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Excursion 035 A

Geology and Tectonics of the Eastern Alps (Middle Sector)

by

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Contents

Summary

The excursion into the middle sector of the Eastern Alps will demonstrate by selected examples along two cross-sections the stratigraphy, the different facies regions, metamorphosis, nappe structure and microtectonics. The sequence of nappes will be shown along the meridian of Salzburg and of Hallstatt. The Penninic nappe system appears as the deepest tectonic unit in the center of the Eastern Alps in the region of the window of the Hohe Tauern. It is characterised by an eugeosynclinal facies and by a high degree of metamorphosis. Above this lowermost unit follows the vast system of Austroalpine nappes ("Ostalpin"), devided into three distinct tectonic units: At the base the Lower Austroalpine nappe system, which is represented by the Radstädter Tauern; the Middle Austroalpine system, which forms especially the large masses of Altkristallin in the central axial region of the Eastern Alps beyond the Tauern Window only with a thin and uncomplete mesozoic cover under specific facies; the Upper Austroalpine nappe system, which comprises firstly the Northern Limestone Alps marked by a typical Tethys facies (aristogeosynclinal facies) rich in fossils, then the Grauwackenzone, furthermore rests of this sheet in the Central Alps like the Gurktal nappe and a remainder near the root zone, the Drauzug in the Gailtal mountains. In its southernmost point the excursion reaches the northern margin of the Carnic Alps, part of the Southern Alps. The northern rim of the Alps is shown in the Helvetic Zone with its series under miogeosynclinal facies, overthrust by the Flysch nappe.

A) General Introduction

By A. TOLLMANN

1. Literature

We can restrict the general introduction to this excursion, because you will receive a short "Einführung in die Geologie Österreichs" on the occasion of this congress. Therefore you will find in the following primarily those special instructions, concerning the middle sector of the Eastern Alps, visited by this excursion.

In the following some newer books and papers concerning this matter are mentioned: In English: E. OXBURGH: The Eastern Alps — a geological excursion guide, Proceed. geol. Assoc., 79/1, p. 47—124, Colchester 1968. — In French: J. GEYSSANT & A. TOLLMANN: Alpes autrichiennes, C. r. Soc. géol. France, **1966**/11, p. 413—472, Paris 1966. — In German: H. BÖGEL & K. SCHMIDT: Kleine Geologie der Ostalpen, 231 p., Thun (Ott-Verlag) 1976; W. DEL-NEGRO: Abriß der Geologie von Österreich, 138 p., Wien (Geol. Bundesanstalt) 1977; M. GWINNER: Geologie der Alpen, 477 p., Stuttgart (Schweizerbart) 1971; A. TOLLMANN: Monographie der Nördlichen Kalkalpen, vol. 1—3, Wien (Deuticke) 1973, 1976; Geologie von Österreich, vol. 1: Die Zentralalpen, 766 p., Wien (Deuticke) 1977.

2. The geological position of the region visited by the excursion within the European framework

(Fig. 1)

The Eastern Alps represent a sector of the northern branch of the young, alpidic Mediterranean mountain system. In this part of the Alps the tectonic movements in the alpidic era indicate a general northward direction. The main structures were built during Upper Cretaceous and Lower Tertiary. The orogenesis diminished

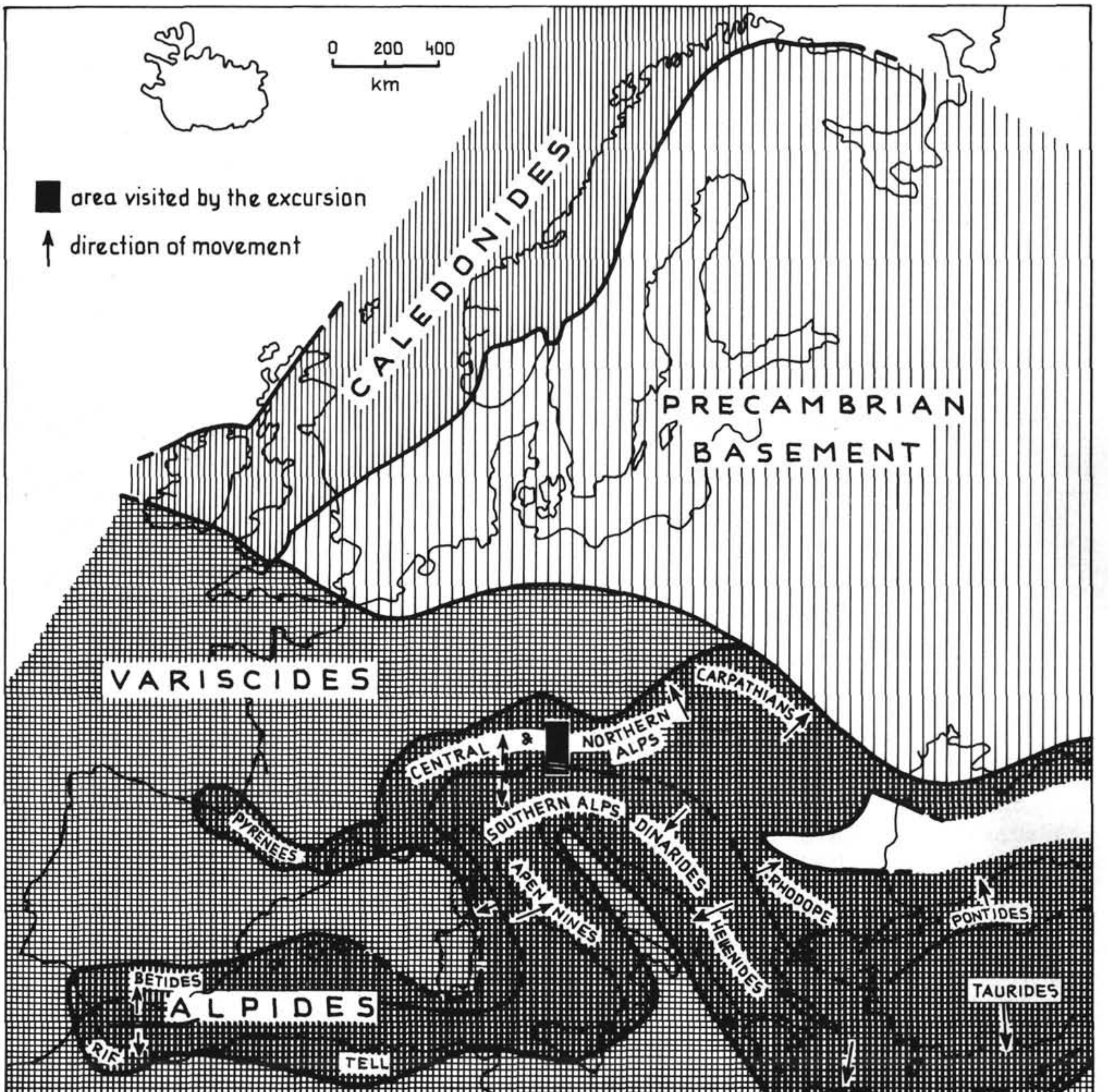


Fig. 1: The position of the Eastern Alps and the excursion route within the geological framework in Europe.

the width of the geosyncline from nearly 1000 km during the middle Mesozoic to approximate 150 km today.

The northern branch of this young Eurasiatic mountain system, built up of rests of the floor of the Mesozoic Tethys ocean, leads from the Betic Cordillera in Spain, from the Alps, Carpathians and the Balkans in Europe to the Pontides in northern Anatolia and to the Elburs. The southern branch of this Mediterranean system, mooving generally southwards, is comprised of the Rif, the Maghrebides within the Atlas, the Apennines, Southern Alps, Dinarides, Hellenides in Europe, Taurides in the Turkey, and leads to the Himalayas.

This mountain system arised from the wide Tethys ocean, which also contained the longish Kreios Plate with its continental crust, and a lot of younger microcontinents. The orogenesis was produced by the collision of the African and the Euroasiatic plates during the Cretaceous and the Tertiary. In the Eastern Alps a part of the former, older mountain system, the Variscides, are preserved with its old tectonic structures, e. g., in the Carnic Alps and in the Altkristallin of the Middle Austroalpine system. This Variscic system is preserved in a width of about 600 km maintaining a continuity in the alpin foreland in middle Europe. In front of the Eastern Alps we find it in the form of the Bohemian Massif with internal Variscic nappe structure, with a southeastern direction of movement.

3. The geological peculiarity of the Eastern Alps

The Eastern Alps are dominated by nappe structure. Six nappe systems are piled up in this chain. Each nappe system in itself consists of individual nappes. The width of the main nappe transport vary from some ten kilometers up to 165 km (Upper Austroalpine nappe system). Already during the stage of geosyncline in the Mesozoic these units had individual facies. There are also differences in the distribution of the non-metamorphic Paleozoic in the different nappe systems. Most of the nappes also contain crystalline rocks as remainders of a continental crust; only in the southern part of the Penninic nappe system are hints of a direct sedimentation of Mesozoic on oceanic crust.

The considerable shortening of the crust in the Eastern Alps during the alpidic orogenesis produced a crustal thickness of 50 km in comparison with 33 km thickness of the crust of the Central European foreland. Only in its eastern part the crust beneath the Alps thins to 27 km, as below the Pannonic Basin in Hungary. This attenuation is a young effect in connection with the exaggeration of the Carpathians bend according to the principle of back arc basin forming.

The piling of the alpine nappes took place in various phases. Shortening of the crust and subduction began already in the younger part of the Lower Cretaceous: Austroalpine phase of the Barrême-Aptian, Austrian phase of the Upper Albian-Cenomanian. During this time the main central nappe systems began their migration. The main nappe building in the Upper Austroalpine system may be fixed by the Gosau formation, superposing in disconformity the limits of the nappes in the Northern Limestone Alps. Therefore the thrusting of the nappes in this part of the Eastern Alps can be dated as pregosauic, that is equal to the Mediterranean phase in the upper Turonian 90 million years ago. This data is in accordance with the radiometric age of the metamorphosis in the Austroalpine system ("Schneeberg crystallisation"). In this time the Penninic system of the Hohe Tauern was subducted beneath the Austroalpine units. The younger main phase of transport of the nappe systems is the Illyric-Pyreneen phase at the end of the Eocene. During this time the central units of the Eastern Alps were transported above the marginal units. In this way vast parts of these marginal zones (Flysch Zone, Helvetic Zone) were covered and the sedimentation was finished in this region. A new foredeep formed. The Alps entered their Molasse stage: Beginning with the Upper Eocene the debris from the Alps and the foreland accumulated in the Molasse Zone.

The younger phase of metamorphosis in the Eastern Alps, dated in the Penninic system, occured in the Lower Tertiary and is perhaps in connection with the second main thrust mentioned above at the end of the Eocene. In the lower part of the Penninic system in the Hohe Tauern the metamorphosis then just attains the amphibolite facies.

After the reduction of the tangential pressure within the upper Tertiary the orogenesis, characterized by nappe building, is replaced by vertical isostatic movements. This late phase of mountain building is called "montigenesis", leading to the morphological forming of mountains: big masses rise to considerable hights, on the other hand great basins are formed. In the Pliocene the chain of high mountains is nearly complete and will be finished in the Pleistocene by the activity of the vast glaciation.

4. The main structure of the Eastern Alps in the section visited

(Fig. 2, 3)

In the middle sector of the Eastern Alps we find the following main tectonic units, advancing from north to south, from the frontal part of the mountain chain to the lower units of the Central Alps:

a) Helvetic Zone } marginal units
b) Flysch Zone }

c) Upper Austroalpine nappe system: Northern Limestone Alps (Mesozoic) and Grauwackenzone (Paleozoic)

d) Middle Austroalpine nappe system: Altkristallin and Stangalm Mesozoic in centralalpine facies

e) Lower Austroalpine nappe system: Crystalline por-

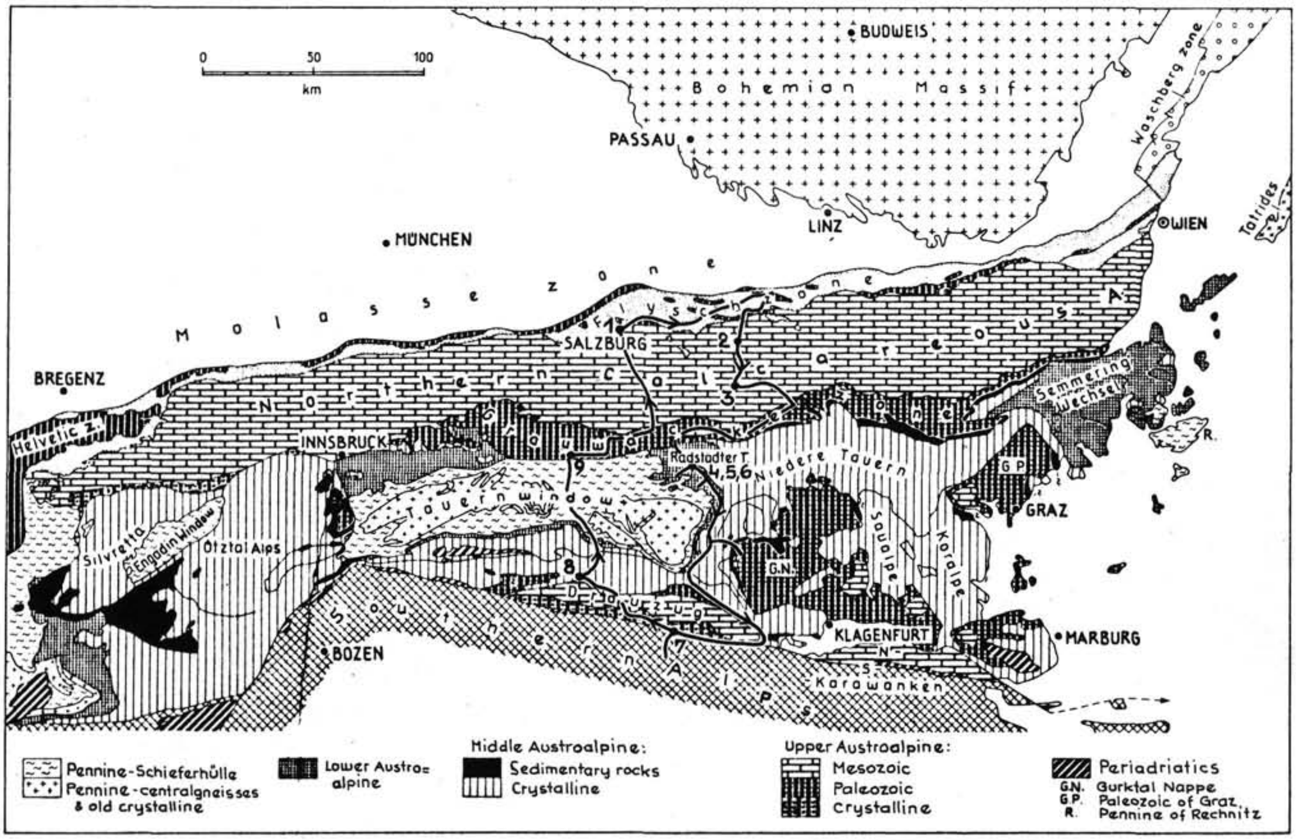


Fig. 2: Tectonic sketch of the Eastern Alps (A. TOLLMANN, 1978) with the excursion route.

tion, Paleozoic and metamorphic Mesozoic in centralalpine facies in the Radstadt Tauern

f) Penninic Zone: Tauern Window with Crystalline portion, Central Gneiss, Schieferhülle with Paleozoic and Mesozoic parts.

Figures 2 and 3 show the arrangement of this nappe pile.

The Penninic system appears as the lowermost unit in the large culmination in the center of the Eastern Alps, namely in the Tauern Window.

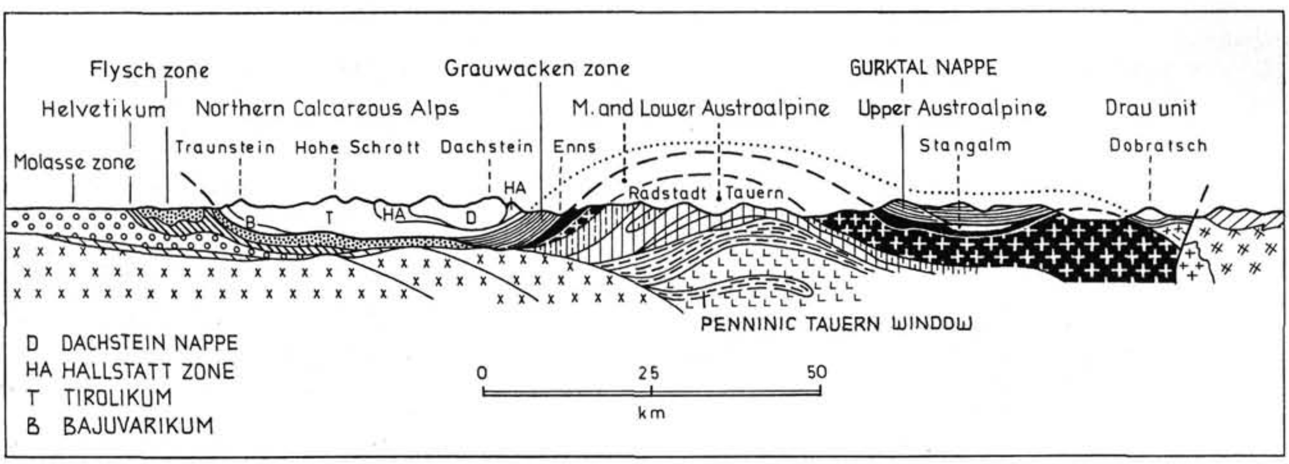


Fig. 3: Cross section in the middle sector of the Eastern Alps (A. TOLLMANN, 1976, fig. 9).

The units of the Austroalpine system originate from the region south of the Tauern and were thrust on and above the Tauern Pennine towards the north. The Lower Middle Austroalpine unit rested in the Central Alps, covers the Pennine and shows specific, slight metamorphic Mesozoic series in "centralalpine" facies, poor in fossils. The Drauzug southernward of the Tauern Window and the Northern Limestone Alps thrust far above the Hohe Tauern, belong to the Upper Austroalpine unit. These two comprise a famous non-metamorphic Mesozoic series, rich in formations and fossils, e. g., the Hallstatt Limestone with the great number of ammonites. The internal nappe structure of the Limestone Alps offers eminent complications. The Palaeozoic basement of the Limestone Alps appears in the Grauwackenzone, built up of low metamorphic series of fossiliferous formations. As an important remainder in the same position as the Grauwackenzone we see the Paleozoic mass of the Gurktal nappe within the central zone of the Eastern Alps.

5. Paleogeography and orogenic cycles

Figure 4 shows the pattern of the main facies regions during the time of geosyncline prior to the orogenesis.

a) A specific zone developed in the cental part of the Tethys during the Upper Permian in the Northern Limestone Alps, characterized by the Haselgebirge, rich in salt, gypsum and anhydrite.

b) During Triassic time distinct differences existed between the facies zones of the Alps, generally arranged in longitudinal direction: The Helvetic zone still did not exist; the Penninic realm shows miogeosynclinal facies with variegated schists and sandstones in the Upper Triassic; in the Austroalpine region the Triassic contains sediments of a carbonate plattform type, whereby the thickness increases southward up to some kilometers. The northern part of this region include the "centralalpine" facies, the southern one the "nordalpine" facies. To the latter belong the Northern Limestone Alps, which show the Hauptdolomit facies (with the Norian Hauptdolomit) in the north, and the Dachsteinkalk facies (with the Norian-Rhaetian Dachstein limestone) in the south. In the last-mentioned region the Hallstatt facies (with thin red Hallstatt limestone in the Middle and Upper Triassic) is intercalated in some narrow channels.

