-sections A, B see Fig.5.

Stop 4: Gasthof Singerin - Naßbach valley, roadside outcrop.

Grafensteig Limestone.
Ladinian to Lower Carnian slope and basinal facies of the Schneeberg Nappe.

Rocks of transitional nature between Middle Triassic platforms and basins are relatively rare in the NCA due to structural complexities. Basinal facies often are tectonically isolated from formerly contiguous platform deposits.

In general we know three different types of Anisian to Lower Carnian carbonatic basinal sediments, the Reifling Limestone, the Grafensteig Limestone and the Hallstatt Limestone.

The **Reifling Limestone** is the characteristic basinal facies in the Bajuvaric and Tirolic nappes. It consists of grey well bedded nodular limestone with thin yellowish to greenish clay intercalations of partial tuffitic origin. A silica content often is concentrated in chert-nodules or -layers. Microfacies shows (pel-)micrites with abundant radiolarians and „filaments" (thin shells of planctonic bivalves) and conodonts, the macrofauna consists of ammonites, molluscs *(Daonella)* and local brachiopods.

The **Hallstatt Limestones** comprises a lot of different lithologies, mostly of variegated micritic limestones with abundant pelagic fauna like conodonts and ammonites. Hallstatt Limestones are restricted almost to the uppermost respectively southernmost tectonic units of the Juvavic Nappe System, representing the sediment of outer shelf and/or local uplifts due to diapirism of Permian evaporites.

The term **Grafensteig Limestone** has been introduced by HOHENEGGER & LEIN 1977. It is characterized by darkgrey to black well bedded limestones, mainly with even bedding planes, more oder less abundant chert-nodules or -layers and - as a main feature - with intercalated allodapic beds of platform origin. It is overlain in the northern Schneeberg-area by grossoolite-breccia facies of an upper slope environment. The Grafensteig facies represents a restricted intraplatform-basin with only minor connection to open marine conditions. Pelagic faunal elements like conodonts seem to be restricted to sporadic beds and are in general poor. The Grafensteig Limestone comprises a maximal time span from Middle Anisian to Lowermost Carnian in the basin interior. At the basin-margins it ends earlier according to the prograding Wetterstein platform.

The outcrop at stop 4 presents a typical development with carbonate turbidites, showing graded bedding.

One of the objects of our excursion is to show the great variety in facies within the Juvavic Nappe System, where we can find close together Ladinian sediments of shallow carbonate platforms, slope and basinal limestones of an intraplatform-basin, open marine Hallstatt Limestones and - as a greeting from the Carpathians - Ladinian red radiolarite olistolites in the Meliaticum at the tectonic Klippe of Florianikogel.