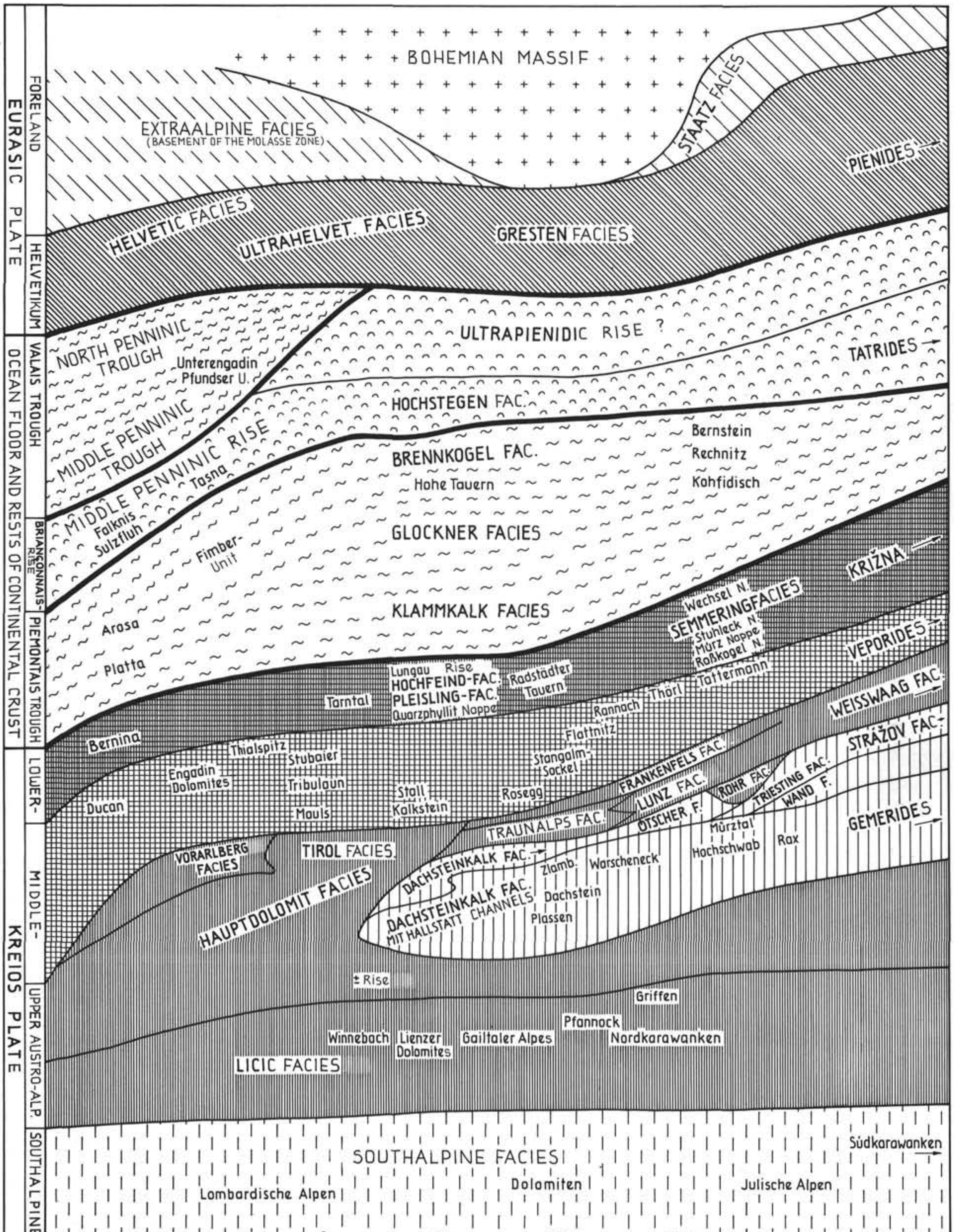
c) While the continental crust of the geosyncline attenuated in the Triassic by fracturation and the first vulcanites appeared, it began to burst during the Jurassic time. In the northern and southern part of the Penninic realm an ocean floor built up the basement for the following sedimentation (Glockner nappe in the southern Pennine, perhaps of the Flysch Zone in the northern Pennine). As a consequence of attenuation and the opening of the continental crust, the floor of the Tethys ocean subsided in accordance with the lows of isostasy. Therefore in the Jurassic sediments like marl, clay, chert and pelagic limestone dominated, accompanied by red nodular limestones. Carbonate platform sediments like reef limestone (Plassenkalk) only reappear in the Northern Limestone Alps toward the end of the Jurassic.

In the eugeosynclinal Penninic realm of the Hohe Tauern during the Jurassic and Lower Cretaceous big series of marly and detritic sediments, also with graded bedding are produced, alternating with submarine basic effusiva with pillow structure — today metamorphosized to blueschists, greenschists and eclogites. Masses of breccias in the Penninic and Lower Austroalpine area demonstrate the high mobility of the crust.

d) At the end of the Lower Cretaceous the geosyncline was transformed to the orogen. During the Middle Cretaceous the subduction started. The sedimentation in the present lowermost tectonic units in the Central Alps ended, because they were covered by thrusts of higher nappe sheets. In the uppermost tectonic unit, the Upper Austroalpine system, the sedimentation during the Cretaceous became very incomplete. It ends early in the Drauzug and in the southern part of the Limestone Alps, continuing only in the northern part of the latter. After the revolution by the nappe formation in the course of the Mediterranean pregosauic phase marine sediments were deposited in the Limestone Alps only in some local "Gosau" basins during Senonian and Lower Tertiary. In the Eocene the sedimentation terminates definitely in the Northern Limestone Alps.

e) The coherent sedimentation during the Tertiary at first was restricted to the Flysch Zone and Helvetic Zone in the north of the Alps, joining the Cretaceous series of these units. The Helvetic realm contains the sediments of the shallow shelf of the Bohemian Massif, rich in macro- and microfossils, divided into a northern subzone, rich in limestone (corresponding to the Helvetic Zone of Switzerland) and a southern one, rich in variegated marls (named Ultrahelvetic Zone). Adjoining to these marginal zones in the south, we find the Flysch belt, a long and deep trough, produced by the beginning subduction in the region of northern Pennine. The series of this trough are partially preserved in the Rhenodanubian Flysch Zone. Here

Fig. 4: Paleogeographic sketch of the main facies zones of the Eastern Alps during geosynclinale stage in the Triassic and Jurassic (A. Tollmann, 1978, fig. 2).


EURASIC PLATE
FORELAND
HELVETIKUM
OCEAN FLOOR AND RESTS OF CONTINENTAL CRUST
VALAIS TROUGH
BRIANÇONNAIS-RISE
PIEMONTAIS TROUGH
KREIOS PLATE
LOWER-
MIDDLE-
UPPER AUSTRO-ALP.
SOUTHALPINE
BOHEMIAN MASSIF
EXTRAALPINE FACIES
(BASEMENT OF THE MOLASSE ZONE)
STAATZ FACIES
PIENIDES
HELVETIC FACIES
ULTRAHELVET. FACIES
GRESTEN FACIES
NORTH PENNINIC TROUGH
Unterengadin
Pfundser U.
ULTRAPIENIDIC RISE ?
TATRIDES
MIDDLE PENNINIC TROUGH
HOCHSTEGEN FAC.
MIDDLE PENNINIC RISE
Tasna
Falknis
Sulzfluh
BRENNKOGEL FAC.
Bernstein
Rechnitz
Kohfidisch
Hohe Tauern
GLOCKNER FACIES
Fimber-Unit
KRIŽNA
Arosa
KLAMMKALK FACIES
Wechsel N.
SEMMERINGFACIES
Stuhleck N.
Mürz Noppe
Roßkogel N.
Tattermann
VEPORIDES
Platta
Lungau Rise
HOCHFEIND-FAC.
PLEISLING-FAC.
Quarzphyllit Noppe
Radstädter Tauern
Tarntal
Rannach
Thörl
WEISSWAAG FAC.
Bernina
Thialspitz
Stubaier
Flattnitz
STRÁŽOV FAC.
Engadin Dolomites
Tribulaun
Stangalm-Sockel
FRANKENFELS FAC.
Ducan
Mauls
Stall
Kalkstein
Rosegg
LUNZ FAC.
ROHR FAC.
TRIESTING FAC.
WAND F.
GEMERIDES
TRAUNALPS FAC.
ÖTSCHER F.
Mürztal
Hochschwab
Rax
VORARLBERG FACIES
TIROL FACIES
DACHSTEINKALK FAC.
Zlamb.
Warscheneck
HAUPTDOLOMIT FACIES
DACHSTEINKALK FAC.
MIT HALLSTATT CHANNELS
Dachstein
Plassen
± Rise
Griffen
Pfannock
Winnebach
Lienzer Dolomites
Gailtaler Alpes
Nordkarawanken
LICIC FACIES
SOUTHALPINE FACIES
Südkarawanken
Lombardische Alpen
Dolomiten
Julische Alpen
0
~100
~200
~300 km

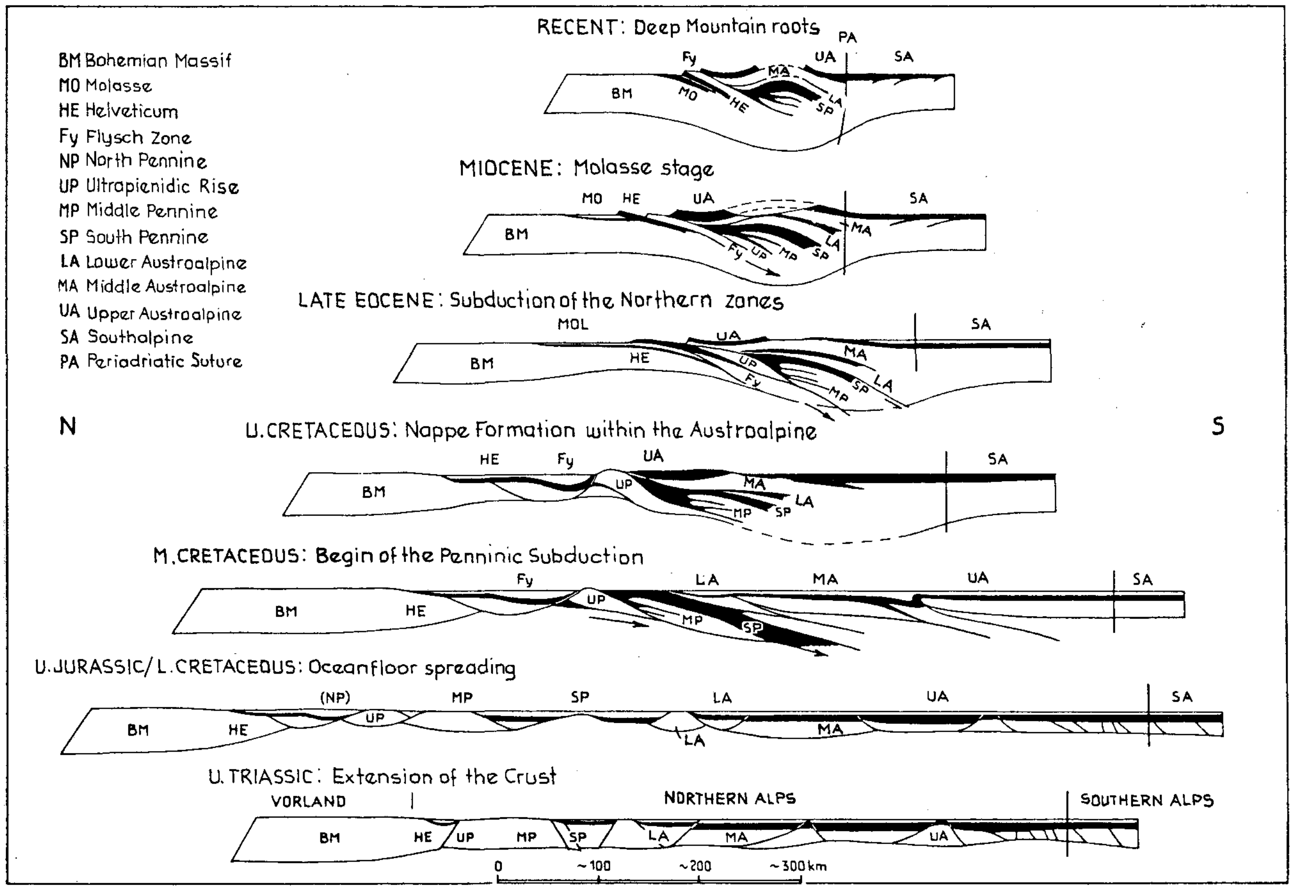


Fig. 5: Model of the genesis of the Eastern Alps shown by the sequence of stages from geosyncline to orogene in schematic sections (A. Tollmann, 1978, fig. 3).

we find a typical flysch sediment with all characteristics of this type of sediment as graded bedding, flute casts, specific ichnofacies etc. Furthermore this trough with his typical "orogenic" sediments, formed a new element in the Eastern Alps, established oblique to the older zones, running from the Northern Penninic region in the west to the Helvetic region in the east, so that the sedimentation took place on different basement.

The change from the Helvetic stage to the Molasse stage mentioned above occured within the Upper Eocene. The exogeosyncline of the Molasse received marine sediments till the Karpatian at the end of Lower Miocene.

Figure 5 shows the tectonic development of the Eastern Alps.

6. Characteristics of the main units of the Eastern Alps in the region visited by the excursion

In the following the tectonic units mentioned above will be characterized by stratigraphic range, tectonic style and degree of metamorphosis. Figure 6 gives an orientation about the stratigraphic sequences of all units, visited by the excursion — therefore, a description in the text is unnecessary.

The description below treats the units in the order of north to south, that is, from the units in higher tectonic positions to those in lower ones — except for the marginal units in the north.

a) The Helvetic unit contains a Mesozoic series from the Liassic Gresten beds to the pelagic limestones and marls of the Cretaceous and the marly Lower Tertiary. The thickness of these series is moderate. The influence of the German foreland in litho- and biofacies is evident. The younger part of the sequence, comprising

Cretaceous and Tertiary, shows a distinct difference between a northern subfacies rich in limestones and a southern one rich in marls. The contrast between the abundance of pelagic foraminifera in the Cretaceous and Tertiary formations in the Helvetic realm, and the poverty of those in the neighbouring and overthrust Flysch nappe (which contains especially arenaceous foraminifera) is striking.

The Helvetic Zone is almost totally thrust by the flysch nappe. It appears only with frontal parts and by slit-like tectonic windows on the surface. It was also found in boreholes beneath the Flysch.

b) Flysch Zone: This unit is totally stripped from its basement, which was built by the older Mesozoic beds of the northern Pennine and the southern Helvetic Zones. The series of the Flysch unit ranges from Albian to Eocene. The Upper Cretaceous part presents in the best way the particularities of flysch facies. The participation of Tertiary formations diminishes toward the west and increases toward the Carpathians in the east. The flysch sediments were deposited in the deep sea, dominating below the CCD. The paleocurrents were directed westward.

In this sector the Flysch Zone forms only one nappe, strongly folded internally. This sheet is divided into three nappes only far in the east, in the Vienna Forest. The flysch, overthrusting the Helvetic Zone, is itself overthrust by the Northern Limestone Alps. One can find flysch windows in two thirds of the Limestone Alps. The beds of flysch rest in an un-metamorphic state.

c) Northern Limestone Alps (Calcareous Alps): The sequence of this unit passes from Permian up to Eocene. The morphological features are determined by thick carbonate masses of Triassic age, which form large massifs of dolomite and limestone, while the Jurassic marls and slates are insignificant for rock face formation. Figures 4 and 6 show the Triassic facies zones of the Limestone Alps. Some remarks on this complicated matter: the Hauptdolomit facies includes in this region in the Middle Triassic Ladinian Wetterstein limestone, in the Upper Triassic Hauptdolomit and the marly and calcareous, fossiliferous Rhaetic Kössen beds. The Dachsteinkalk facies, adjoining to the south, comprises vice versa the (Ramsau-)dolomite in the Middle Triassic and thick limestone (Dachstein limestone) in the Upper Triassic. The reefzone of this carbonate platform in the Upper Triassic appear in the southern region of Dachsteinkalk facies, divided into many individual reefs, while the northern part is formed by thick bedded Dachstein limestone of lagoon type. A detailed reconstruction of the original position of the channels with Hallstatt limestone in between the platform sediments is still to be made.

Now one supposes three channels with Hallstatt facies within the Dachsteinkalk area: The northern one in the region Ischl—Grundlsee is characterized by a facies rich in marls in the Upper Triassic; rests of the middle channel can be seen in the Mandlingzug near Radstadt; the southern channel joins at the southern rim of the Dachstein massif — tectonical outliers of this southern channel are preserved near Mitterndorf in the Styrian Salzkammergut. Mount Plassen near Hallstatt also seems to derive from this channel.

This middle part of the Northern Limestone Alps was divided by the orogenesis during the Mediterranean phase in Turonian time into the following nappes, piled from bottom (north) to top (south): Lunz nappe with the Langbath Mass, the Staufen-Höllengebirge nappe, the Totengebirge nappe. These three units show mainly Hauptdolomit facies (only the latter passes to the Dachsteinkalk facies), followed by the Zlambach Mass (Hallstatt facies), the Warscheneck nappe, the Mandling Mass, the important Dachstein nappe and finally isolated outliers of the southernmost Hallstatt unit, that is, the Mitterndorf nappe. The contrast in facies and thickness of the latter units is striking.

The great rock-masses of the Limestone Alps did not suffer a metamorphosis. However in the southern third of the mountain one can see an anchimetamorphic transformation. Finally, in the basal beds of the southern margin one can find low graded greenschist metamorphosis.

d) Grauwackenzone. It forms the stratigraphic basement of the Limestone Alps and therefore occurs along the southern margin of these mountains bordering the Altkristallin of the Central Alps. This zone comprises a sequence from the Ordovician to the Upper Carboniferous. In the Lower Palaeozoic slates dominate. Vulcanites of basic or acid character and carbonates also participate in the composition of the Grauwackenzone. Coarse detritic Upper Carboniferous is reduced in this middle part. Variscan and Alpine tectonics affected this zone. During both orogenesis the metamorphism attained only the greenschist facies.

In the Central Alps, the excursion arrives at the western border of the Gurktal nappe, which represents a part of the Upper Austroalpine. It consists of a very thick mass of slates of Ordovician and Devonian age (Eisenhut slates), few carbonates and a thick Upper Carboniferous mass of sandstones and conglomerates. This nappe with a width of 60 km is thrust far in a northern direction, in consequence of the west-east orientation of its fold axis, combined with the underlying Stangalm Mesozoic along its western rim.

e) Middle Austroalpine: The vast and thick Altkristallin of the Central Alps outside the Tauern Window, which is touched during the excursion in the Schladming Tauern near Radstadt, along the Lieser valley in Carinthia and between Kreuzeck and the Schober mountain NE of Lienz, does not form the normal basement of the Paleozoic mentioned above. It represents — as decided only twenty years ago — an independent tectonic unit, a typical basement nappe with only few remnants of its own Mesozoic cover in

ZONE →		MOLASSE ZONE	HELVETIKUM	ULTRAHELVET.	FLYSCH ZONE	PENNINE ZONE			LOWER AUSTRO-A.		MIDDLE AUSTRO-A.
FACIES →		Germanic facies within the basement	Miogeosynclinale facies		Eugeosynclinale facies				Centralalpine facies		
TIME ↓						Penninic facies					
					Flysch facies part. below CCD	Hochsteg facies (rise)	Brennkgl. facies	Glockner facies	Hochfeind facies	Pleisling facies	Stangalm (Gurktal Alps)
TERTIARY	NEOGENE	M.-U. MIOCENE Fresh-water series									
	PALEOGENE	L. MIOCENE –U. EOCENE Molasse marine	U.EOC. Stockletten M.EOC. Adelholz-, Erz-beds L.EOC. Mittel-, Roterz beds PALEOC. Lithothamn. lst. marls, sandst.	EOCENE-PALEOCENE: Variegated marl Nummulitic limest.	L.PALEOGENE – U.CAMPANIAN: Soft sandstone Uppermost variegated shales Zementmergel series Upper varieg. shales Reiselsberg sandst.						
CRETACEOUS	UPPER CRET.	U.CAMPANIAN-L.TURON.: Marls, sandstones CENOMANIAN: Green sandstone	SENONIAN: Grey & variegated marls TURON: Red marls, lst. CENOM: Spotted limest. ALBIEN: Black marls	SENONIAN-ALBIAN Variegated and spotted marls							
	LOWER CRET.			U.NEOCOM.: Black marls L.NEOCOM.: Aptychus limestone	Gault quartzite U.Neocom. Flysch	Kaserer series Bünden shists	Bünden schists Black phyllite, quartzite, breccias	Bünden schists; calc-schists, prasinites, microbreccias Fusch facies with slates and flysch	Schwarzeck-series: breccia, quartz.		
JURASSIC	MALM	Massive limestone and dolomite p.p. oolitic Glauconitic sandstone		Aptychus limestones, Vulcanites *Ruhpolding chert*		Hochsteg limestone, dolomite			"Aptych." lst. *Chert with manganese*		„Aptychus" limest. Chert with mangan.
	DOGGER			Waidhofen and Neuhaus beds		Phyllite			Türkenkogel-series: slates, breccias	Violett Crinoid. limest. Black calc-slates	Siliceous calc-shales
	LIAS			Gresten beds (Limest., marls, arkose + coal)		Hochsteg quartzite			Limestone + Crinoides		Sandy shales
TRIASSIC	RHAETIAN	Keuper: Variegated shales and sandstone					Keuper-series (Quarten schists)		U.Rhaetian limestone Kössen beds		Calcphyllites
	NORIAN								Plattenkalk Hauptdolomit		Hauptdolomit
	CARNIAN					Locally remnants of Permotriassic sediments (analogous to the other Penninic series)	Dolomite and gypsum	Locally remnants of analog. Permotriassic sedim.	Carnian dolomite Breccias, shales *Partnach dolomite*		Dolomite, breccia, Cidaris limestone? *Black shales*
	LADINIAN								Wetterstein dolomite		Tuffs Wetterstein dolomite
	ANISIAN						Marble Rauhwacke		Trochites dolomite Dol. streaky limest. Banded limestone Rauhwacke		Dolomite Banded limestone Rauhwacke
	SKYTHIAN						Wustkogel series: Quartzite		Alpine Röt shales Lantschfeld quartzite		Alpine Röt shales Semmering quartzite
PERMIAN	ZECHSTEIN						Wustkogel series: Alpine Verrucano		Alpine Verrucano: Serizit- and Phengite schists		Alpine Verrucano: Quartzite, Quartzkeratophyre
	ROTLIEGEND										
CARBONIFEROUS	SILESIAN	WESTFALIAN: sandstone, conglomerate, schists									
	DINANTIAN										
DEVONIAN											
SILURIAN											
ORDOVICIAN											
CAMBRIAN											
BASEMENT		Bohemian Crystalline		Buch-monument granite	Northpenninic and Ultrahelvetic socle	Central gneiss		Oceanic crust: Serpentinite	Tweng Crystalline		Liesertal Crystalline

Fig. 6: Stratigraphical sequences of the main units of the Eastern Alps in its middle sector.

UPPER AUSTROALPINE UNIT							SOUTHERN ALPS	ZONE
Aristogeosynclinale facies							Southalpine facies	FAC.
Northalpine facies								
Northern Limestone Alps				Licium				
Bajuvarikum and Tirolikum Nordtirol fac. (Hauptdol. fac.)	Lower Juvavikum Zlambach fac.	Hallstatt facies Salzberg fac.	U.Juvav. Dachst.k.f.	Gurktal nappe with Krappfeld Trias.	Pfannock wedge (Gurktal Alps)	Drau Range	Carnic Alps	TIME
				Miocene: gravel, sand, clay, coal				NEOG.
Gosau formation: Ypresian marls of Scharn Zwieselalm beds (Paleocene-U.Maestricht.): marls, sst., conglomerate Nierental beds (Maestricht.-U.Campan.): red pelag. marls, sandstone Gosau rich in fossils (L.Campan.-L.Coniac.): marls, sst., Rudiste lst., congl.				Krappfeld Paleogene: Nummulitic limest., marl, clay				PALEO.
Losenstein beds (Alb.-Turon.) Conglom., sandst., marl Tannheim beds (U.Apt.-Alb.) dark grey and red marls Rossfeld beds (Valendis.-Apt.): sst., congl. Schrambach beds (Berrias-Apt.) Calcmarls				Krappfeld Cretac. Gosau beds		Lavant flysch (U.-Albian)		U. / L. CRETAC.
Oberalm-, Aptychus-, Barmstein- and Tressenstein limestone Haselberg- and Agatha limestone (red nodulose Ammonite limest) Ruhpolding radiolarite (chert)		Plassen (reef) limest. Oberalm-Tressenstein Agatha limestone Ruhpolding radiol.	Oberalm limest. Radiol.			Calpionella limest. (M.-U. Malm) Red nodular limestone		MALM
Strubberg beds (slates, cherts with manganese, breccias) Klaus limest. (red nodulose limest.)		Cherty slates	Klaus limest.					DOG.
Allgäu beds (spotted marls) Hierlatz limestone (Crinoidal limest.) Adnet limestone (red nodulose Ammonite limestone)	Allgäu beds (marl)	Allgäu beds (spotted marls) Adnet limestone	Spotted marls Hierlatz limest.			Adnet limestone (M.-U. Lias) Spotted marls (L. Lias)		LIAS
U.Rhaetian (reef) limestone Kössen beds (dark marls and limestones)	Zlambach beds (marl, limestone) Pötschen limestone	Zlambach marl			Kössen beds	U. Rhaetian reef limestone Kössen beds		RHAET.
Plattenkalk Hauptdolomit	Pedata limest. and dolomite	Hallstatt limest. (Sevation - M. Anisian): white massif lst., red, grey, violet bedded limest	Dachstein limest (and dolom.)	Hauptdolomit	Plattenkalk Hauptdolomit	Plattenkalk Hauptdolomit		NOR
Opponitz beds (dol., lst.) Lunz beds (sandst) Trachyceras beds (slates) / Northalpine Raibl beds	U. slates Cidaris limest, dol. Lunz beds		Cardita beds	Northalp. Raibl beds: Fossilif. limestone Calcmarls Black marls	Cardita beds	Northalpine Raibl beds		CARN.
Wetterstein limestone and dolomite Reifling limestone (nodul. cherty lst.)	Black Reifling limest. Reifling limestone	Hallstatt dol. Ladin dol.	Ramsau dolomite Wetterstein limest.	Reifling lst with tuffs / Wetterstein dolomite	Wetterstein dolomite	Wetterstein limest and dolomite Partnach limestone, Porphyrite tuffs	Schlern dolomite	LAD.
Steinalm limestone and dolomite Gutenstein limest. (black, bedd. lst.) Reichenhall rauhwacke	Steinalm limestone Anisian dolomite Gutenstein limestone	Steinalm limest. Reifling lst. and dolom. Gutenstein limestone Reichenhall rauhw.	Steinalm limest. Gutenstein dol. lst.	Anisian dolomite with tiny horizons of sst., dol. brecc. Reichenhall rauhwacke	Anisian dolomite Pfannock beds (sandstones)	Red limestone Zwischendolomit Nodulose limestone Terrigen infl. series Mottled limestone	Anisian limestone Tuffs; Richthofen congl	ANIS.
Werfen beds (red and green sandy shales and sandstones)	Werfen limestone Werfen shales	Werfen limestone Werfen shales	Werfen beds	Werfen beds with gypsum Buntsandstein	Werfen beds	Werfen beds with gypsum Buntsandstein	Campil beds Seis beds	SKYTH.
Haselgebirge + gypsum Mitterberg beds (green series) Hochfilzen beds / Prebichl conglom.		Haselgebirge with salt; metaphyre	Haselgebirge	Griffen beds congl., sandst.	Gröden beds	Gröden beds sandstone, conglomerate	Bellerophon dolom. Gröden beds Tarvisio breccia	ZECHST.
Fellersbach beds (violett series)				Werchzirm beds: red shales, sandst.		Quartzporphyre Werchzirm beds	Tragkofel limest. Rattendorf beds	ROTL.
GRAUWACKEN ZONE Westfalian sandstone Gainfeld conglomerate				Stangalm-Carbonif. conglom., sandst., Stefan-Westphal D.		Nötsch group (sandst., conglom., shales) Westphal- U. Tournais	Auernig beds Hochwipfel flysch	SILES.
Viséan sandstone							Cephalopodes limest.	DINANT.
U. DEVON.: limest., red chert, slates M. DEVON.: black dolomite L. DEVON. red mottled limest., dolomite				Murau limestone, Althofen beds, shales		Calcphyllite of Zlan / Goldeck	Goniatites l., Lydite Reef-lst. / Red nod. lst.	DEV.
U.SILUR.: grey and black dolomites Steigwand lst., Langeck lydite M.-L.-SIL.: Upper Wildschönau phyllite				Shales, quartzites lydites, limestones		Shales, graywackes quartzites and Metavulcanites (Diabase, tuffs etc.) of the Goldeck	Bedded limestone shales / Siliceous shales / Graptolites shales	SILUR.
Porphyroide Lower Wildschönau phyllite with metadiabase and tuffs				Quartzporphyroide Magdalensberg ser. Eisenhut shales, Metadiabase series			Crinoides limestone, Nodulose limest. Himmelberg sandst., lydite, tuffs, shales	ORDOV.
							Visdende beds, Fleon beds	CAMB.
Crystalline preserved only by pebbles				Ackerl micaschists	Pfannock orthogneiss	Gailtal crystalline	Brixen phyllite	BASEM.

a facies typical for the Central Alps but by no means identical to those of the Northern Limestone Alps. In contrast to the Permomesozoic of the latter these sediments of the Middle Austroalpine unit in its lower tectonic position always show a slight metamorphism, specific tectonic deformation and an individual facies. It rests without intercalations of Paleozoic rocks directely on the Altkristallin. From all remainders of Middle Austroalpine Mesozoic particularly the Stangalm Mesozoic, underlying the Gurktal nappe, was of great importance to proove the tectonic independency of this unit. The formation of the Middle Austroalpine crystalline mass is long and complicated and better known from the Saualpe in the east and the Oetztaler Alps in the west of the Tauern Window. Tectonics and metamorphosis there reach back to the Caledonian and Variscic era. In Variscic time an important nappe structure developed in this crystalline sheet, with a distance of thrusts more than 35 km in the region east of the Tauern. In the Alpidic era this crystalline mass was transported as a vast nappe without young internal nappe building, but only with a Schuppen structure in the frontal part. A considerable metamorphosis affected this crystalline mass in Alpidic time. Along the thrust on the top of this Middle Austroalpine Crystalline (and some remainders of its own cover) diaphthoresis took place by the transport of the Upper Austroalpine nappe system during the Cretaceous orogenic phases.

f) Lower Austroalpine unit: The Radstadt Tauern, which form a part of the framework built up by this unit around the Pennine of the Tauern Window, gives the best insight into the Lower Austroalpine nappe system. This Radstadt Tauern shows an intensive nappe structure, directed towards the north and built up of some Altkristallin (Twenger Kristallin), a monotonous series of phyllitic Lower Paleozoic and a thicker mass of Permomesozoic, with formations up to the Lower Cretaceous. Five nappes are piled up in a normal, non reversed order, only the uppermost sixth unit, the Quartzphyllit nappe, is an example of a gigantic inversed nappe, rolled off by the "traineau ecraseur" of the Middle Austroalpine mass.

The Alpidic metamorphosis caused diaphthoresis in the Tweng crystalline and a progressive transformation of the Mesozoic formations into greenschist facies. At 450° conditions were such that flow folds formed in limestone and quartzites and huge recumbent folds with thick reversed limbs were built. The face of the anticlinal fold is directed towards the north — a proof of the general overthrusting of the Tauern Window from south and therefore also a proof of the existence of this window, a fact, which has been contradicted for many decades.

g) Penninic system: The culmination of the axis of the Central Alps in the region of the Hohe Tauern exposed the Penninic system, which runs below the Austroalpine nappes from the Western Alps to the east. It is characterized by Mesozoic rocks in facies of "Bündner Schiefer", of "schistes lustrés". Recently the Penninic system also has been detected on the eastern border of the Alps in the region of Rechnitz, which means that this unit passes through the whole basement of the Eastern Alps.

The excursion crosses the Tauern Window along the Glockner route only in its upper part, the Schieferhülle. The Tauern Window extends from the Brenner pass in the west to the Katschberg pass in the east, is 170 km long and nearly 50 km wide. The central gneiss, intruded during the Upper Carboniferous and Permian, transformed in the Alpidic era, appears in the lowest position. Above this one finds remainders of Altkristallin, and finally the Paleozoic (Habach Series) and Permomesozoic covers, called Schieferhülle. The relation of Schieferhülle and central gneiss is similar to that of the Upper Austroalpine sedimentary series and the Austroalpine crystalline mass; it is a tectonic, not a sedimentary ensemble, affected by vast thrusts — both phenomena were discovered recently. Only the thin sedimentary cover in Hochsteg facies belongs primarily to the central gneiss. The latter probably shows an Alpidic fold nappe structure. Above this socle in the region of the Glockner route we find first the Lower Schieferhülle nappe (Rotewand nappe) with Brennkogel facies rich in breccias followed by the Upper Schieferhülle nappe (Glockner nappe) with Glockner facies, rich in "Kalkglimmerschiefer" and greenschists. The uppermost unit is the Matrei Schuppenzone, already garnished by Lower Austroalpine tectonic slices.

The older Alpidic metamorphosis of the Pennine was characterized by high pressure (8—11 kbar, 400—500°). Perhaps it was connected with the Cretaceous orogenesis. The younger "Tauernkristallisation" during the Lower Tertiary was marked by higher temperatures (550—600°), leading to (epidote-)amphibolite facies.

h) Southern Alps: In the Carnic Alps the northern rim of the Southern Alps will be reached. They are built up of Paleozoic and Mesozoic formations. The facies difference to the Northern Alps is striking. The non-metamorphic series of this mountain range show a distinct division into two tiers. 1. The variscic basement consists of marine series from Caradocian to the Westfalian in several facies. It is famous for its abundance of fossils. This basement was folded by the Sudetic and Asturic phases (at the boundary of the Westfalian and the Stefanian) and formed into a pile of nappes in a northern direction. 2. The uppermost Paleozoic, comprising Stefanian to Permian and the Mesozoic in south alpine facies, rests above all with transgressive contact as the superior tier. This cycle begins with the Variscic "Molasse", the Auernig formation of the Stefanian. The difference between the facies of the Northern and Southern Alps is also augmented by the dextral wrench fault along the Periadriatic line.

7. Remarks on the mineral deposits in the scope of the excursion

As a consequence of the very complex structure and a composition of many individual units formed in different orogenic cycles the Eastern Alps are rich in various mineral deposits, generally not of important dimensions. The classic dogma of an unitaristic origin, i. e. that all ore deposits in the Eastern Alps were built in the younger period of the alpine orogenesis, has now been abandoned in favor of a theory of origins different in time (prealpidic and alpidic era) and in kind of formation (syngenetic and epigenetic).

Since 1956 a lot of oil- and gas fields has been discovered and exploitated in the Molasse Zone of Upper Austria. The main oil bearing horizon appears in the basal sandstone formation of the Upper Eocene at the base of the Molasse Zone. Some important gas fields can be found in this unit in the Oligocene and Lower Miocene.

In the Helvetic Zone coal has been exploitated in the Gresten formation of Liassic age.

The Northern Limestone Alps include in their lowermost formation, the Permian Haselgebirge, deposits of salt. They have been exploitated in the region of Hallstatt for 4500 years. Along the route of the excursion one finds salt mines at Ischl, Hallstatt, Aussee, Hallein and Berchtesgaden, which show complicated Alpine tectonics. Gypsum and anhydrite, accompanying the Permian salt, is also frequent (e. g. Grundlsee).

In past times deposits of sedimentary iron ores in the Permian and Werfenian, sedimentary Pb-Zn-ore in Lower Carnian Wetterstein limestone and manganese ore in the Upper Jurassic were interesting for practical use. Bauxite of Turonian age can be found in some places at the base of the Gosau formation. Coal-seams of slight thickness in the Carnian Lunz beds and in the Senonian Gosau formation have been exploitated in many places in the past. Bitumina have been found in the Norian Hauptdolomit: Ichthyol in shales, accompanying this dolomite, oil and gas in this formation as reservoir rock — namely in the basement of the Vienna basin.

The Grauwackenzone contains the most important ore deposits of our country. Since the Bronze Age (1800—700 b. c.) copper ore has been gained in mines near Mitterberg and Kitzbühel. In the Middle Ages Schwaz in Tyrolia was the center of silver mining, one obtained this metal in good quantities out of Fahlerz (total output in Schwaz: 250.000 t of silver). Magnesite is still produced in the Grauwackenzone, in the west in Lower Paleozoic formations, in the east from Lower Carboniferous — here of synsedimentary origin. Also of Paleozoic age is the sedimentary iron-metallization of the Devonian limestone, which has been exploitated at the Eisenerz Erzberg in Styria since Roman times — producing today 3,5 Million tons of ore per year. Deposits of talcum and graphite in the Carboniferous are utilized today. The bulk of other ores in this zone, like Fahlerz, oxidic iron ore, manganese, nickel, cobalt, uranium etc. can not be discussed in detail. The main part of these ore deposits is — in contrast to older opinions — of prealpidic age and mainly of sedimentary origin.

In the Lower Austroalpine system the uranium metallization in the Permian Alpine Verrucano near Forstau in Styria is interesting. It belongs to an eastern spur of the Radstadt system in the Schladming Tauern. The uranium ore was accumulated in a coal substance in Permian quartzites. The ore deposit has a lenght of 15 km with an estimated content of 0,08% Uranium, so that one has deduced a reservoir of 1500 tons of Uranium — too much with respect to the real average ore content.

In the neighbouring crystalline of the Middle Austroalpine of the Schladming Tauern the silver-copper-lead-cobalt-nickel-deposits of Zinkwand and Vöttern have been exploited intensively and are now exhausted. The town Schladming owes her wealth to these mines.

The two most important ore deposits of the Tauern Pennine are gold and tungsten. The alpidic epigenetic gold together with arsenical pyrites in quartz veins has been known as "Tauern gold" since 4000 years. A first rush for this Tauern gold took place by the Romans about 130 b. c. The main period of exploitation was during the Middle Ages after 1300 and between the 15th and 17th centuries with a yearly production of 2600 kgs of gold. The gold mining was determinated by the advance of glaciers in some places.

The giant deposits of tungsten in the Penninic Schieferhülle in the Felber valley were discovered as late as 1967. The content of this Scheelite deposit, named "Mittersill", with a syngenetic sedimentary origin in the Lower Paleozoic is valued at 2,5 million tons of ore with 0,7% WO_3. The exploitation expects an annual production of 250.000 t ore.

B) Excursion description

Day 1

Ultrahelvetikum and Flysch in Upper Austria near Gmunden

(S. PREY) *)

R o u t e: Salzburg-Rehkogelgraben E of Gmunden-Gschliefgraben-Hatschek Quarry in Gmunden—Ischl.

S u b j e c t: Stratigraphy, facies and tectonics of the Ultrahelvetic Zone and of the Flysch Zone at the northern border of the Alps near Gmunden.

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T o p o g r a p h i c a l m a p s: Österreichische Karte 1 : 50.000: Sheet Gmunden (66), sheet Grünau i. Almtale (67).

G e o l o g i c a l m a p s: Sheet Gmunden-Schafberg (4851), sheet Kirchdorf (4852) (the Flysch Zone is out of date).

Introduction

The dominating feature of the Flysch Zone ist the contrast, resulting from the fundamentally different facies of Flysch and Ultrahelvetikum. The first one is a formation of real flysch deposits consisting of sandstones (turbidites), marls and shales, reaching a thickness of a few thousand meters. In contrast the Ultrahelvetikum is a relatively thin formation of pelagic marls rich in foraminifers, comprising only Paleocene to Lower Middle Eocene members, showing a distinct terrestric influence. The Ultrahelvetikum changes to the northwest into the real Helvetikum, developed typically in the Helvetikum of Switzerland. This Helvetikum dips eastwards below the Rhenodanubian Flysch Zone. Flysch and Helvetikum s. l. are both overthrust over the Molasse of the Alpine Foreland.

The great facial difference points out an enormous distance between the geosynclinal through. Nevertheless the author believes, that the flysch trough was situated immediately south of the ultrahelvetic realm. The substratum of this zone is built up by the Gresten Klippen Zone. Other geologists have the opinion that the Flysch originates in a southernmore area, belonging to the Penninic realm. The St. Veit Klippen Zone near Vienna is proved as a witness of the flysch basement.

In consequence of the facial contrast, we observe a different tectonic style. A big flysch nappe has overthrust a small nappe of Ultrahelvetikum. Being folded and slightly sliced, even not arranged in nappes, the flysch unit has sliced and tectonically squeezed the Ultrahelvetikum intensively. In the Gschliefgraben near Gmunden we can see, that two various facies of Paleocene-Eocene have been closely approached. Narrow ultrahelvetic tectonic windows appear in disturbed zones in and below the flysch nappe, surrounded by lower members of the flysch series and arising from disturbed anticlines.

Concerning the structures of the Flysch Zone in the section near Gmunden there are interesting tectonic windows of Ultrahelvetikum in the northernmost part near Ohlsdorf as well as in the southernmost in the Gschliefgraben SSE Gmunden. In the middle region two strip-like windows appear: in the Dürre Laudach Valley, poorly exposed, and in the Rehkogelgraben, 2 km southwards, wider and better exposed.

In the R e h k o g e l g r a b e n W i n d o w we can see ultrahelvetic series of Albien to Santonian, while surrounding Gault Flysch and Variegated Shales are tectonically squeezed and in the west accumulated in a complicated anticline. The flysch is steeply overthrust in the south.

The area between the windows is marked by Upper Cretaceous flysch, covered in the north and in the vicintiny of the Traun River by diluvial deposits.

The G s c h l i e f g r a b e n W i n d o w on the northern border of the Northern Limestone Alps is lifted up as a anticlinal structure below the flysch nappe containing about three strips of Eocene rocks with intensively folded and sliced ultrahelvetic marls. In the southern flank the flysch is squeezed out, the northern flank is dipping north and in the east the anticline is closed. The flysch in the northern framework of this window on the top of the Grünberg mountain comprises a series from Gault to Maastrichtian.

The q u a r r y o f t h e H a t s c h e k c e m e n t f a c t o r y near Gmunden is situated in the middle of the Flysch Zone. This Maastrichtian Brittle Sandstone Member shows typical flysch character.

Stop 1.1. Rehkogelgraben east of Gmunden

Traversing diluvial morains and gravel terrasses the road reaches the Dürre Laudach valley SE Kirchham near the region of small northern tectonic windows of Ultrahelvetikum. We will not visit them. Close to this window the borehole Kirchham 1 is located.

*) Geologische Bundesanstalt, Rasumofskygasse 23, A-1031 Wien.