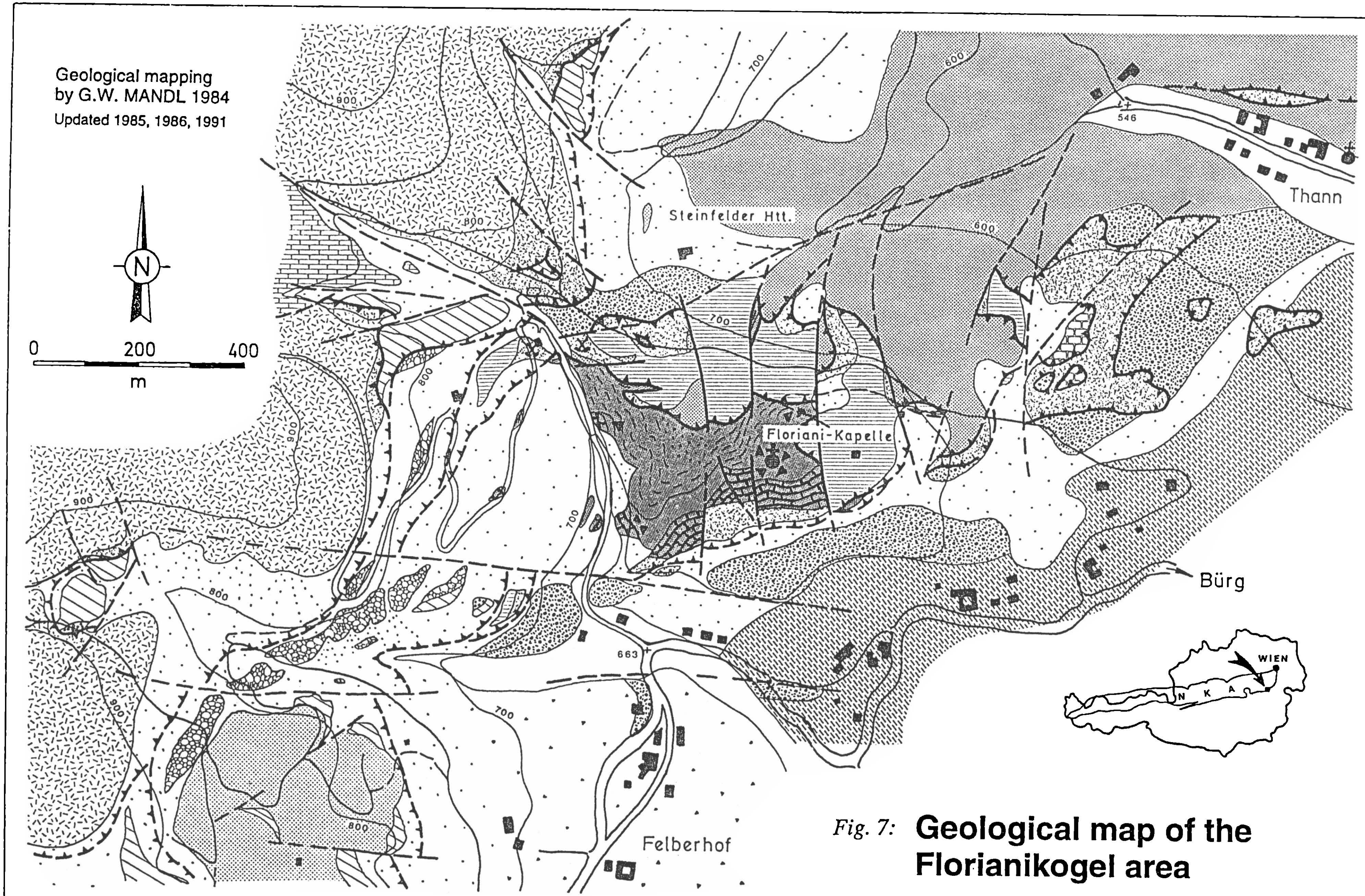
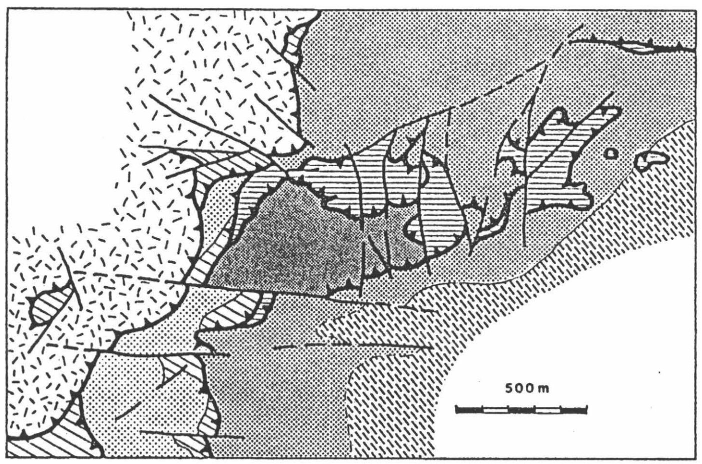


Fig. 7: **Geological map of the Florianikogel area**

Tectonic sketch map



Schneeberg Nappe
- Central part
- Basal slices
  - Gosau Group (U.Cretac.- Paleocene)
  - Triassic Carbonates

Flaser Limestone Slice

Floriani Klippe (Meliaticum)

Werning Zone

Greywacke Zone

Quaternary
- Alluvium
- Gravel / local lithified

Schneeberg Nappe

Central part
- Gutenstein Limestone (Anisian)
- Gutenstein Dolomite (Anisian)
- Rauhwacke

Basal Slices
- Limestone breccia (Paleocene)
- Sandstone and marl (Maastrichtian - Paleocene)
- Orbitoid Sandstone (Maastrichtian)
- Wetterstein Formation (Langobardian - Cordevolian)