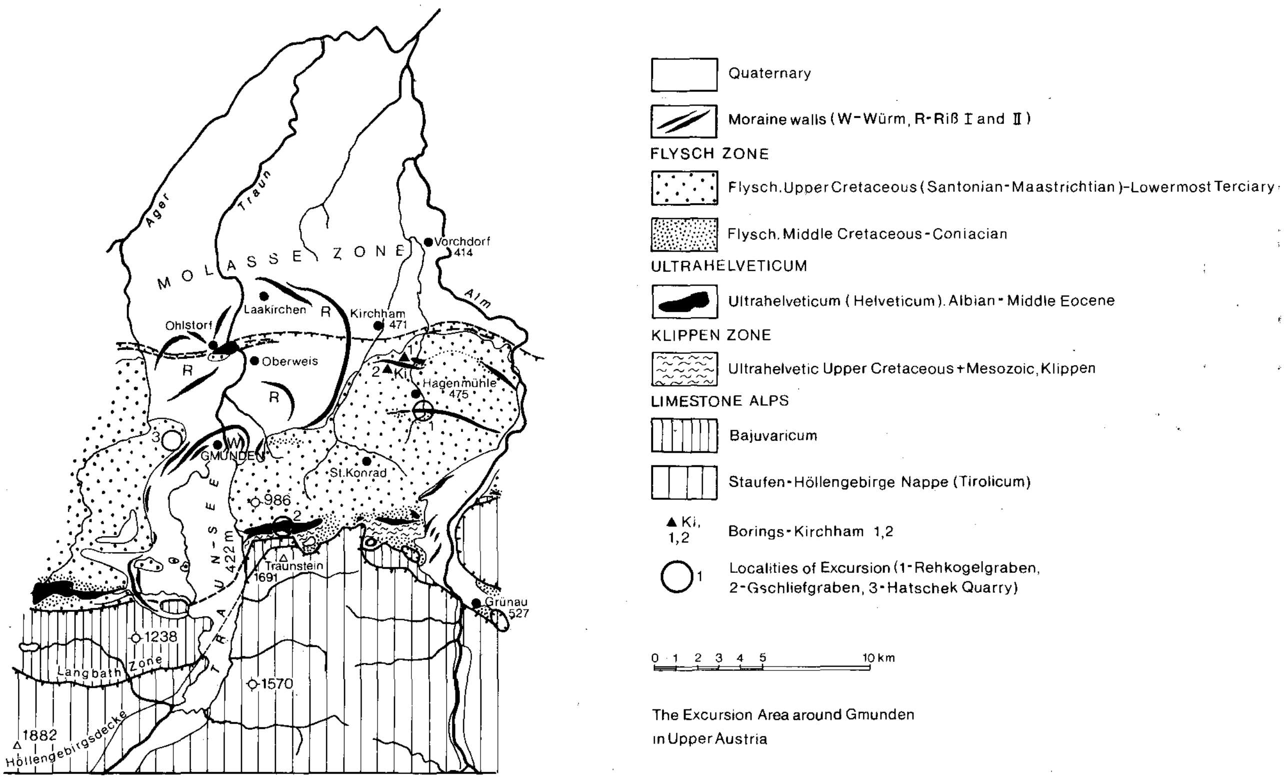


Fig. 7: General view of the region of the Flysch Zone near Gmunden (S. PREY).

The mountains of the neighbourhood consists of Maastrichtian Brittle Sandstone Member with a small anticline of Cementmergel Member. We see little outcrops of the Maastrichtian flysch along the river south of the Hagenmühle.

The northern border of the Rehkogel Window is not exposed. There are outcrops where the river approaches the left slope of the valley (fig. 9).

The ultrahelvetic sequence in the Rehkogelgraben: At first we find red and white Senonian marls with *Globotruncana* ex gr. *lapparenti*, seldom *Gl. ventricosa*, *Gl. cretacea*, *Gl. lapparenti tricarinata*, *Hedbergella infracretacea*, *Gümbelina* and some others. *Thalmanninella ticinensis* proves Cenomanian age for the two small tectonical intercalations of spotted marly limestones and the layers of marly slates. These red marls turn to red Turonian marls with white and reddish limestone beds (containing two-keeled Globotruncanas), exposed in the river and on the left shore. After a fault with remainders of Cenomanian spotted limestones there follows dark spotted and black marls about 30 m thick with *Hedbergella infracretacea*, *Anomalina lorneiana* and *Bigenerina complanata* of the Albian. Slices of Cenomanian spotted limestones are intercalated. Here is the centre of an anticline. In the south there are again red and greenish marls of Lower Senonian age of nearly 30 m.

The overthrust by Maastrichtian flysch beds, dipping southward, can bee observed in the south. Blocks of Gault quartzite remember at older flysch beds. Adjointing, in the south a flysch anticline built by the Variegated Shales and Cementmergel Member is poorly exposed.

Stop 1.2. Gschliefgraben SSE Gmunden

We can reach this locality either by car over the Grünberg Mountain, or better by using a forest path. The way crosses the southern part of the Flysch Zone built up by some northward overturned folds consisting of Cementmergel Member and Brittle Sandstone Member. Even N Radmoos Sattel (about 800 m high) below the Cementmergel Member emerges the lower part of flysch series (Gault Flysch, Reiselsberg Sandstone, Variegated Shales) — fig. 10.

Entering the Gschliefgraben (the name "Gschlief" derives from sliding) we walk into a district, where ultrahelvetic marls are outcropping up to 600 m. The impermeable underground and the high quantity of rain on the northern side of the Traunstein mountain (1691 m), marking the front of the Limestone Alps, is responsible for many slides. In historical time many mud flows reached the Traunsee.

		Northern Ultrahelvetikum			Southern Ultrahelvetikum and Klippen Zone	Flysch Nappe
Lower Tertiary		Stockletten and Lithothamnium Limestone				
	Middle Eocene	Northern border: *Clavulina szaboi* Beds	Middle part:	Rote Kirche Nummulitic Limestone (Adelholz Facies)		
	Lower Eocene to	Roterz Nummulitic Limestone	Gap	Numm. Limest. (only similar Adelholz Facies)		
	Paleocene	Sandy glauconitic marls	Very seldom Lithothamnium	? Gap		
		Gap	Gap	Gap		Brittle Sandstone Member („Mürbsandsteinführende“) Upper Cretaceous and Lower Tertiary
Upper Cretaceous	Maastrichtian	Dark grey marls. Gerhardsreut Member			Mostly red, sometimes marly clay slates with *Reussella szajnochae*	Uppermost Variegated Shales
	Campanian	Light grey, sometimes spotted marls. Pattenau Member				Cementmergel Member („Zementmergelserie“)
	Santonian to Coniacian	Variegated, often brick-red marls				Upper Variegated Shales („Obere Bunte Schiefer“)
	Turonian	Red marls with reddish, below with limestone layers				Reiselsberg Sandstone accompanying flysch
	Cenomanian	Whithish limestone layers and marls, often spotted				Gault Flysch
Lower Cretaceous	Albian to Aptian Neocomian	Dark grey spotted to black soft marls				Neocomian Flysch

Fig. 8: The sequences in the Flysch Zone and the Ultrahelvetic unit in Upper Austria near Gmunden (S. Prey, original).

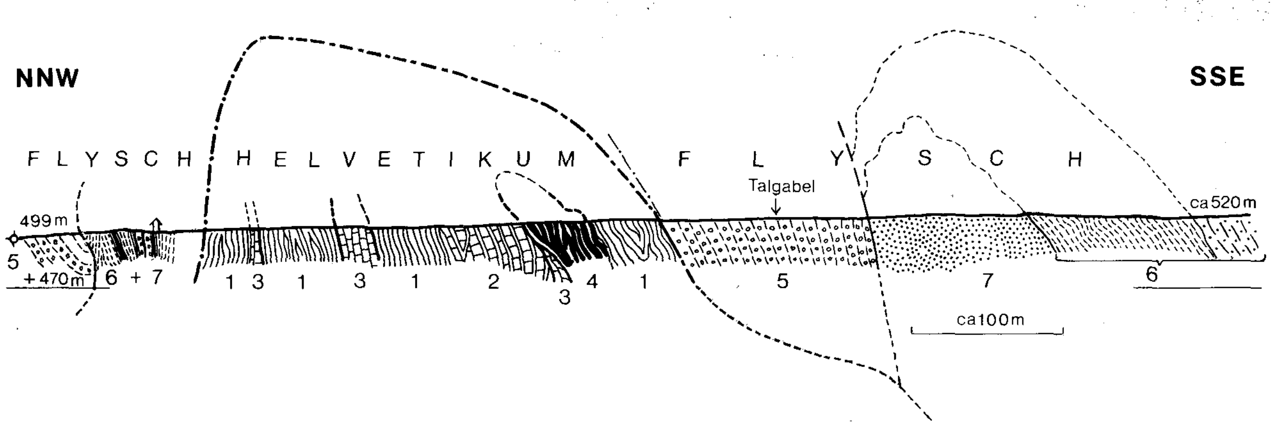


Fig. 9: The Ultrahelvetic sequence along the Rehkogelgraben (S. Prey, 1951, Tab. 7). Ultrahelvetikum: 1 = Red and white marls (Coniacian — Santonian); 2 = Red marls with reddish and white limestone layers (Turonian); 3 = White spotted limestones and marls (Cenomanian); 4 = Dark marls (Albian). Flysch: 5 = Brittle Sandstone Member (Maastrichtian); 6 = Cementmergel Member (Santonian — Campanian); 7 = Variegated Shales (Coniacian), Reiselsberg Sandstone, Gault Flysch.

The marls are mainly of Cretaceous age. Incorporated are three different thin rows of Paleocene-Eocene rocks. We visit two of them. On the southern border there is a little narrow remainder of Klippen Zone with Liassic Gresten Beds, Aptychus Limestone and red Cretaceous clays. A lower unit of the Limestone Alps, composed of Rhaetic dark limestones and Liassic spotted marls, is enclosed in the Klippen Zone, overlaid by the big Triassic mass of the Limestone Alps. This incorporation can rich in Globotruncanas (*G. stuarti*, *G. contusa*). There are dark sandy and glauconite bearing brown weathering marls with limestone layers exposed in rocks up to 20 m high. There we find microfaunas as well as megafossils (*Gryphaea pseudovesicularis*, *Exogyra eversa*, (?) *Linthia insignis*, small Nummulites, Crabs). *Globorotalia aragonesis* and *G. soldadoensis* appear in basal beds. A thin layer of Nummulitic limestone rich in Fe-ooids disappeared by erosion.

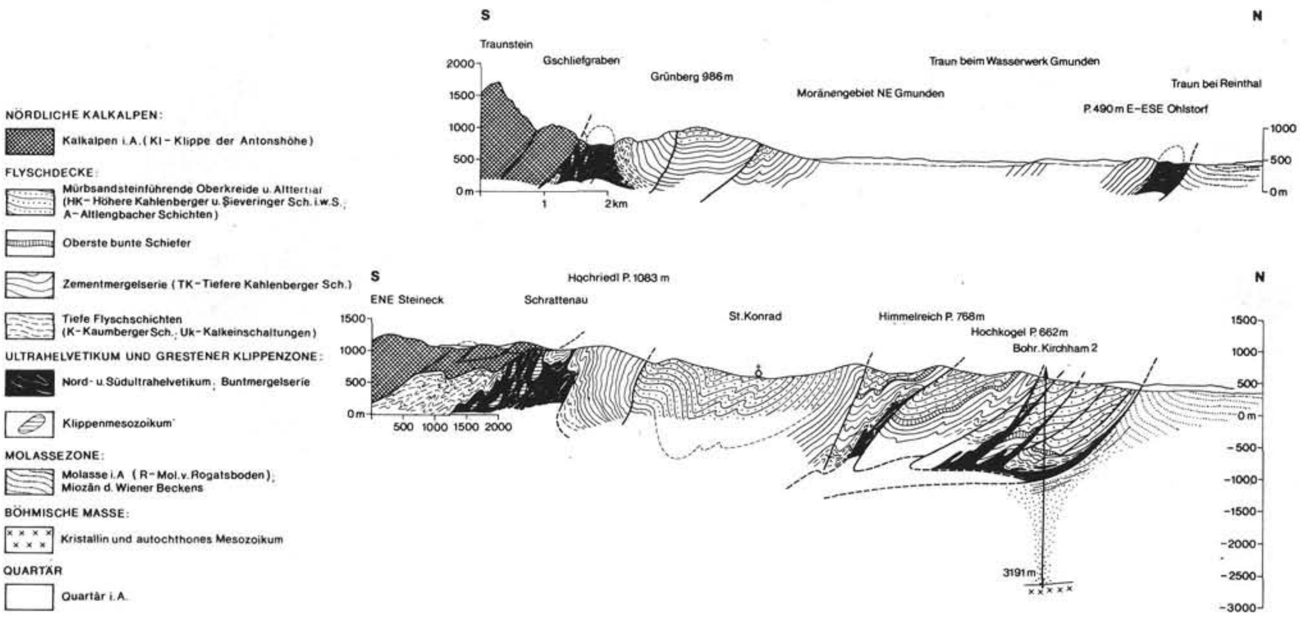


Fig. 10: Survey of the marginal zone of the Eastern Alps in the region of Gmunden by generalized sections. a) Section Gschliefgraben-Ohlsdorf. b) Section E of Gschliefgraben-Kirchham (S. PREY, 1980).

be seen on the western end of the Gschliefgraben near the shore of the Traun Lake. Red clays with *Reussella szajnochae* as a cover of klippen are exposed here. All these marls and clays are summarized as the Northern and Southern Ultrahelvetic Buntmergelserie (Variegated Marls Series).

At the upper end of the Gschliefgraben we survey outcrops of diluvial breccias. Their blocks moove down with mud flows.

Stop 2a: On the road in the Gschliefgraben on the Gaisrücken we find variegated Lower Senonian to Lower Campanian marls. Further on this way there are different marls mostly of Cretaceous age.

Stop 2b: The "Rote Kirche" ("Red Church", fig. 11) is situated 400 m WSW of the road.

As a conspicuous rock Paleocene to Lower Eocene beds rest with a gap on dark marls of Maastrichtian age,

The sequence is terminated by about 2 m nummulitic limestone bearing Fe-ooids and glauconite. *Prenaster alpinus* proves a Lower Eocene age, while Middle Eocene is lacking.

Stop 2c: Descending about 200 m in northwestern direction we see an outcrop of small nummulitic limestone in Adelholz facies, consisting mainly of large Nummulites and Assilinas (*Assilina exponens*) of Middle Eocene age. The basal beds are dark, rich in glauconite, containing small Nummulites and resting on Paleocene or even tectonical on Albian beds. Dark Maastrichtian marls enclosing a fine grained sandstone lense have been found south of these rock. Red marls in the vicinity belong to Lower Senonian.

Stop 2d: Ascending the northern slope we find above the Gaisrücken path a small block of whitish Lithothamnian limestone with quartz grains and small

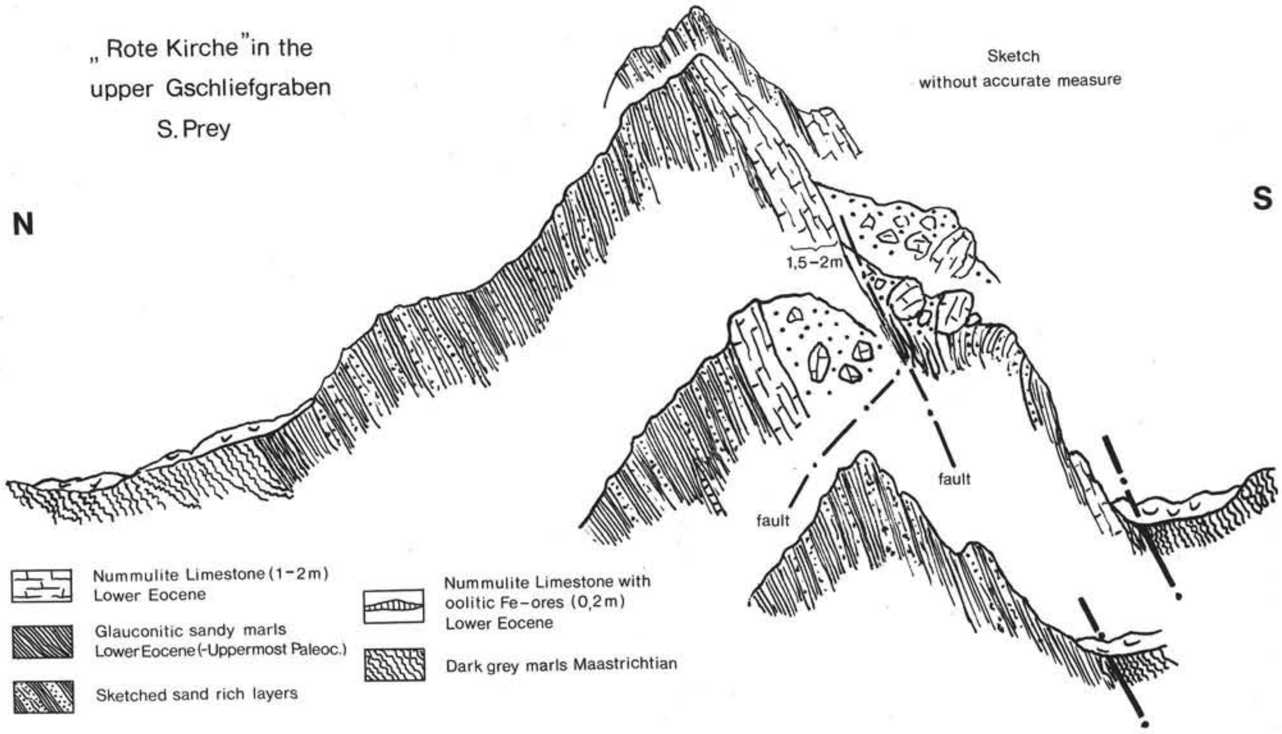


Fig. 11: Sketch of the "Red Church" in the Gschliefgraben SSE Gmunden (S. PREY, original).

Discocyclinas. In the vicinity there are whitish marls of Middle Eocene age (Stockletten). From this point we have a nice view at the Gschliefgraben area.

By the Gaisrücken path we return to the Radmoos Sattel.

Stop 1.3. "Hatschek" Quarry

This quarry of the Hatschek cement factory is established on top of the Pinsdorf mountain W Gmunden. The Brittle Sandstone Member (Maastrichtian) of Rhenodanubian Flysch is very good exposed here.

Thick- and thin-bedded sandstone beds (turbidites) alternate with layers of dark grey and grey marls (with rare Chondrites). Graded beeding, different kinds of flysch bedding and sole marks are common. Characteristical intergredients are soft weathering marly sandstones (greywackes; "Mürbsandstein"; Brittle Sandstone) mostly without graded bedding, but rich in mica, plant rests and sometimes in fragments of shales. The microfauna is characterized by big representatives of the genera *Dendrophyra, Trochamminoides* and *Rzehakina epigona.* In some types of coarser grained basal layers of calcareous sandstones *Orbitoides* have been found.

The beds, representing a typical flysch, are dipping to the south; the position is upright.

In fine weather one has an instructive view at the southern surroundings of Gmunden and the Traun Lake (Flysch Zone: Gschliefgraben, Grünberg mountain and mountains west of the lake. Limestone Alps: Traunstein mountain and Höllengebirge Mountains).

Day 2

The Hallstatt Zone and its framework near Hallstatt

(A. TOLLMANN)

R o u t e: Ischl — Hallstatt — Sommeraukogel — Salt mine — Hallstatt — Gosausee — Hallstatt.

S u b j e c t: Stratigraphy and tectonics of the Hallstatt zone above Hallstatt. Litho- and biofacies of reef and lagoon in the carbonate platform of the Dachstein massif at the Gosau lake, Upper Austria.

R e f e r e n c e s: E. FLÜGEL (1975): Guide book int. symp. on fossil Algae, p. 117 ff., Erlangen (Univ.); O. GANSS et al. (1954): Erläut. geol. Karte Dachsteingruppe, Wiss. Alpenver. h. **15**, 82 p., geol. map, Innsbruck; T. GATTINGER (ed.): Arbeitstagung Geol. Bundesanst., 1976, 48 p., Wien (Geol. B.-A.); W. KLAUS (1953—1972): Verh. Geol. B.-A., **1953**, 161—175, Wien; Z. dt. geol. Ges., **105** (1953), 776—788, Hannover 1955; Verh. Geol. B.-A., **1972**, p. 33 f., Wien; E. KRISTAN—TOLLMANN et al. (1976): Int. Sympos. Ecol. Zoogeogr. rec. fossil Ostracoda, 6—28, Wien (Limnol. Inst. Ak. Wiss.); L. KRYSTYN et al. (1971,1972): N. Jb. Geol. Pal.

Abh., **137**, 284—304, Stuttgart; Ann. Inst. geol. publ. hungar., **54**, fasc. 2, 607—629, Budapest; Exk.-Führer Tagg. Paläont. Ges., 61—106, Graz; W. MEDWENITSCH (1958): Mitt. geol. Ges. Wien, **50** (1957), 133—200, Wien; J. SCHADLER (1951): Verh. geol. Bundesanst., Sdh. **A**, 49—64, Wien; O. SCHAUBERGER (1949, 1955): Berg- hüttenm. Mh., **94**, 46—56, Wien; Z. dt. geol. Ges., **105** (1953), 736—751, Hannover; W. SCHLAGER (1967): Mitt. Ges. Geol. Bergbaustud., **17** (1966), 205—282, Wien; A. TOLLMANN (1976): Monogr. d. Nördl. Kalkalpen, vol. **2**, p. 169 ff., p. 501 ff., vol **3**, p. 331 ff., Wien (Deuticke); A. TOLLMANN et al. (1970): Geologica et Palaeont., **4**, 87—145, Marburg.

Geolog. map: 1 : 75.000, sheet Ischl—Hallstatt; 1 : 25.000 E. SPENGLER in Wiss. Alpenvereinsh., **15** (1954). Topogr. map: Österr. Karte 1 : 50.000, sheet 95, 96.

Introduction

In the region of Ischl and Hallstatt in Upper Austria there are four main tectonic units (fig. 12): 1. The Tote Gebirge nappe with Dachsteinkalk facies in its southern part occupies the northeastern sector. 2. The northern Hallstatt zone, representend by the parautochthonous Zlambach mass, extending from Ischl to Goisern, Hallstatt, Aussee and Grundlsee. In this zone there is a specific Hallstatt facies, called Zlambach facies, rich in Upper Triassic marls and thin-bedded limestones (Carnian marls, Norian Pötschen- and Pedata limestone, Rhaetian Zlambach marls) — fig. 6. Whether Hallstatt limestone masses are included primarily in this zone is still under discussion. 3. Thrust above this zone follows the Dachstein nappe with Kater mountain and Sarstein in the front, exhibiting the Dachsteinkalk facies. The main part of this unit is built up of thick bedded Dachstein limestone of lagoon type, only in the southwest of this unit is a massive reef limestone of the same age forming the Gosaukamm near Gosau. 4. Above Hallstatt the Plassen peak and the Hallstatt salt plug with neighbouring Hallstatt limestones form an isolated Hallstatt mass, resting today partially on the back of the Dachstein nappe, partially side by side with

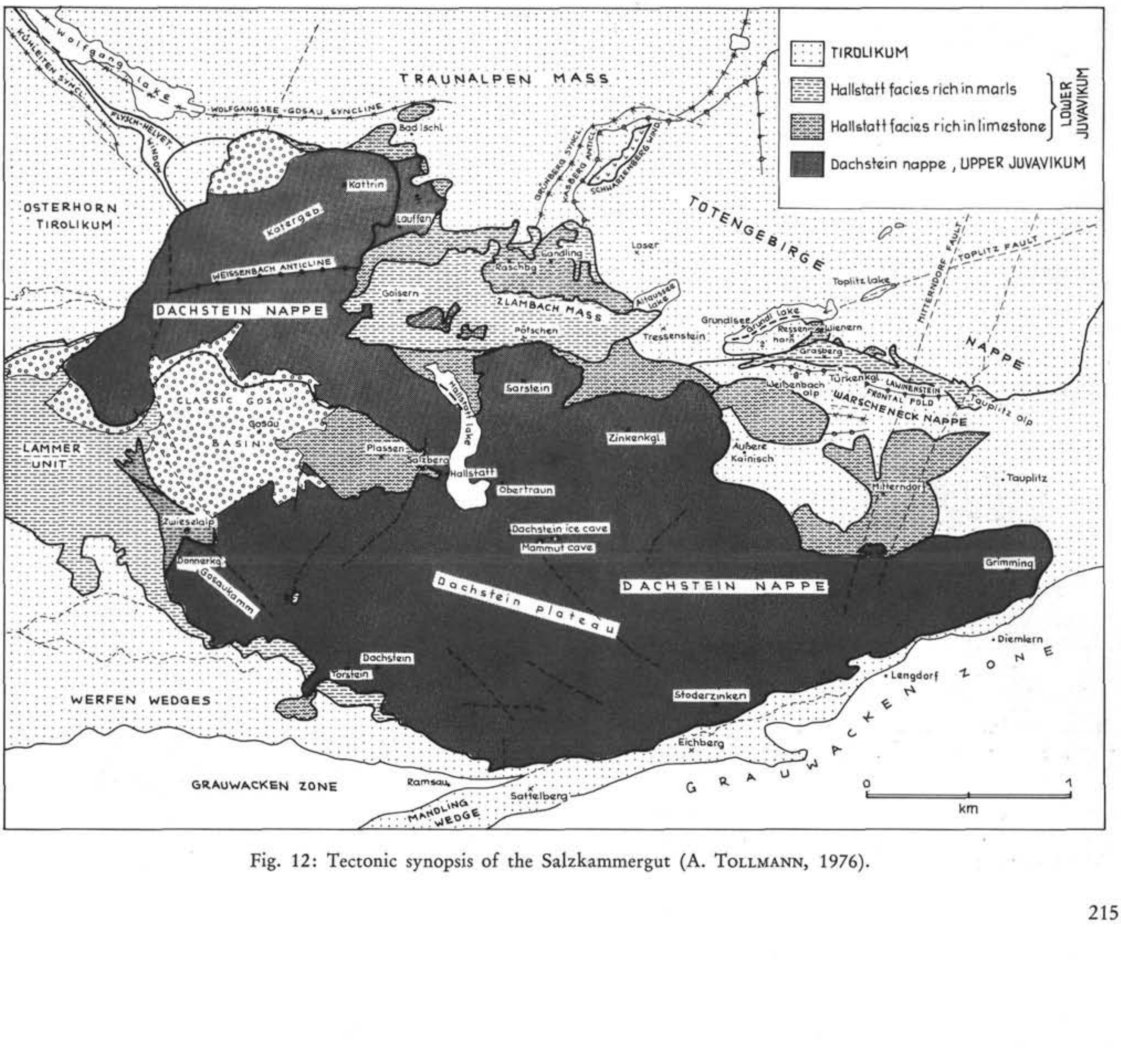


Fig. 12: Tectonic synopsis of the Salzkammergut (A. TOLLMANN, 1976).

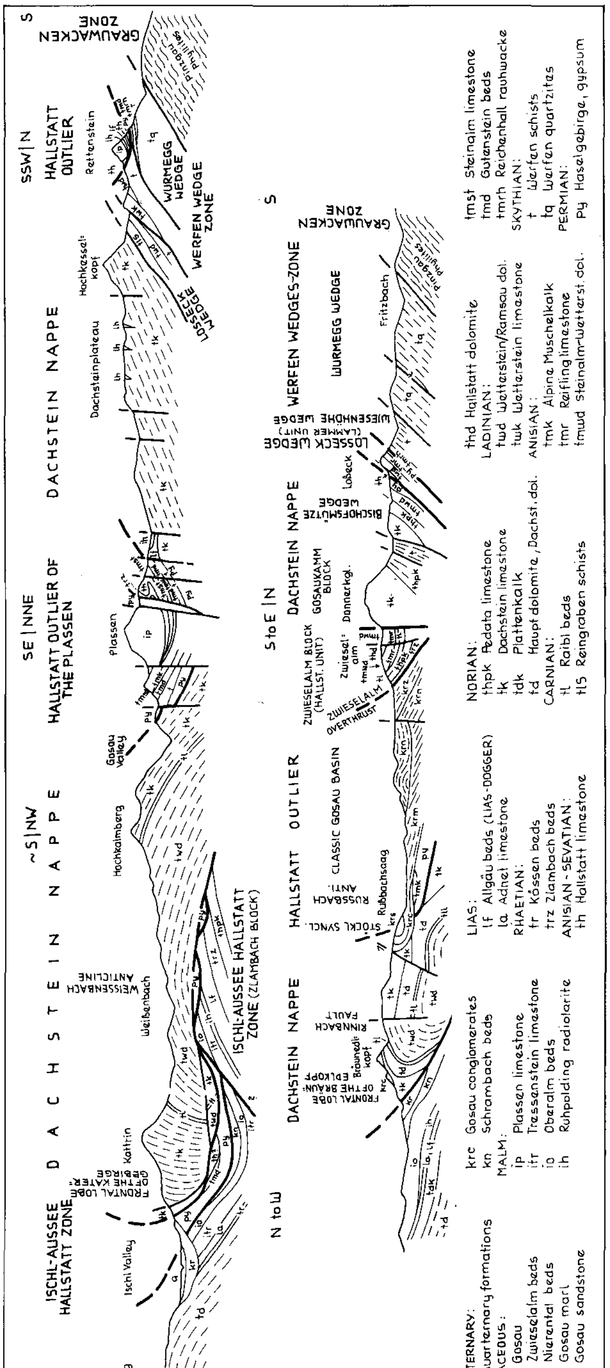


Fig. 13: Sections across the Salzkammergut along the meridian of Hallstatt and the Gosau chain (A. Tollmann, 1976).

this unit according to fault tectonics and dipping partially also below this nappe. We assume that this southern thrust block with its "Salzberg facies", rich in Hallstatt limestones, derives from a southern Hallstatt zone south of the Dachstein massif — fig. 13. 5. The Gosau formation transgressively overlies as a posttectonic sediment the main tectonic structures, like nappe limits and some old faults.

I t i n e r a r y: The view from Ischl to the southwest shows the frontal lobe of the Dachstein nappe in the shape of the steep dipping strata of the Katrin summit. At Goisern the Hallstatt zone widens toward the east and forms a broad lower region along the Stambach-, Zlambach brook and Pötschen pass, in consequence of an abundance of Triassic and Liassic marls in this facies region.

We proceed from Hallstatt with the funicular to the Hallstatt Salzberg and have a splendid view from the Rudolfsturm to the Dachstein plateau and into the narrow Traun valley, formed by the glaciers till 11.000 years b. pr.

Stop 2.1. Sommeraukogel

Stratotype of the Norian (L. Krystyn et al. 1971, 1972). The wall of Hallstatt limestone on the northern flank of this peak consists of steep-dipping condensed red limestone from Lower Norian to the Sevatian and

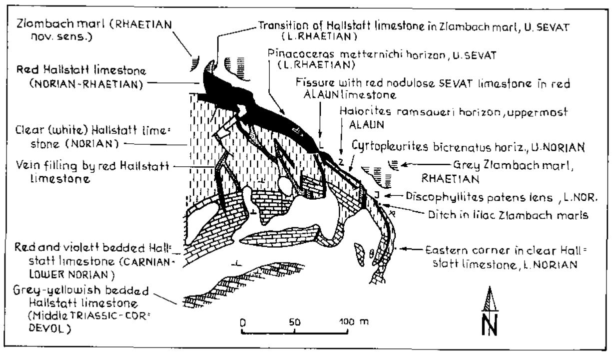


Fig. 14: Geological sketch map of the Sommeraukogel (L. Krystyn, 1973, fig. 3).

			Salzkammergut (KRYSTYN 1979)		N-America (TOZER 1971)
RHAETIAN			Choristoceras marshi		Choristoceras marshi
NORIAN	Sevat		Rhabdoceras suessi		Rhabdoceras suessi
	Alaun	2	Himavatites columbianus		Himavatites columbianus
		1	Cyrtopleurites bicrenatus		Drepanites rutherfordi
	Lac	3	Juvavites magnus		Juvavites magnus
		2	Malayites paulckei		Malayites dawsoni
		1	Guembelites jandianus		Mojsisovicsites kerri
CARNIAN	Tuval	3	Anatropites - Bereich		Klamathites macrolobatus
		2	Tropites subbullatus		Tropites welleri
		1	Tropites dilleri		Tropites dilleri
	Jul		Trachyceras austriacum	Sirenites-Subzone	Sirenites nanseni
				Austriacum- -"-	Trachyceras obesum
	(Cordevol)		Trachyceras aonoides	Aonoides-Subzone	Trachyceras desatoyense
				Aon-Subzone	

Fig. 15: Upper Triassic Ammonoid zones (L. Krystyn).

includes three horizons rich in Ammonites (Patens-, Bicrenatus-, Metternichi fauna) — see fig. 14—15. Joint fissures, also filled with red Hallstatt limestone of somewhat younger age, transverse the beds. At the top of this section in the Zwischenkögel region the nodulare limestone leads to the Rhaetian Zlambach marls rich in Foraminifers and Ostracodes (Bairdiidae, Healdiidae etc.) — E. KRISTAN-TOLLMANN, 1976.

Stop 2.2. Salt mine of Hallstatt

The visit gives an impression of the type of an alpine salt deposit. The salt takes part in the Upper Permian Haselgebirge (Zechstein 4), a chaotic breccia of salt, anhydrite, clay etc., in which larger part of pure rock salt also occur. In spite of the extreme tectonics caused by high mobility, a constant succession could be found by O. SCHAUBERGER (1949, 1955) considered by him as a stratigraphic sequence. The Permian age is determined by spores and by the sulphur isotope methode (W. KLAUS). The Haselgebirge breccias have a sedimentary origin after O. SCHAUBERGER, but show fluidaltectonic structure after W. MEDWENITSCH. Diapirism, halokinesis and polymetamorphosis sensu H. LOTZE also affected the alpine salt deposits.

The Haselgebirge of the salt mine of Hallstatt is deeply implanted by faults into the Dachstein limestone framework of the Dachstein nappe. In a long narrow zone high above Hallstatt a sequence from the Haselgebirge, passing the Triassic Hallstatt limestone up to the Malmian reef limestone of the Plassen peak (Plassen limestone) is squeezed into this frame (J. SCHADLER & W. MEDWENITSCH, 1951).

Salt mines have existed here for 3000 years, salt production for 4500 years. Therefore, this center of the Hallstatt civilisation has been wealthy since prehistoric times.

The structure of the salt mass is a complicated one (fig. 16 a b) — E. SPENGLER in O. GANSS et al. 1954. Beginning at the country rock of the salt deposit one finds always the following sequence: Grausalzgebirge, Rotsalzgebirge, Greenish Salztongebirge, Variegated (Buntes)Haselgebirge with melaphyre and finally Stinkdolomitisches Grausalzgebirge. The tectonic intercalation of slices of Norian Hallstatt limestone and Rhaetic Zlambach marls (in the "Vorhaupt"- and "Zentrale Einlagerung") and of Permian Grödener sandstone ("Nördliche Einlagerung") within this sequence illustrates the intense tectonic deformation. The marginal parts of Haselgebirge are leached to a pure argillaceous coat ("Lebergebirge"), partially deformed by tectonics to lustrous slates ("Glanzschiefer").

The gallery at the base of the mine at 536 m ("Erbstollen") develops an intensive penetration of salt and Haselgebirge and also of Liassic marls etc. into the superimposed Dachstein limestone (fig. 17) — J. SCHADLER & W. MEDWENITSCH 1951. Therefore, the origin of the mass Hallstatt/Plassen in Hallstatt facies is still

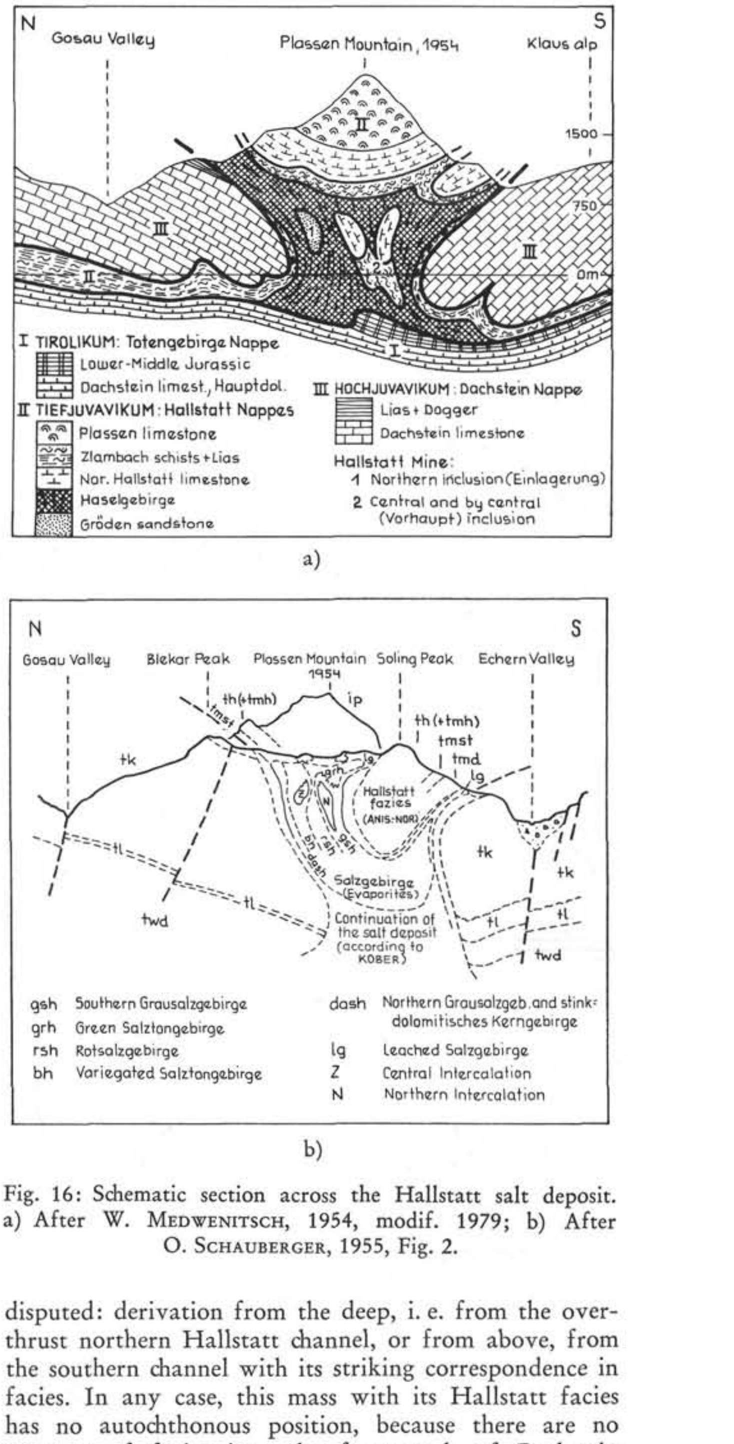


Fig. 16: Schematic section across the Hallstatt salt deposit. a) After W. MEDWENITSCH, 1954, modif. 1979; b) After O. SCHAUBERGER, 1955, Fig. 2.

disputed: derivation from the deep, i. e. from the overthrust northern Hallstatt channel, or from above, from the southern channel with its striking correspondence in facies. In any case, this mass with its Hallstatt facies has no autochthonous position, because there are no passages of facies into the framework of Dachstein limestone, which does not include the intervening types of reef limestone, consisting here only of the incompatible lagoon type. The theorie of premature sliding tectonics, at the beginning of the Jurassic is also unsatisfactory, because there are no gaps, no breccias or other indications in the sediments between Rhaetic and Lias-

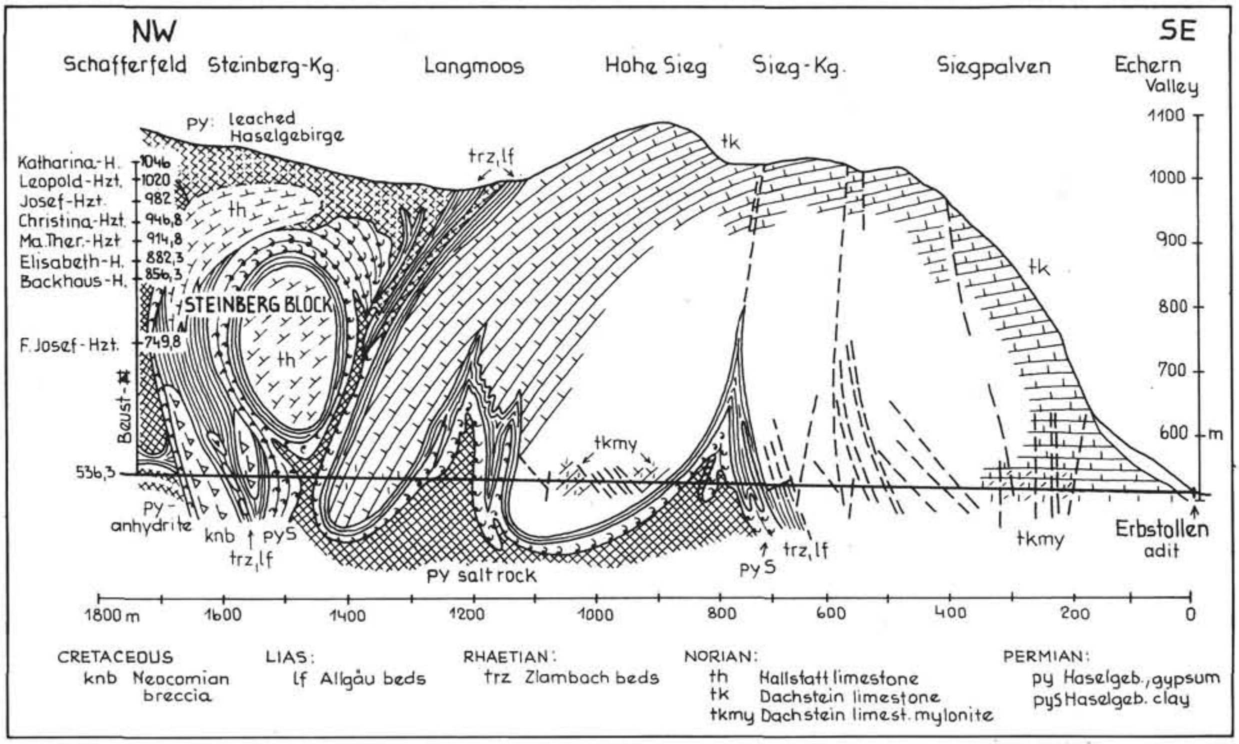


Fig. 17: Section along the Erbstollen of Hallstatt (O. SCHAUBERGER, 1952).

sic formations in this Hallstatt mass, which would serve as proof.

In the afternoon we drive to the region of Gosau, west of Hallstatt. Along the brooks west of Gosau the Gosau formation is exposed with its different facies types, particularly those with marls. The basin of Gosau contains a 2600 m thick series of the famous Gosau formation, rich in fossils, varying in lithological character and having great importance with respect to tectonics: the disconformable sedimentation after the building of the nappe structures in the Limestone Alps, it comprises formations from Coniacian to Lower Eocene. Coarser detritic series appear particularly in lower position (Coniacian, Santonian) and in the so-called Zwieselalm formation of Maastrichtian — Paleocene age.