Flaser Limestone Slice
- Grey bedded limestone +/- chert (? Carnian)
- Grey to variegated Flaser Limestone (Lower Anisian)
- Rauhwacke
- Werfen Formation (Scythian)

Floriani Klippe
- Floriani Formation (Doggerian)
  - Dark sandstone and shale
  - Dark shale
- Greygreen radiolarite (Doggerian)
- Red radiolarite (Middle Triassic; Olistolites)
- White marble (Anisian; Olistolites)

Werning Zone
- Werfen Formation (Scythian)
- Prebichl Formation (Permian)

Greywacke Zone
- Grey shale with sandstones and lydites (Lower Paleozoic)

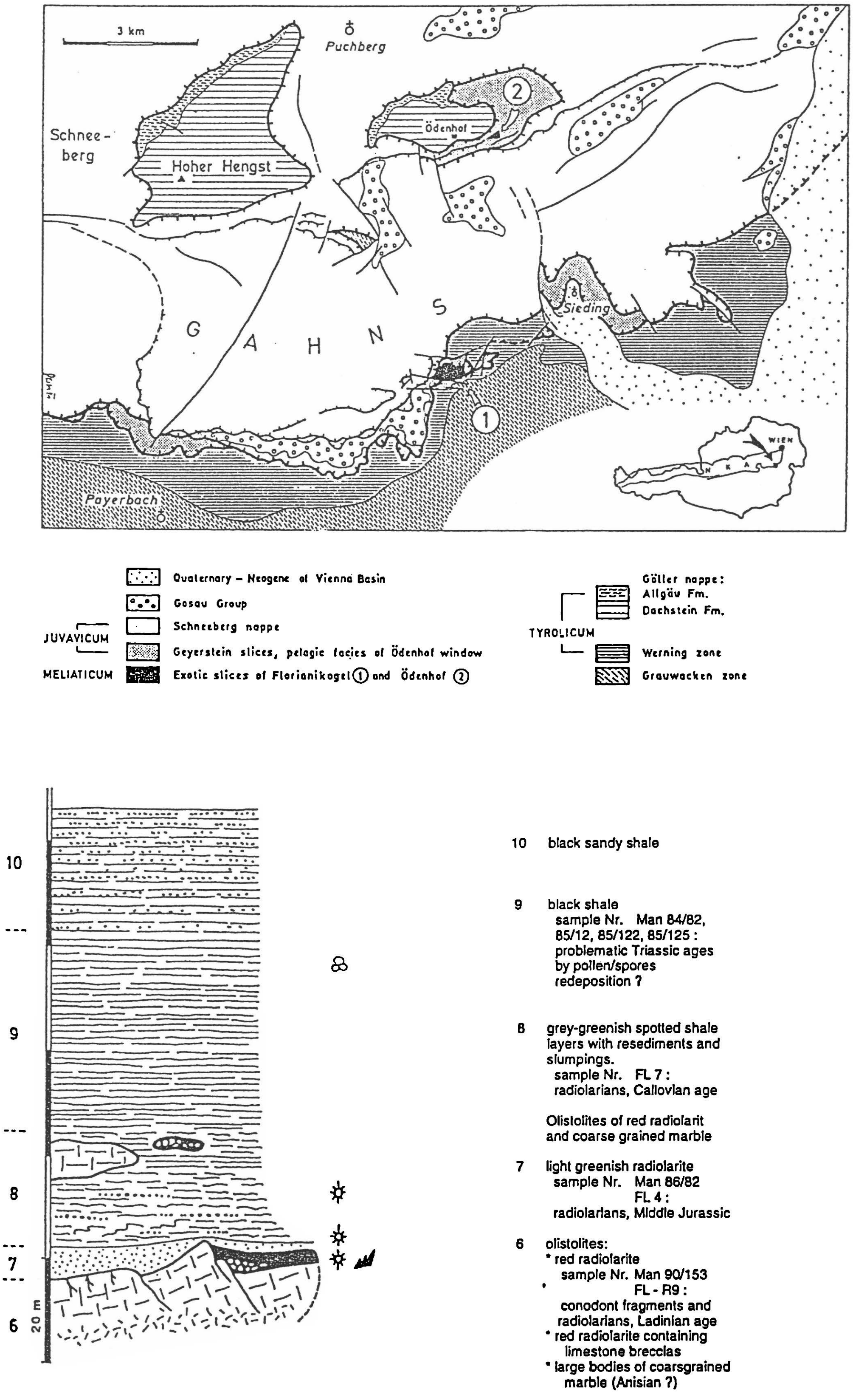


Fig. 8: Tectonic sketch map of the southeastern Schneeberg area and the Triassic to Jurassic sequence of the Meliaticum-Klippe at Florianikogel.

Stop 5: Florianikogel - walk on forest paths up to the hill peak.

Tectonic Klippes of Meliaticum.
Olistolites of Triassic deepwater facies within Jurassic deepwater sediments (radiolarite, shale).

Recently two occurrences of radiolarite and associated carbonates have been proved to be of Middle Triassic age - MANDL & ONDREJICKOVA 1991, 1993, KOZUR & MOSTLER 1992.
This was the first proof of a Triassic deepwater facies in the Eastern Alps, comparable to the Meliaticum of the Western Carpathians.

The sequence is tectonically embedded between Permian Prebichl conglomerates of the Werning Zone below and the Schneeberg Nappe above, having nearly the same tectonical position as the Geyerstein-Sieding Slices - see Figs. 7 and 8. Anisian so called "Flaser limestone" and rauhwackes on the northern slope of Florianikogel may be part of the Schneeberg Nappe as well as part of the Geyerstein-Sieding Slices. The latter interpretation seems more probable.

The contrast in Triassic facies between the rocks of Geyerstein-Sieding Slices, Schneeberg Nappe and Floriani Klippe points at the significance of the overthrust plane between Werning Zone and Schneeberg Nappe. This overthrust cannot be interpreted as a local and secondary post-Cretaceous backthrusting within a former sedimentary succession.

The sequence consists of dark, partly sandy shales, associated with greenish cherty shales and radiolarites of about Middle Jurassic age - radiolarians: *Acaeniotyle diaphorogona, Triactoma trigonum, Tritrabs simplex* and others.
Red radiolarites, containig Ladinian radiolarians - *Pseudostylosphaera compacta, P. japonica*, and *P. tenuis* together with *Baumgartneria retrospina* and *Eptingium manfredi* - are interpreted as olistolites within the Jurassic shales. Unfortunately no outcrop exists which exposes the contact between them.
Large bodies of a light coloured coarsegrained marble are also thought to be of olistolitic origin. In comparison with the Carpathian Meliaticum an Anisian age is assumed. The Ladinian red radiolarit locally contains breccias of a similar marble as well as of a white limestone exhibiting a Steinalm microfacies. These observations confirm the assumption above.

Basic volcanics like in the Carpathian Meliaticum have been found until now in the eastern NCA Meliata Klippes only as reworked detritus in a few thinsections. A small occurence of serpentinite has been reported in older maps in the area of Ödenhof Window, it is not exposed any more.
Larger bodies of serpentinite exist between the villages Puchberg and Höflein, embedded in Permo-Scythian evaporites, Werfen Shales and rauhwacke. The contact seems to be tectonically, the association may be interpreted as a salinar melange. The age of the serpentinite remains doubtful, the origin as a dismembered Ladinian ophiolite could not be proved until now.