Stop 2.3. Gosau—Zwieselalm

We stop at the Vorderer Gosau lake south of Gosau. By the funicular we reach the Zwieselalm. We find ourselves confronted by a reversed series of Hallstatt facies, in prolongation of the mass of Hallstatt, visited in the morning. Around the Gablonz house we pass outcrops of clear and variegated Ladinian dolomites. Near the Thörleck pass south of this house one sees in the "Schneckengraben" a primary connection between the fossil-bearing Zlambach marls and the Dachstein limestone of the Kesselwand in reversed position (fig. 18).

The Gosaukamm, starting here with the Donnerkogel (2055 m), represents the reef along the southwestern border of the thick-bedded lagoonal Dachstein limestone of the Dachstein massif, isolated by the Reißgang fault. The reef limestone primarily is composed of reef detritus. Small patch reefs are widely intercalated. These patch reefs include particularly sponges (*Peronidella*), corals, Solenoporides and Hydrozoans. Rarely also *Heterastridium*, ammonites and conodonts have been found, which prove a Norian-Sevatian age.

Stop 2.4. Vorderer Gosau-See

Returning to the southwestern beach of the Vorderer Gosaulake, we find at the large slope ("Steinriese") a fauna-association typical of this Dachstein reef limestone. Here this limestone is rich in calcareous sponges, algae [*Solenopora endoi* FLÜGEL, *Parachaetetes maslovi* FLÜGEL, *Thaumatoporella parvovesiculifera* (RAIN.) etc.], corals, hydrozoans, the problematic fossil *Microtubus communis* FLÜGEL and specific foraminifera [*Alpinophragmium perforatum* FLÜGEL, *Galeanella tollmanni* KRISTAN, *Nubecularia*, *Ophthalmidium* etc.]. The red algae indicates an original position in the outer part of the central reef flat, near the fore-reef.

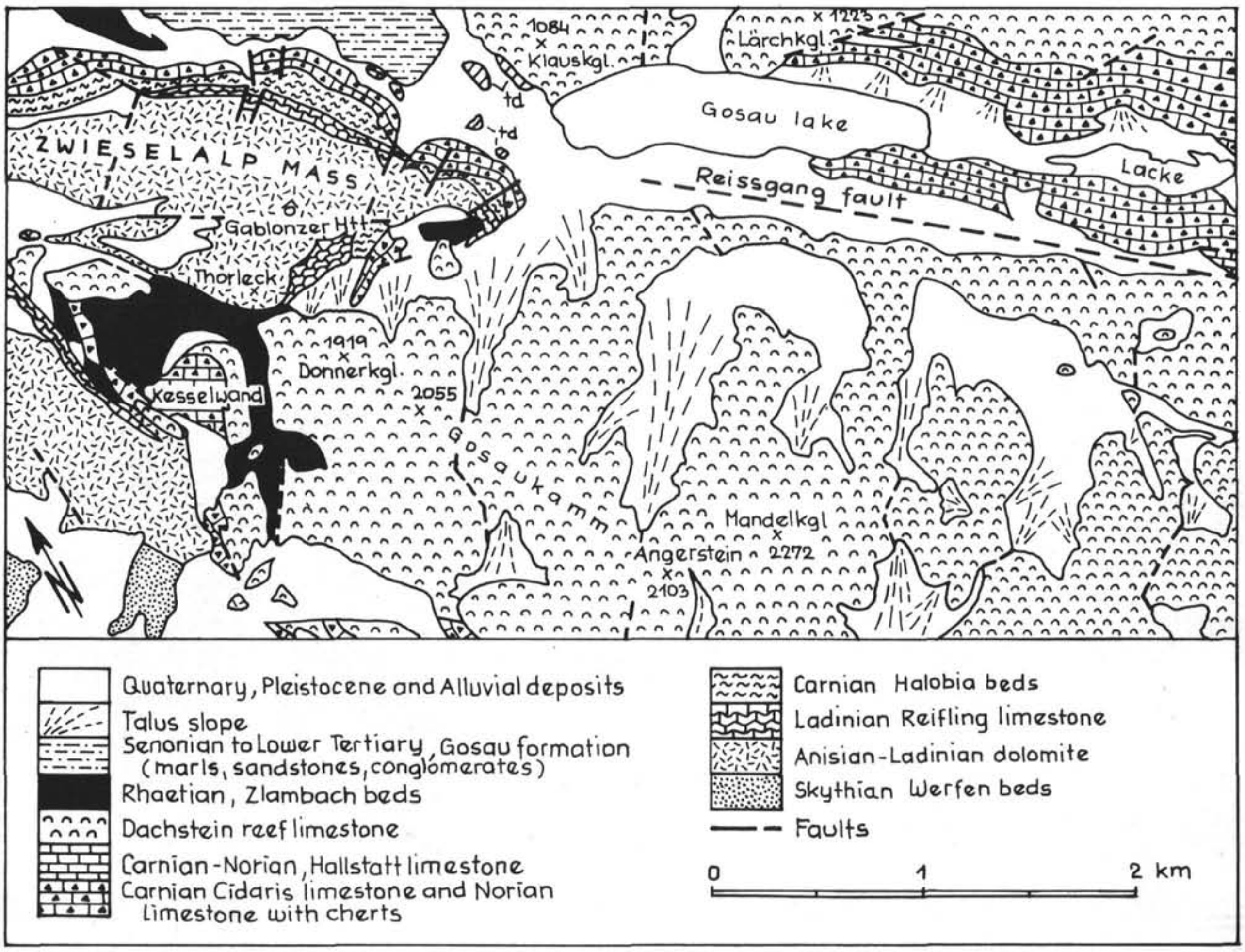


Fig. 18: Geological sketch map of the Zwieselalp area at the Vorderer Gosau Lake (mainly after W. SCHLAGER, 1967).

Day 3

Tectonics and facies of the Hallstatt Zone in the eastern Salzkammergut

(A. TOLLMANN)

Route: Hallstatt — Mitterndorf — walk across Feuerkogel and Weissenbach alp to Grundlsee — Schladming — Radstadt — Obertauern.

Subject: The differences between Hallstatt facies rich in limestones and in marls and Dachstein limestone facies are striking in the eastern Salzkammergut because of the strong contrasts within a narrow limited space between Mitterndorf and Grundlsee. Furthermore nappe tectonics and parautochthony of masses in Hallstatt facies can be demonstrated.

References: L. KRYSTYN (1973): Verh. Geol. Bundesanst., **1973**, 113—153, Wien; W. SCHÖLLNBERGER (1973): Mitt. Ges. Geol. Bergb. Wien, **22**, 95—153, Wien; A. TOLLMANN (1960, 1976): Jb. Geol. Bundesanst., **103**, 37—131, Wien; Monographie d. Nördl. Kalkalpen, vol. **2**, p. 501—577; vol. **3**, p. 352 ff., Wien (Deuticke). Geol. map 1 : 75.000, sheet Ischl—Hallstatt and Liezen; Topogr. map 1 : 50.000, sheet 96, 97, 126, 127, 128.

Introduction

In the region of the eastern Salzkammergut in Styria one finds east of Bad Aussee the series of two in its facies different Hallstatt zones between the carbonate platform sediments. Because thrusting and faulting characterize this region, the home and origin of the Hallstatt zones has been a subject of fervent disput.

Recently the origin, stratigraphy and tectonics of this region largely has been clarified by new mapping, facies analysis and paleontological survey. The northern Hallstatt zone with its facies rich in Upper Triassic marls have been originated in a northern channel-like basin, the northern Juvavian channel, running from

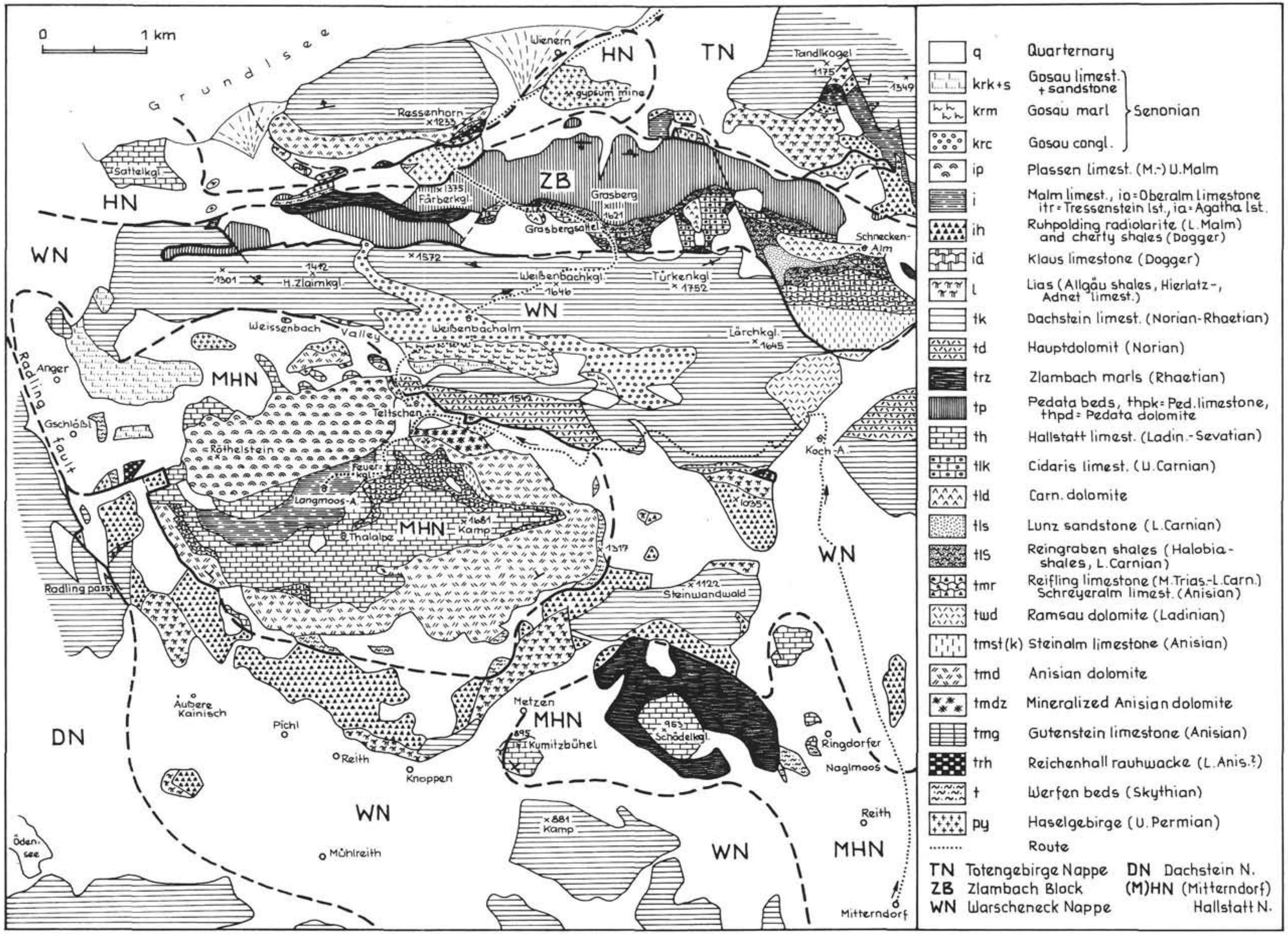


Fig. 19: Geological sketch map of the region between Kainisch and Grundl Lake in Styria (A. TOLLMANN, 1960 and W. SCHÖLLNBERGER, 1974).

Goisern to Aussee and Grundlsee. The series of this zone in its specific facies is shown in figure 6. The characteristics of this series in Zlambach facies is the Middle Triassic with Anisian dolomite, Anisoladinian Reifling limestone and the Upper Triassic with a Carnian sequence of shales, sandstone and dolomite (as in the Lunz facies), beginning however with the Norian stage, with typical Hallstatt facies (Pötschen- and Pedata limestone), few Hallstatt limestone and Zlambach marls.

In contrast to this development in the northern Juvavian channel are the thrust slices in the region of Mitterndorf, which one can deduce from the southern Juvavian channel. These tectonic outliers, which overly the Warscheneck nappe with its Dachsteinkalk facies, include a series from Permian Haselgebirge to Hallstatt limestone and up to Upper Jurassic limestone. The red Hallstatt limestone starts in this southern channel with the Middle Anisian and shows namely in Carnian and Norian eminent condensation.

The tectonic position of the series of the northern Hallstatt Zone today is explained as parautochthonous, isolated by faults or local thrusts. Facies transitions between the Rhaetic Dachstein limestone of the neighbouring Totes Gebirge and the Zlambach formation of this northern Hallstatt Zone in Zlambach facies prooves this hypothesis.

I t i n e r a r y: The route from Hallstatt across the P ö t s c h e n p a s s and Aussee to Mitterndorf leads at first along the northern Hallstatt Zone. The view from the curve north of the Pötschen pass shows the Hallstatt limestone mass of Raschberg and the more complete series up to the Malm of the Sandling mountain. Close to the Pötschen pass, in the north one can see the type locality of Pötschen limestone, a typical formation of the Norian in the Zlambach facies zone.

View from the route NW of Aussee to the northern and southern framework of the Hallstatt Zone, the Totes Gebirge with Triassic and Jurassic carbonates in the North and Sarstein and Dachstein as parts of the higher tectonical unit, the Dachstein nappe, in the south.

Stop 3.1. Feuerkogel-Röthelstein

March from Äußere Kainisch or Mitterndorf to the Feuerkogel-Röthelstein-peak, a part of a thrust Hallstatt slice, deriving from the southern Hallstatt channel with Salzberg facies (fig. 19). The base of this massif consists of Jurassic of the Warscheneck nappe, the higher

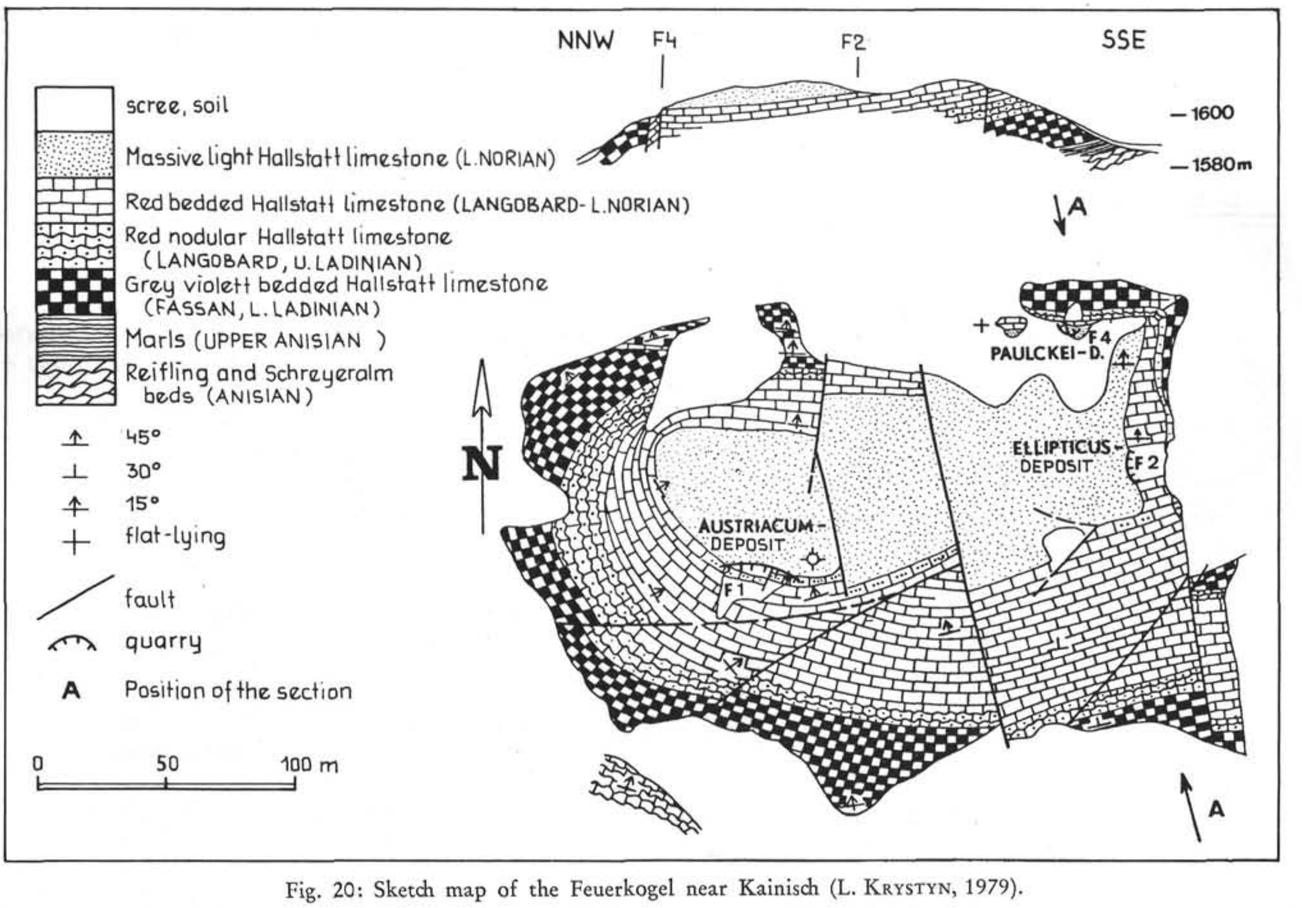


Fig. 20: Sketch map of the Feuerkogel near Kainisch (L. KRYSTYN, 1979).

part of a sequence starting with Permowerfenian and reaching up to the Malmian Plassenkalk of the Röthelstein. The Carnian-Norian sequence of Hallstatt Limestone in extreme condensation is exposed in a little quarry on the summit of the Feuerkogel (fig. 20). A section of 2 m thickness offers Julian, Tuvalian and Lower Norian, the latter with a level of *Halobia styriaca* MOJS. This quarry represents one of the most famous places at all, were ammonites have been found. Already in the classic era of investigation 464 species of cephalopodes, 78 of gastropodes and many other elements have been described from this locality.

The quarry on the northern side of the Feuerkogel (fig. 21, 22) shows similar to the summit a condensed Hallstatt limestone sequence of Upper Carnian and Lower Norian with sedimentary tilting and discordance.

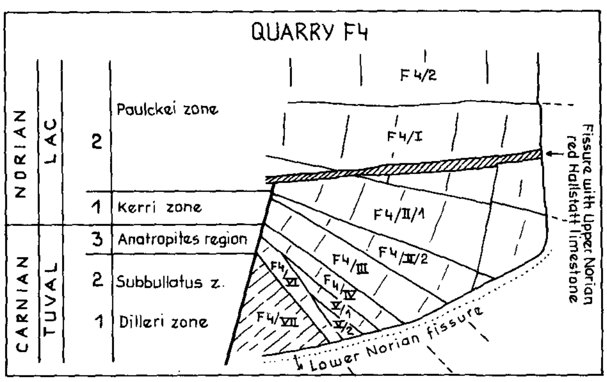


Fig. 21: Stratigraphic sequence of the Hallstatt limestone in the quarry F 1 on the Feuerkogel near Kainisch (L. KRYSTYN, 1979).

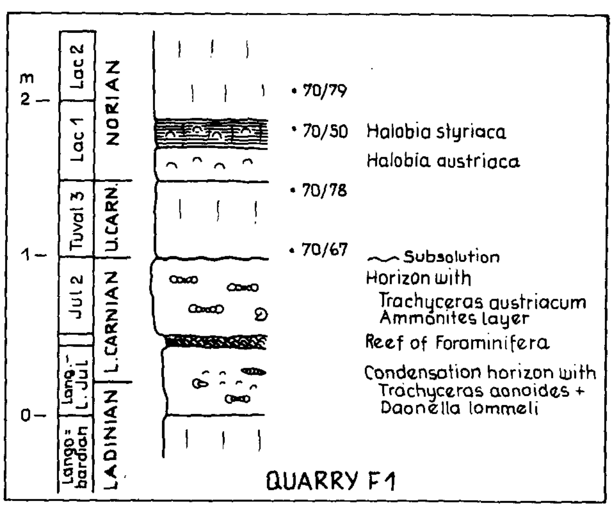


Fig. 22: The quarry F 4 on the Feuerkogel (L. KRYSTYN, 1979).

Stop 3.2. Weißenbach alp

The following way across the Weißenbach alp crosses the basal conglomerate of the Gosau formation. The equivalent of this Lower Senonian (Coniacian) conglomerat covers with transgressive contact the nappe limits and prooves so the pre-Senonian age of nappe formation in the Limestone Alps.

Stop 3.3. Grasberg pass

Northeast of the Weißenbach alp we meet the thick bedded Upper Triassic Dachstein limestone of the underlying Warscheneck nappe. This type of lagoonal formation, today in the tectonic vicinity of the basin-type of Hallstatt limestone gives a good impression of facies contrast, intensified by tectonics. We see the third facies of the same age, the Zlambachfacies with the Norian Pedata limestone just beyond the Türkenkogel ridge near the G r a s b e r g p a s s. Finally, before reaching the Grundlsee, we cross near Wienern the Haselgebirge rich in gypsum and anhydrite, which forms the base of a next tectonic outlier (fig. 23).

Our bus passes Irdning, Schladming and Radstadt. It turns round the Dachstein massif. The G r i m m i n g mountain W of Irdning offers a nice frontal lobe in thick bedded Dachstein limestone. The view from the Enns valley includes to the north at the base the shales of the Grauwackenzone, characterized by the gentle morphology, and above the steep walls of the Dachstein massif, formed mainly by Ramsau dolomite and Dachstein limestone. At Mandling one crosses a slice (Mandlingspan) of the Limestone Alps, tectonically planted into the Grauwackenzone.