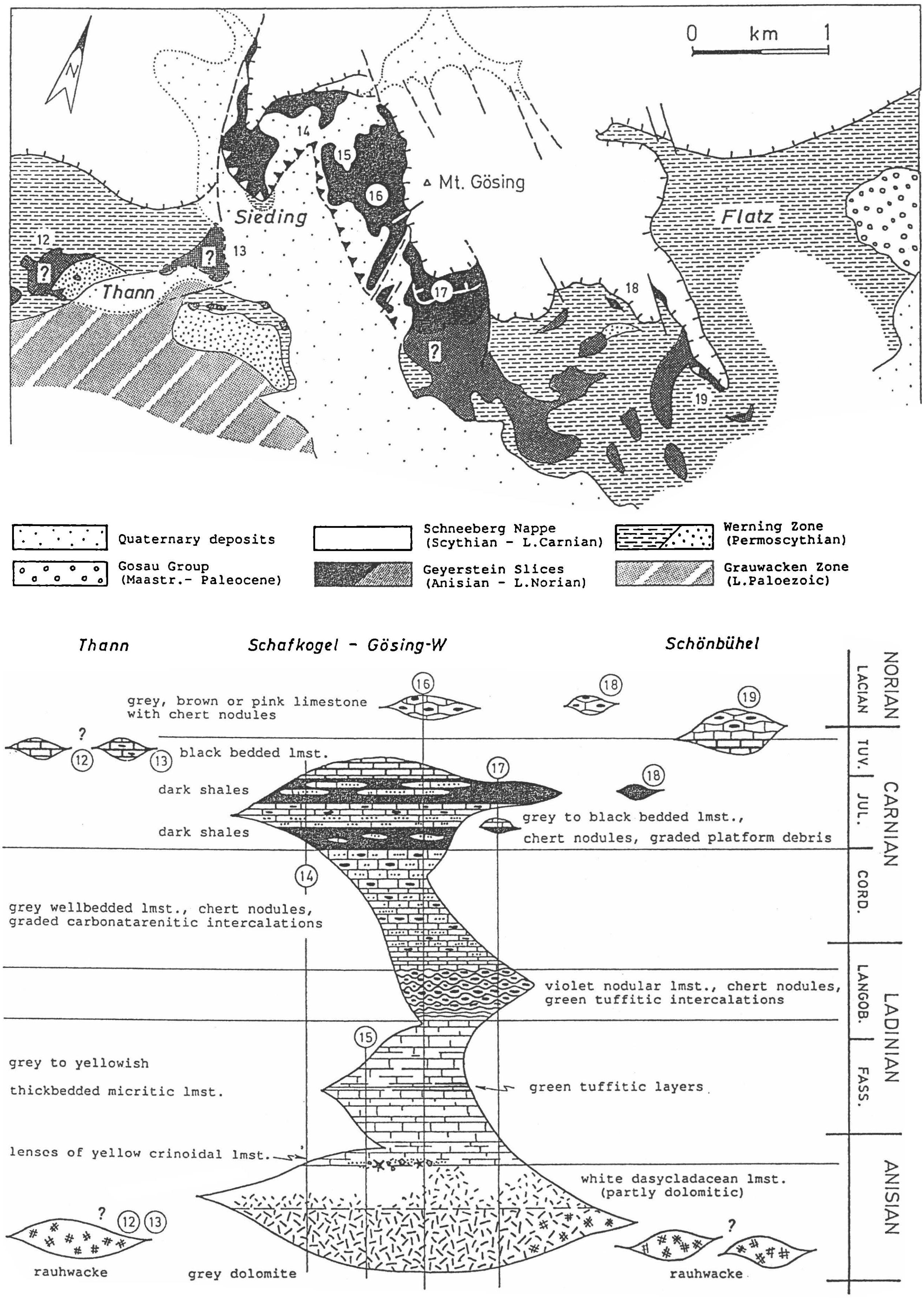


Fig. 9: Tectonic Position and Stratigraphy of the Geyerstein-Sieding Slice System in the surrounding of the Village Sieding.

Stop 6: Village Sieding - short walk, outcrop in the Nature Park.

Juvavic Geyerstein-Sieding-Slice. Middle Triassic Hallstatt limestone in sedimentary contact to Steinalm Limestone (Anisian shallow water facies with dasycladaceans), section 15 in Fig.9..

The rocky cliffs at the western slope of Mt. Gösing near the village Sieding expose some of the best sections of this tectonic unit. These slices are arranged along a main overthrust plane and separate the Permo-Scythian siliciclastics of the Werning Zone below from the Middle Triassic carbonates of the Schneeberg Nappe above.

Despite tectonical fragmentation the complete sequence from Anisian to Upper Carnian can be reconstructed:

The section starts with about 100 meters dark grey Gutenstein Dolomite. At the top the dolomites become light-coloured and grades into Steinalm Limestone of about 10 meters thickness. Its common microfacies is a dasycladacean grainstone with *Physoporella / Oligoporella* and a few foraminiferas as *Meandrospira dinarica* and *Glomospira semiplana*. The fossil content points to an Anisian age.
After a questionable erosional discordance (local relief of some 10 cm) pelagic sedimentation of Hallstatt-type facies starts with lightgrey and yellowish thickbedded pelmicritic limestones. At the boundary often dm-sized lenses or layers of a crinoidal wackestone occur, rich in ostracodes, holothuroidean sclerites, echinid spines, radiolarians and „filaments". This basal horizon is proved by conodonts as Upper Anisian. The total thickness is affected by tectonics but should exceed 15 meters. The following 6 meters consists of violet nodular limestone with chert nodules and greenish tuffitic intercalations. Due to strong recrystallisation and beginning dolomitization the original microfazies is not preserved. Conodonts point at an Upper Ladinian age.
Still in Uppermost Langobardian a well bedded lightgrey limestone with thin yellow marly layers is following. It contains fine-grained distal carbonate turbidites from an former adjacent Wetterstein platform. The age is Lowermost Carnian („Cordevolian"), the thickness will be in the range of about 40 m.
The Julian sequence is composed of two horizons of black shales (Reingraben Shale) with a few thin biodetritic limestone layers and an interbedded horizon of 18 m dark allodapic limestones. Characteristic bioclasts are fragments of calcisponges. The age is proved by conodont samples, containig *Gondolella auriformis*.
The sequence ends with black micritic limestones of Tuvalian age.
The Lower Norian shown in Fig.9/sect. 16 is a poorly exposed and tectonized limestone near the overthrust of the Schneeberg Nappe. The Norian rocks are much better exposed at the „Geyerstein-cliff" near the village Payerbach. Also the Middle Triassic to Carnian sequence is exposed there. It differs from the sequence described above in the lack of allodapic platform debris in the Upper Ladinian and Carnian. The Cordevolian is represented there by thickbedded grey to pinkish Hallstatt Limestone.