The route from R a d s t a d t to Obertauern reaches the Lower Austroalpine unit soon after leaving the Enns valley. Before reaching Untertauern we drive through the monotonous masses of Paleozoic quartz phyllite of the uppermost nappe of this system. The lower nappes of the Lower Austroalpine with masses of Mesozoic carbonates appear southward from Untertauern, at first with a dark, thick bedded Anisian dolomite.

Day 4

The Lower Austroalpine of the central Radstadt Tauern in the Pleisling range

(A. TOLLMANN)

R o u t e: Obertauern — Wisenegg — Felseralm — Wildsee — Teufelskar — Obertauern/Lungau, Salzburg. Mainly march.

S u b j e c t: Stratigraphy, fossils, facies, metamorphosis and tectonic style of the Lower Austroalpine system as shown by the Pleisling nappe in the Pleisling range near Obertauern. Excellent outcrops in rocky

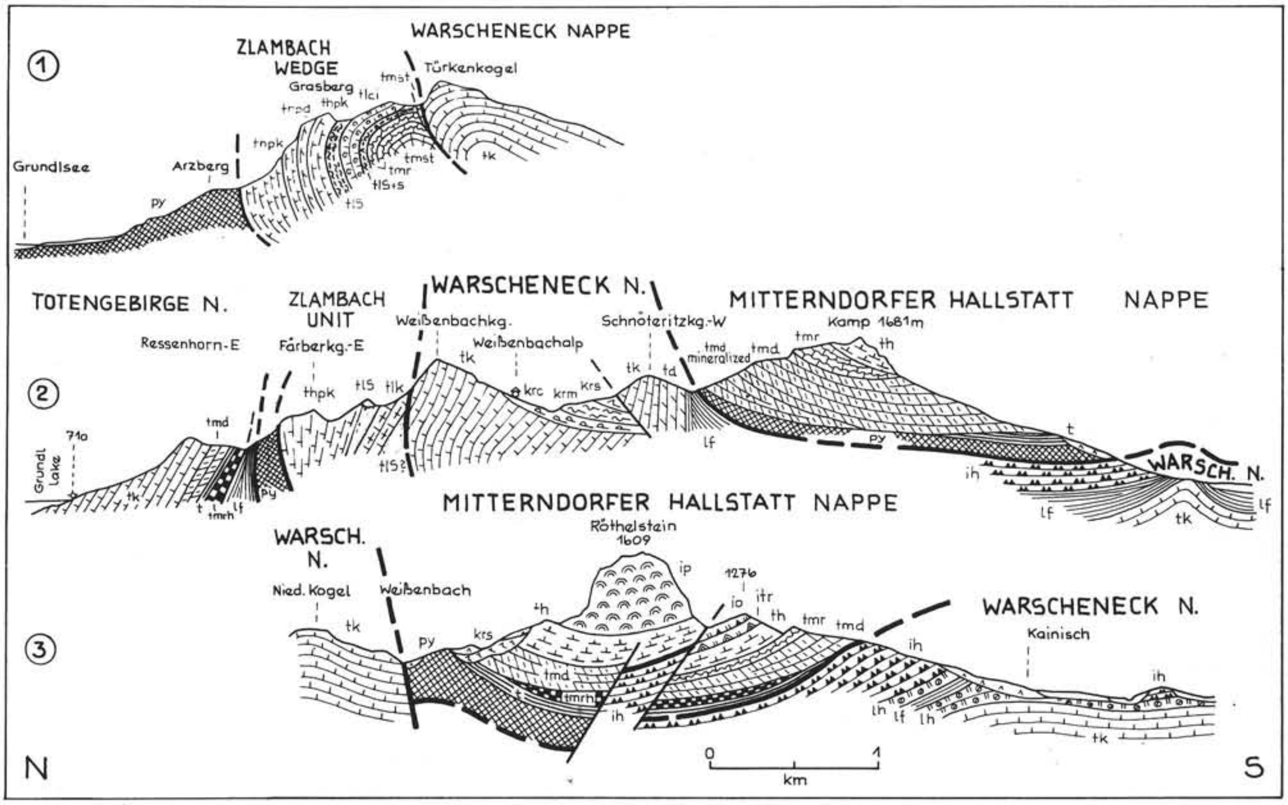


Fig. 23: Sections between Kainisch and Grundl Lake (A. Tollmann 1960 and W. Schöllnberger 1974).

terrain. The huge recumbent folds directed toward the north, here in the framework of the Tauern window, have been of great importance improoving the existence of this window.

References: W. Schwan (1965): Verh. geol. Bundesanst., Sdh. **G**, 214—245, Wien; A. Tollmann: Ibid., **1956**, 146—164; Mitt. geol. Ges. Wien, **57** (1964), 49—56; Geologie v. Österreich, vol. **1**, p. 101—131, Wien (Deuticke) 1977. — Topogr. maps: Österr. Karte 1 : 50.000, sheet 156, 157.

Introduction

The Radstadt Tauern (Fig. 24) are the best exposed and most extensively studied region of the Lower Austroalpine system in Austria, with a series most plentiful in formations and fossils. The Mesozoic sequence represents the type of the wide spreaded, so-called "Centralalpine" facies, a development in distinct contrast to the "Northalpine" facies of the Limestone Alps. It is possible to determine the fossils inspite of the alpidic metamorphosis in greenschist facies, however, the mobility attained was such, that today impressive tectonic structures can be studied. The highest temperature during this metamorphosis was 450° at 4—4,5 kbar, as indicated by the development of cyanite and chloritoide.

Fig. 6 shows the stratigraphic sequence. The Pleisling nappe includes in the central part of the Radstadt Tauern a Permomesozoic series approximately 1750 m thick, which comprises formations from Permian Alpine Verrucano to the Upper Jurassic radiolarite. The main rocks, determining the morphological character as rocky, are the 300 m thick Ladinian Wetterstein dolomite and the 500 m thick Norian Hauptdolomit.

Of interest is the facies of this series. In comparison with the facies of the Northern Limestone Alps the centralalpine facies is characterized by the following facts: less thickness, less fossiliferous, more paradiagenetic breccias in Triassic and Jurassic demonstrating an increased mobility of crust. These are the specific differences: the Permian consists of quartzites and sericitic-phengitic schists and not of Haselgebirge (with salt and gypsum); the Werfenian consists of Lantschfeld quartzites instead of Werfen schists; the Middle Triassic shows throughout the whole of the Central Alps a striking uniformity instead of the great variability of this epoch in the Limestone Alps. The Lower Jurassic shales are very typical, resembling the Penninic "Schistes lustrés", which comprises, in contrast to the Limestone Alps, generally a considerable amount of dolomite sand and dolomite breccias. Jurassic sand-

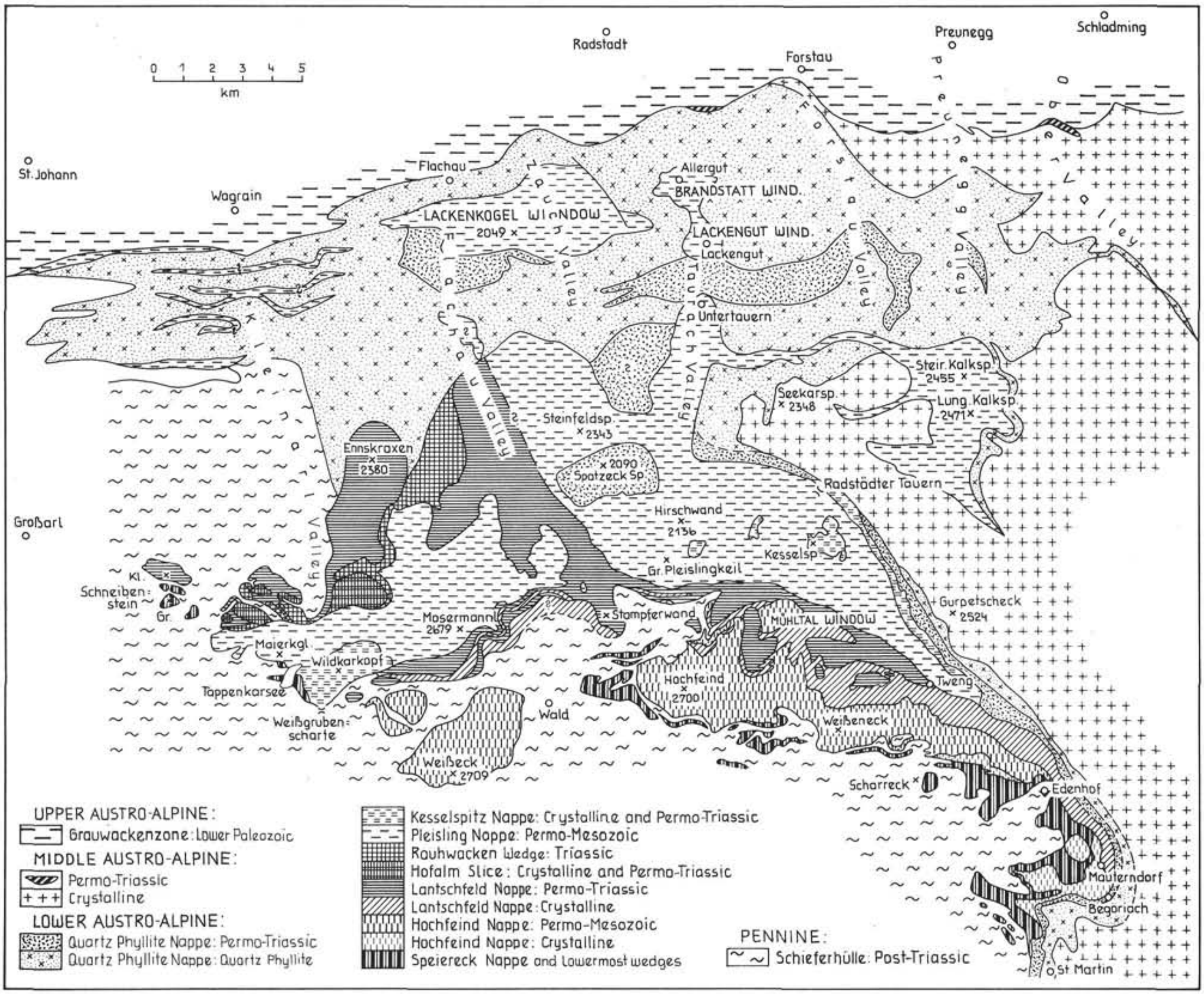


Fig. 24: Position and nappe structure of the Lower Austroalpine unit in the Radstadt Tauern (A. TOLLMANN, 1977, fig. 30).

stones and sandy slates are very rare in the Limestone Alps and bear only quartzsand.

Furthermore facies differences of subordinate importance can be found between the nappes within the Radstadt Tauern, so that the "Hochfeind facies" in the south includes a much higher content of breccias in Jurassic and Lower Cretaceous than the "Pleisling facies" in the central part of these mountains.

From the tectonic point of view the generally position is remarkable at first: the masses of light Mesozoic dolomites are in strong contrast to the dark shales of Penninic Schieferhülle below (SW) and to the dark crystalline sheet of the overthrust Middle Austroalpine above (NE, E) — surprisingly not only for the geologist. This specific position can only be explained by the nappe theory. The splendid survey of the regional depression of the Lower Austroalpine system below the Altkristallin here at the northeastern corner of the Tauern Window must be stressed. The Middle Austroalpine unit is thrust in an upright, non-inverted position and with diaphthoresis of its base above the Radstadt Tauern. The huge recumbent folds in the Pleisling nappe, especially those of the Schwarze Wand (see fig. 31), show the movement towards the north.

Position and structure of the Radstadt Tauern are shown by figure 24, 25. One distinguishes six nappes from bottom (S) to top (N): Speiereck-, Hochfeind-, Lantschfeld-, Pleisling-, Kesselspitz- and Quarzphyllit nappe. All these sheets — except the last — have series of upright, non-inverted position, although some show huge recumbent folds as internal structure. NE of the Tauern pass the Middle Austroalpine crystalline pierces

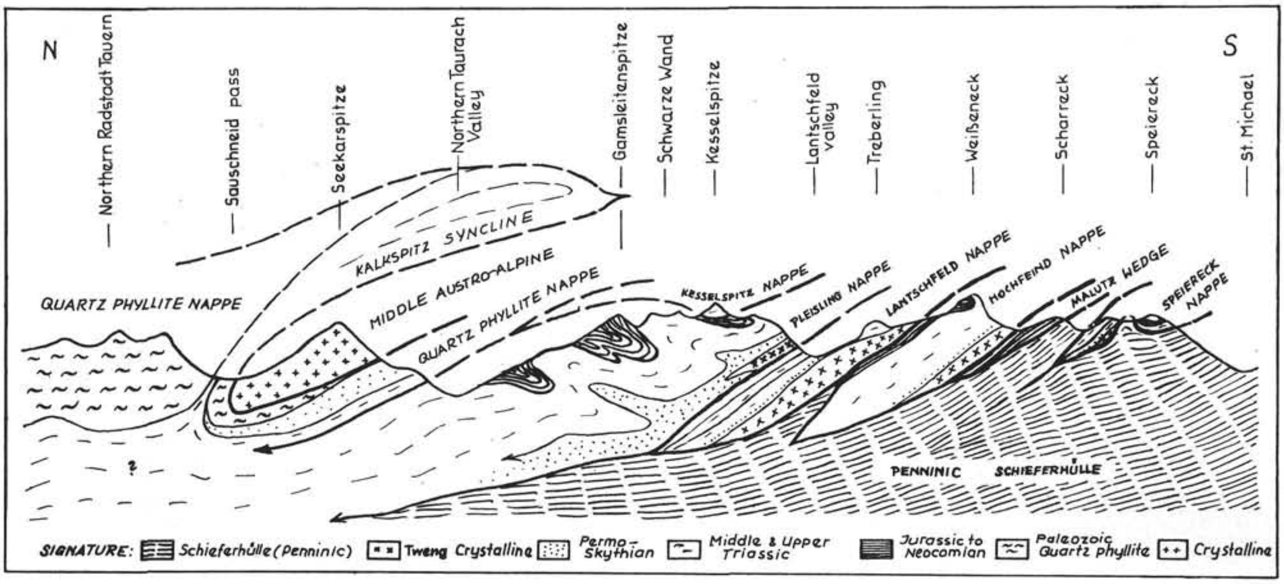


Fig. 25: Schematic section of the Radstadt Tauern in Salzburg (A. Tollmann, 1964).

by digitation into the tectonic substratum, which formes a great back fold in the Kalkspitzen peaks — with bright dolomites contrasting to the surrounding dark crystalline rocks.

The difference in plasticity between the more rigid dolomite and the more mobile limestones, shales and quartzites in this lower level of alpine orogenesis is manifested clearly by the varability of fold structures, attaining in some cases flow fold characteristics. The fault structures have no importance.

Stop 4.1. Felser alp

The path from Wisenegg to Felser alp leads along a Carnian series rich in dolomites, breccias, shales, accompanied in the south by a reversed younger series above. The outlook towards north shows the superposition of the reversed quartz phyllite nappe (Scheck, Spatzeck) and Middle Austroalpine crystalline (Seekarspitze) above the Pleisling nappe.

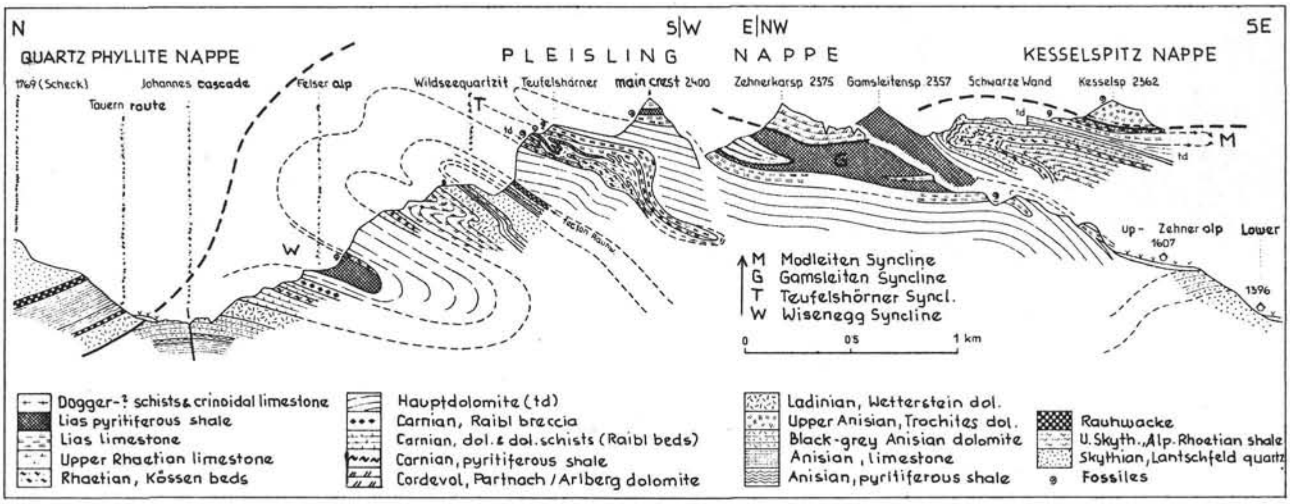


Fig. 26: Section across the Pleisling nappe in the central Radstadt Tauern (A. Tollmann, 1956).

Hirschwand
Wildsee
Hütte
Scharte
Wild-see
1925
Teufelshörner
2262
Glöcknerin
2432
Wildkar
Großwand Sp.
2436
Großwand-Sp.
2380
Teufelskar
Predigtstuhl
2361
Zackenscharte
Zehnerkar Sp.
2381
Gamsspitze
Zehner-Sattel
Zehnerkarseilbahn
Breitstein-Alm
Neuhof-A.
Kapelle
1660
Felser-A.
1676
1647
0
0.5
1
km
V = scree
Λ = moraine

v,ra	Talus, Alluvium	tdS	Triassic dolomite-schists	tmd	Anisian Trochites dolomite
ʌ	Moraines	to	Triassic dolomite	tmdS	Anisian dolomitic schists
kb	Malm/Lower Cretaceous Schwarzeck breccia	td	Triassic limestone	tmk	Anisian banded limestone („Muschelkalk")
kq	Lower Cretaceous Schwarzeck quartzite schists	trkd	Upper Rhaetian dolomite	tmS	Lower Anisian basal slates
ia	Lower Malm „Aptychus" limestone	trk	Upper Rhaetian limestone	trh	Lower Anisian rauhwacke
ih	Lower Malm radiolarite (chert)	tr	Rhaetian Kössen beds	tqS	Upper Skythian Alpine Röt schists
ihS	Lower Malm quartzite schists	tdk	Norian Plattenkalk	tq	Skythian Lantschfeld quartzite
iS	Dogger/L.Malm banded slates	td	Norian Hauptdolomit	tS	Permoskythian quartzite-schists
id	Dogger Crinoides-limestone	tlrh	Carnian rauhwacke	pq	Permian Alpine Verrucano
lib	Lias/Dogger breccia	tld	Carnian dolomite	Krist.	Tweng crystalline ± slices of sedimentary rocks
liS	Lias/Dogger banded slates	tldS	Carnian dolomitic schists	⊛	Fossils
lb	Lias breccia	tlk	Carnian limestone		Dip angles of beds: à 15°
lq	Lias quartzite	tlS	Carnian slates		
lS	Lias shales/slates	tpd	Lower Carnian Partnach/Arlberg dolomite		Dip angles of axis:
lkS	Lias calc-slates	tpS	Lower Carnian Partnach slates		
lk	Lias calk-marble	twd	Ladinian Wetterstein dolomite		

Fig. 27: Geological sketch map of the area visited in the Pleisling massif (Original). PN = Pleisling Nappe, KN = Kesselspitz nappe. Legend to figs. 27—34.

Stop 4.2. Wildsee

The ascent from the Felseralm to Wildsee passes through a reversed series (Fig. 26). Along the path one can study the reversed section with Liassic shales with an impression of Penninic "schistes lustrés" at the bottom, followed by fossiliferous Rhaetic limestones of Koessen beds, then the tectonical reduced Norian Hauptdolomit, finally the Carnian dolomites and sandstones on top. The Cordevolian (lowermost Carnian) is represented by well-bedded dolomites, the Ladinian by Wetterstein dolomite full of remainders of the algae *Diplopora annulata* (SCHAFH.). The Anisian comprises cherty limestones, banded limestones and such with dolomite nodules. At the bottom of the Anisian dark dolomitic schists with *Costatoria costata* (ZENKER) appear. The uppermost Werfenian consists of sericite schists of Alpine Roet, the rest of this stage of Lantschfeld quartzites. Along the lake Wildsee the intensive folding of basal Triassic formations is impressing.

Stop 4.3. Teufelshörner

Rising from Wildsee to the Teufelshörner circus one surveys the better developed Upper Triassic of the following non-reversed series of the next recumbent fold. It consists in the region of Teufelshörner (fig. 27) and in the circus east of this peak of Hauptdolomit, fossiliferous Koessen beds of Rhaetic age, fossiliferous greyblue thick-bedded Upper Rhaetic limestones with *Thecosmilia*, gasteropodes and megalodontes, yellowish Liassic marble with *Isocrinus* cf. *basaltiformis* (MILL.), and finally, very thick Liassic shales, containing dolomitic sand and some belemnites. The Koessen beds in the Teufelshorn circus bear the most abundant fauna with *Thecosmilia clathrata* EMMR., *Th. oppeli* RSS., *Th. bavarica* FRECH, *Astraeomorpha crassisepta* RSS., *Oppelismilia rudis* (EMMR.), *Stylophyllum paradoxum* FRECH, *St. irregulare* FRECH, *St. zitteli* FRECH, "*Stephanocoenia*" *schafhäutli* WINKL., *Isocrinus bavaricus* WINKL., *Triadocidaris lungauensis* TOLLM. etc.