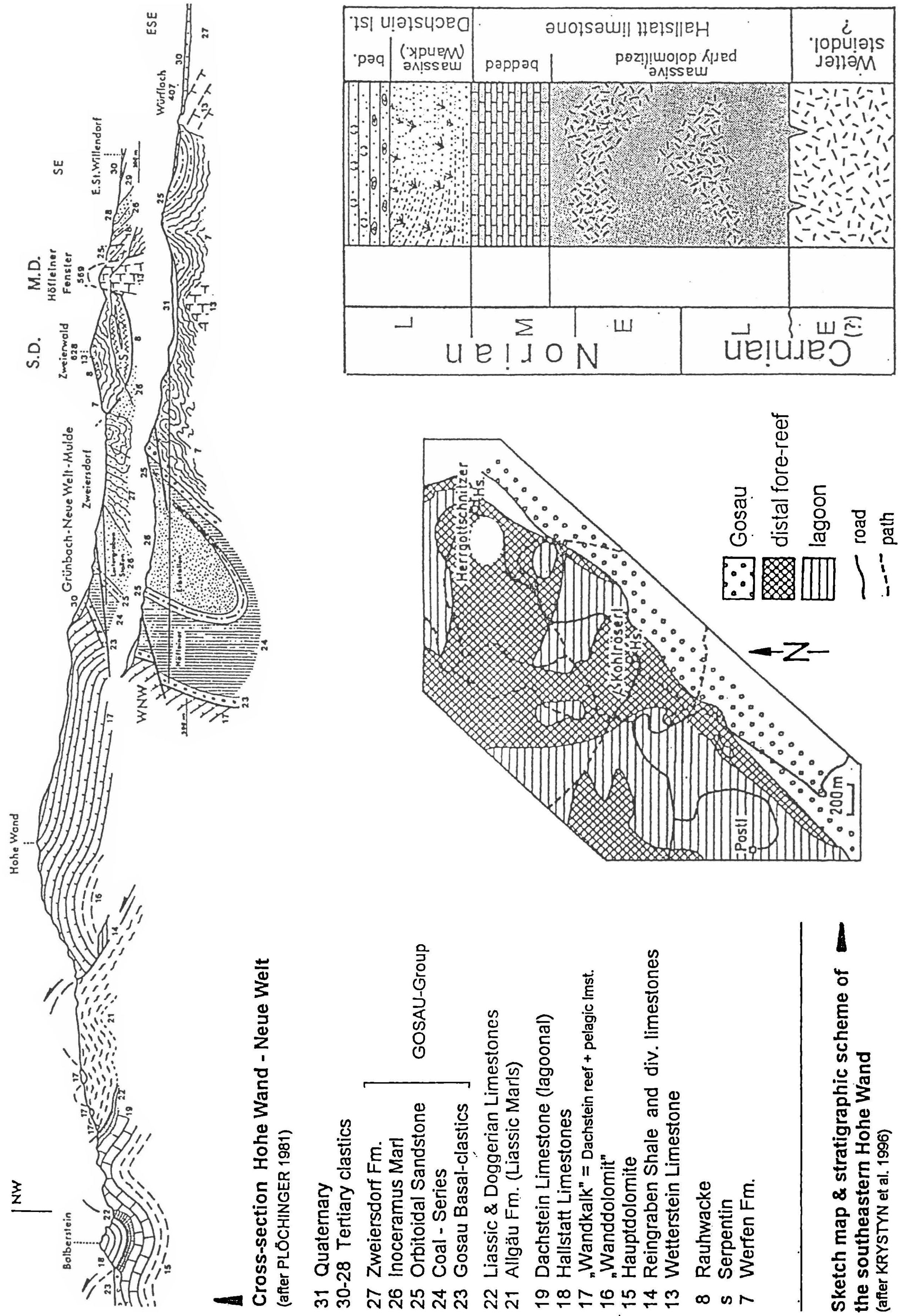


Fig. 10: The Hohe Wand - Neue Welt area.

Stop 7: Hohe Wand - roadside outcrop near Herrgottschnitzer Hütte.

Dachstein Limestone, Upper Triassic (Norian) carbonate platform, reef facies.

The Hohe Wand is the easternmost carbonate plateau mountain of the NCA with altitudes up to 1100 m. It is part of the Juvavic Nappe System and consists mainly of Upper Triassic carbonates. In the northwest it is thrusted over the Jurassic Allgäu Formation of the Tirolic Göller Nappe. On the southeastern side it is bounded by the Upper Cretaceous to Paleocene rocks (Gosau-Group) of the Grünbach-Neue Welt Syncline. In its western part it is overthrusted by some Juvavic outliers in Upper Triassic slope- and basinal facies and by an outlier of the Schneeberg Nappe.

Although the Hohe Wand - area was mapped several times during the last century many subjects remained controversial due to complex tectonics, low stratigraphic resolution and bad outcrop situation. The narrow neighbourhood of pelagic sediments (Hallstatt Lmst.) and reefoidal limestones has led to the establishment of a separate lithologic unit, the „Wandkalk", summarizing both facies. Microfacial studies by SADATI 1981 interpreted the Wandkalk as Dachstein Limestone „being formed within an extended shallow lagoon with numerous ... small patch reefs". Unpublished results of extensive conodont research by SCHAUER have been briefly summarized by KRYSTYN et. al. 1996 - see Fig.10.

The lower part of the sequence is built by a dolomite which probably can be assigned to a Middle Triassic - Early Carnian Wetterstein carbonate platform. After a sedimentary gap due to the Carnian sealevel lowstand a massive, reddish to greyish partly dolomitized Hallstatt Limestone (50 to 150 meters) and the following thin bedded red limestone (20 m) reflect a transgressive event from Upper Carnian to Middle Norian. Upsection the pelagic influence decreased and a reefoidal limestone has been deposited. The transitional part corresponds to the „Wandkalk".
The top of the sequence is built by bedded Dachstein Limestone, deposited in a shallow subtidal lagoon. Intertidal Lofer facies is not developed.

The massive Dachstein Limestone with reefoidal biota (calcareous sponges, rare corals) will be visited at stop 7.

The lateral transition from the Dachstein reef to an adjacent basin is not preserved at the Hohe Wand, maybe it is burried below the Gosau sediments of the Grünbach - Neue Welt Syncline. Only one of the tectonic outliers in the western part of Hohe Wand consists of Pedata- and Pötschen Limestone. This one could originate from such an Upper Triassic platform slope as well as the other outliers represent the deposits of the Hallstatt basinal realm.

The nappe stack of the NCA dips down toward the east below the Tertiary sediments of the Vienna Basin, reaching maximal depth of about 5.600 m (top of NCA). Several drillings by OMV as well as geophysical investigations have shown the continuation of the NCA rocks and structures toward the Western Carpathians - see KRÖLL et al. 1993.

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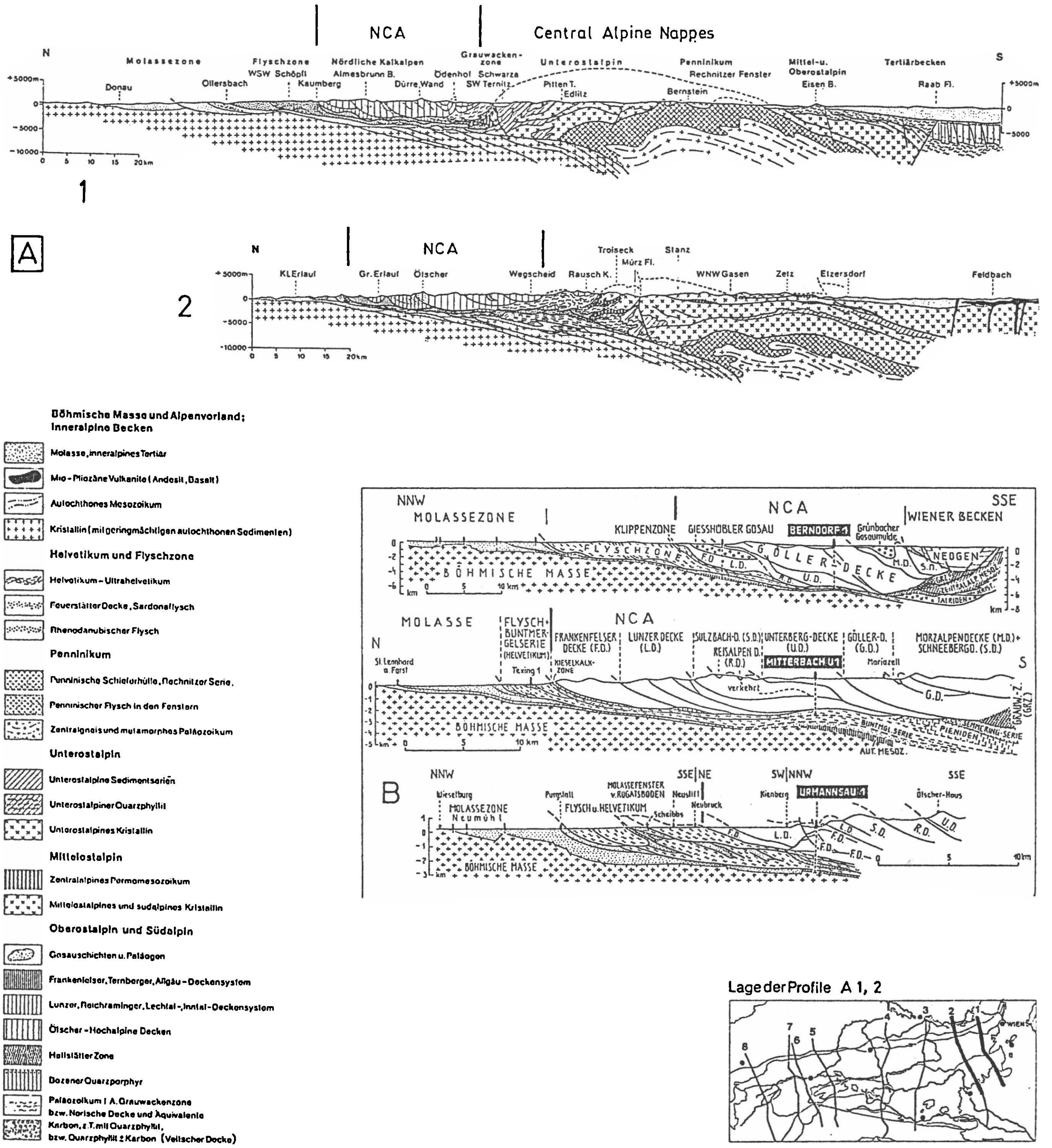

Fig. 11: Cross-Sections through the Eastern Alps.
A. General situation (according to PREY 1980).
B. Sections of the easternmost NCA Nappe System and location of deep drillings (TOLLMANN 1981).