In the walls of the socle of Zehnerkarspitze one distinguishes the fold structure of the Teufelshorn syncline and a thrust sheet consisting of Ladinian-Carnian dolomit of the Kesselspitz nappe, forming the top of this peak (fig. 28—29). Dolomite slices of this Kesselspitz nappe are scattered in the Jurassic shales below the thrust plane. At the Mitterriegel one notices an isolated upfold of Hauptdolomit, dividing the big

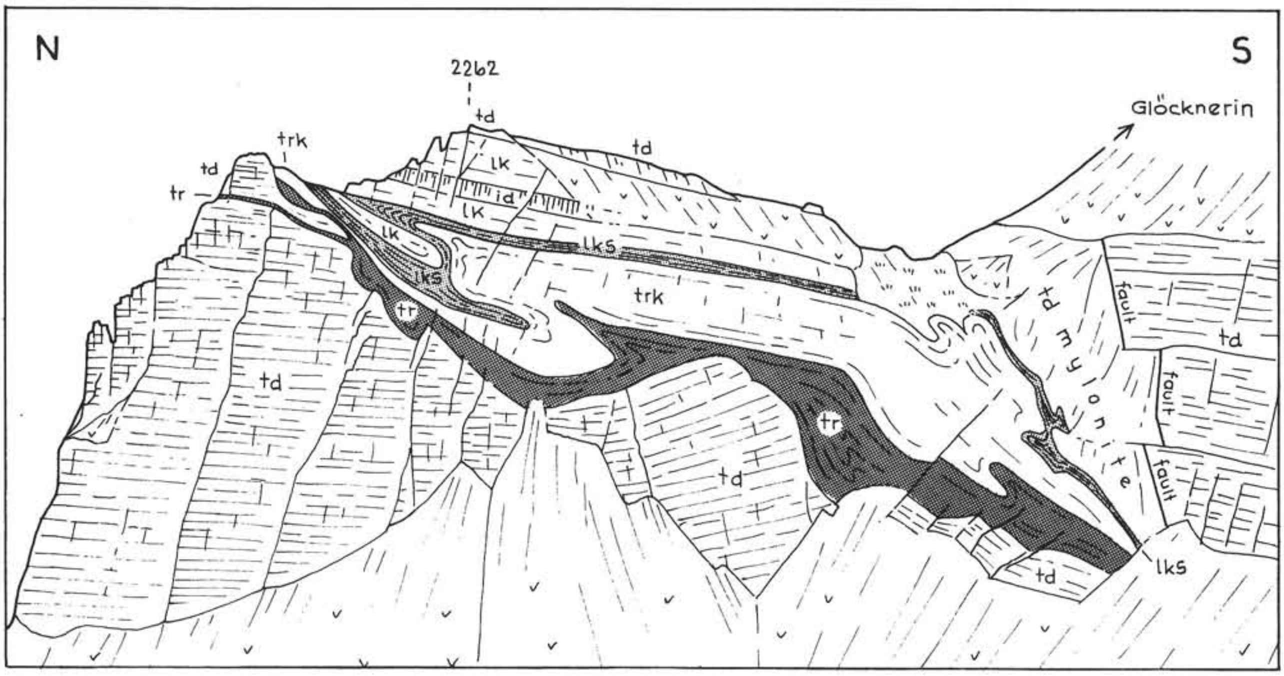


Fig. 28: The Teufelshörner in the Radstadt Tauern, view from west (A. TOLLMANN, 1977). Legend see fig. 27.

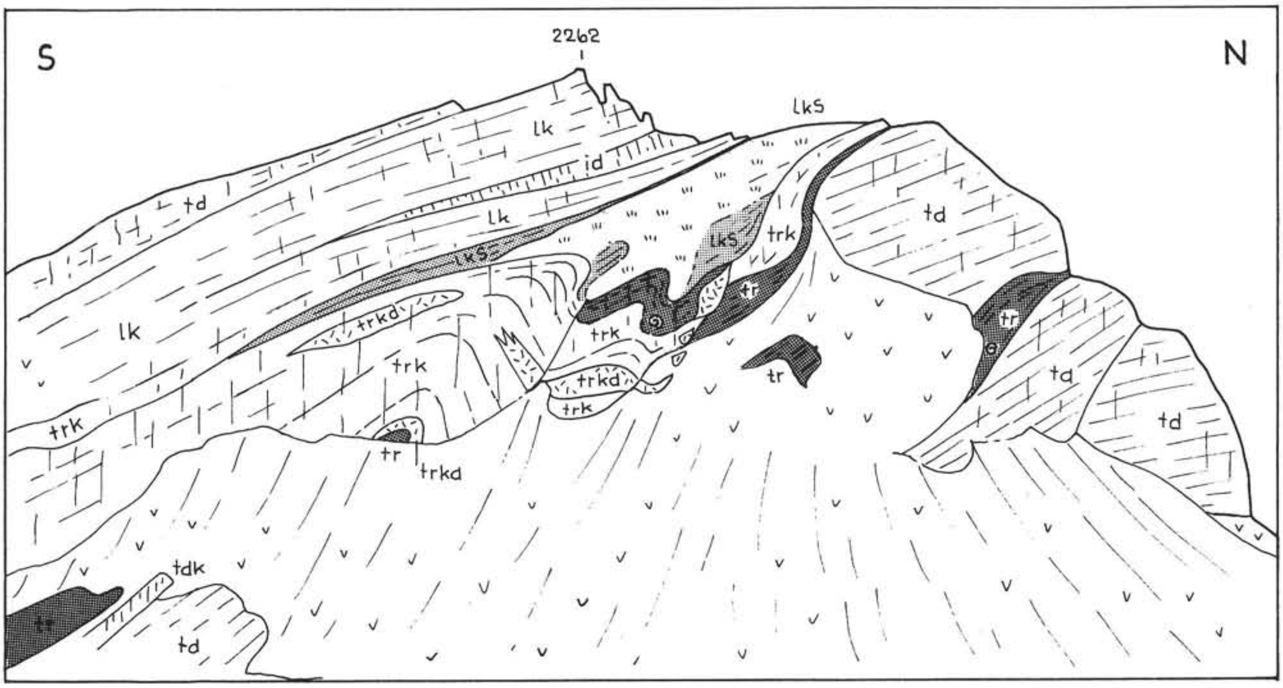


Fig. 29: The Teufelshörner, view from east (Original). Legend see fig. 27.

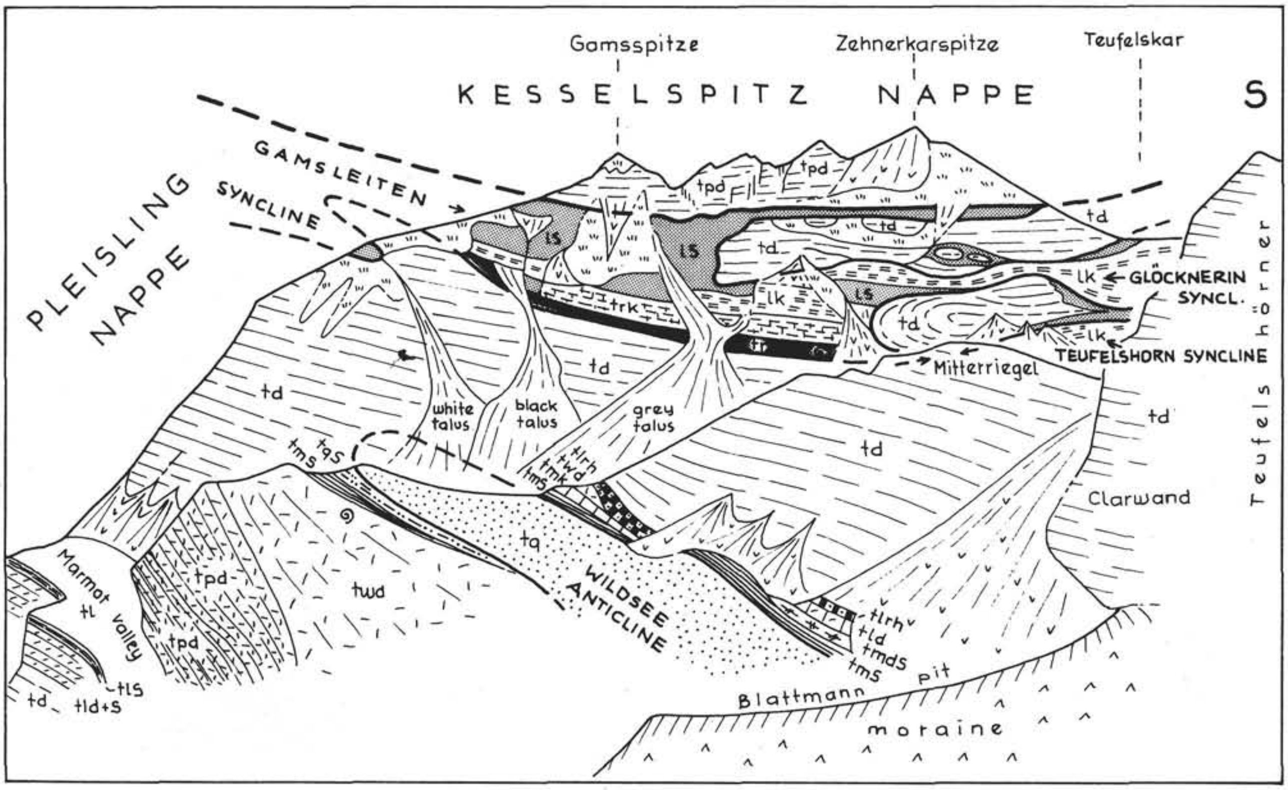


Fig. 30: The western wall of the Zehnerkar peak in the Radstadt Tauern (A. TOLLMANN, 1958). Legend see fig. 27.

Teufelshörner syncline into two parts. The prolongation of this dolomite lamella can be seen on the top of the Teufelshörner.

Stop 4.4. Zehnersattel

Advancing to the Zehnersattel pass one sees the beautiful panorama of the Zehner circus, which shows the upper part of the folded Pleisling nappe and remains of the Kesselspitz nappe (fig. 30) — compare also fig. 26. The recumbent fold of S c h w a r z e W a n d with bright dolomite and black shales of Carnian in its core demonstrates the main direction of tectonic transport towards the north (fig. 31). This fact is important, because for decades the autochthonists, who refused the existence of the Tauern Window, postulated a southward direction of movements to explain the supperposition of units here in the northeastern framework of the Tauern Window by local overwhelming. On the summit of the Kesselspitze as on the Zehnerkarspitze an analogous remain of the Kesselspitz nappe is preserved. This Anisian portion of the dolomite is proven by *Encrinus liliiformis* (LAM.) and *Entrochus silesiacus* BEYRICH.

Day 5

Lower Austroalpine unit in the southern part of the Radstadt Tauern within the Hochfeind range

(A. TOLLMANN)

R o u t e: Obertauern — Tweng — Lantschfeld valley — Fuchs alp — Schwarzsee cirque — Obertauern. Region of Lungau in Salzburg. Mainly march.

S u b j e c t: Characteristic breccias and "Wildflysch" of the late stage of geosyncline, Hochfeind facies in the lowermost tectonic units of the Radstadt Tauern, Jurassic and Cretaceous sedimentation in the Lower Austroalpine unit. Micro- and macrotectonics.

R e f e r e n c e s: E. CLAR (1937): Sitzber. Akad. Wiss. Wien, math.-natw. Kl., I, **146**, 249—316, Wien; A. TOLLMANN: Verh. geol. B.-A., **1959**, A 91—95; Mitt. geol. Ges. Wien, **53** (1960), 117—131; Geologie v. Österreich, vol. **1**, p. 108 ff. (Wien 1977). Topogr. map: Österreichische Karte 1 : 50.000, sheet 156.

Introduction

The southern range of Radstadt Tauern indicates the individual facies of the lowermost unit of the Lower

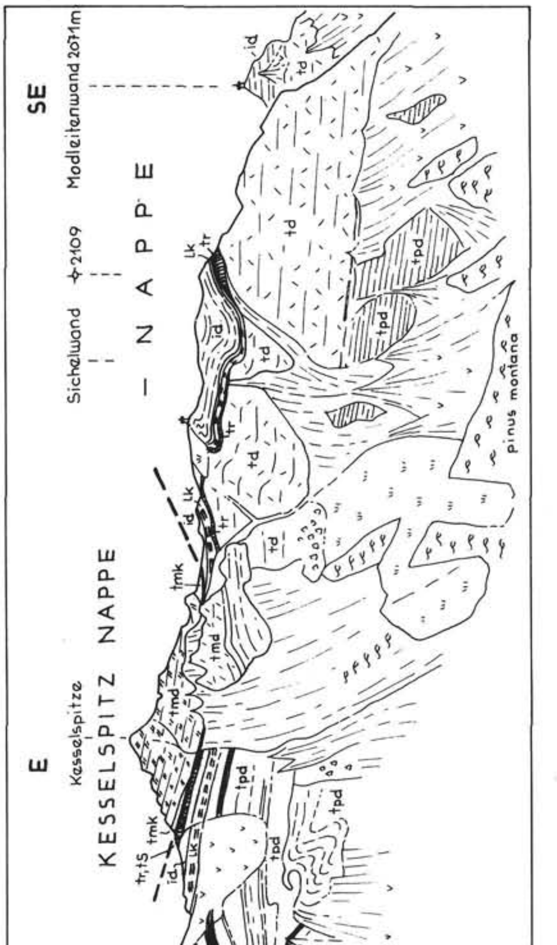


Fig. 31: Panorama of the range Schwarze Wand-Sichelwand-Kessel peak in the eastern part of the Pleisling massif. View from west, from the Zehnerkar peak (Original). Legend see fig. 27.

Austroalpine. In contrast to the Pleisling facies mentioned above one finds here an enormous abundance of breccias within the Jurassic and Lower Cretaceous. In fact, this part of the Lower Austroalpine system resembles the Penninic trough wich formerly adjoined it and was divided partially by the Lungau rise.

The stratigraphic development within the Triassic sequence of the Hochfeind range resembles that of the Pleisling range, up to the Upper Rhaetic limestone rich in megalodonts, which will be demonstrated in the background of the Schwarzsee circus (see fig. 6). Vigorous movements at the beginning of Liassic lead to eminent unconformities, so that locally the Liassic breccias directly overly Hauptdolomit. Above all the Liassic is marked by a thick mass of breccias, called Türkenkogel breccies. It comprises coarse types with components and blocks of dolomite, limestone and quartzite with indications of mass-flow mechanism, but also levels of dolomitic and quartzitic sandstone. The formation of this type of breccias continues during the Dogger. Within the Lower Malm laminated radiolarites with manganese ore were formed, which characterize a deep sea basin. Inspite of the metamorphism the structure and also the red colour of this radiolarites is preserved locally, radiolarians have been identified in thin sections. A layer of marble within this radiolarite is called "Aptychenkalk".

The series beyond, belonging to the higher Malm and the lower Cretaceous, consist of an alternation of immature sandstones and coarse breccias. The content of crystalline components increase in the upper part more and more. The most impressive phenomena of this late- and post-malmian "Schwarzeck breccias" are gigantic sedimentary blocks in dimensions of houses or hills, mostly composed of dolomites. The sedimentary (and not tectonic — as believed in the past) origin is documentated by a scattering of the marginal zone of these blocks, deposited in the clastic sediment. This phenomenon demonstrates the important role of the young-Kimmerian phase.

Also in the Hochfeind range the main tectonic feature aside from nappe structure is folding in a northern direction. At the Hochfeind and Schwarzeck peak the younger series are preserved in huge synclines, closed to the south. In the sector visited around the lake Schwarzsee the microtectonic structure shows a distinctly selective character depending on the lithofacies: the radiolarite of high mobility forms impressive flow folds; the differences between the soft shales and the brittle dolomites strike just in this tectonic position. Back folding towards SE is only of local importance.

Stop 5.1. Lantschfeld valley

Along the route from Tweng to the Lantschfeld valley one finds outcrops of Werfenian and Anisian of the Lantschfeld nappe north of Ambroshütte. The ascent to the Fuchsalm crosses the Altkristallin at the base of

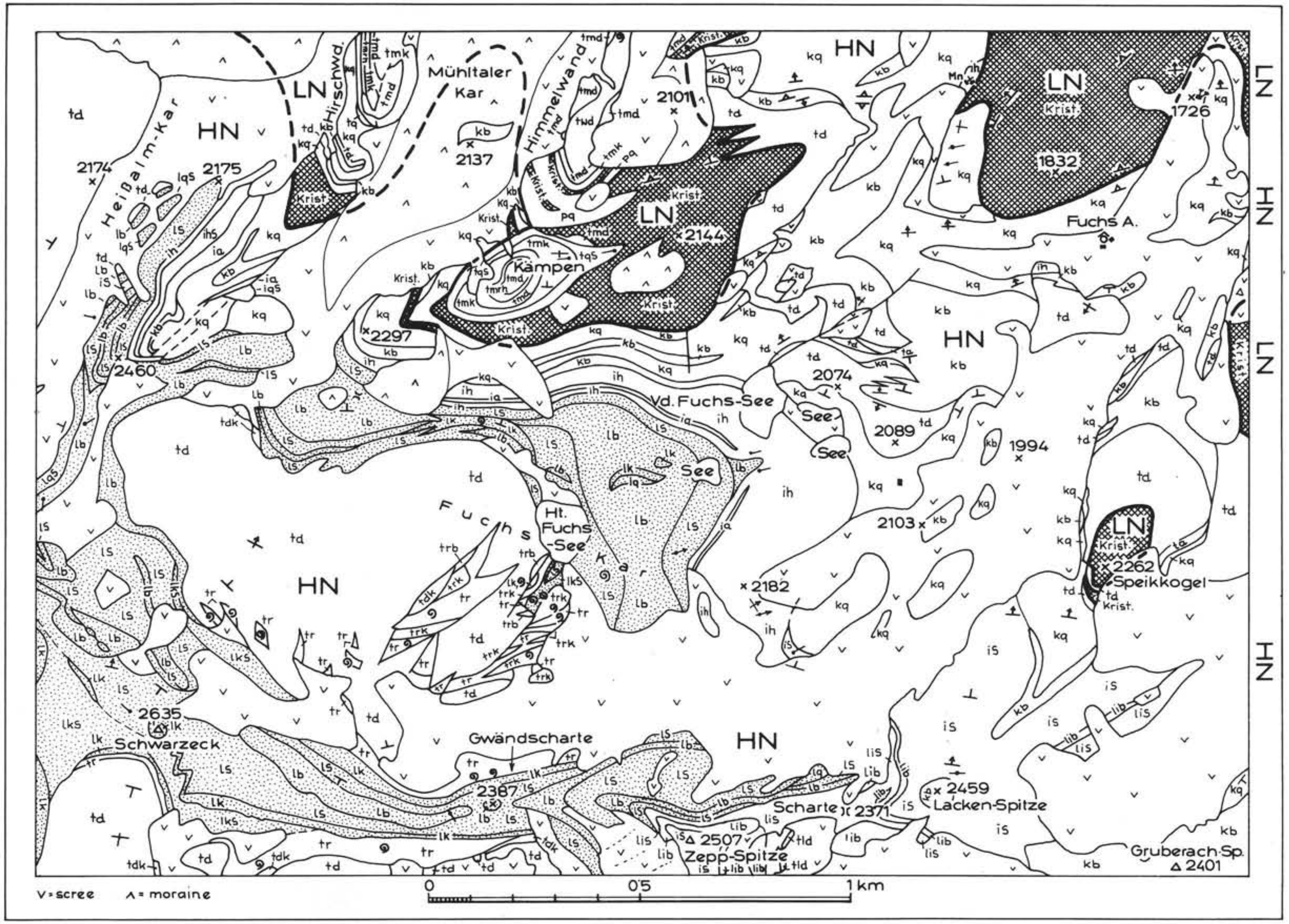


Fig. 32: Geological map of the Fuchs circus in the southern range of Radstadt Tauern (Original). HN = Hochfeind nappe, LN = Lantschfeld nappe. Legend see fig. 27.

Lantschfeld nappe, dipping northward. This diaphthoritic Tweng crystalline consists of greenish paragneisses and of micaschists. In the southeastern prolongation of the Tweng crystalline amphibolites, granites etc. also belong to this crystalline zone. The diaphthoresis — the locus classicus lies SE of Tweng — has changed the mineral association in greenschist facies: chlorite, phengite, epidote, zoisite, plagioclase and quartz are now the typical association of minerals in these gneisses.

Stop 5.2. Fuchs alp

At the northern border of the Fuchs alp one sees the thrust of Tweng crystalline of the Lantschfeld nappe above the youngest formation of Hochfeind nappe, namely the Schwarzeck breccias, sandstones and graywackes. The assimilation of these two complexes — Tweng crystalline and Schwarzeck sandstone of the Lower Cretaceous — by alpidic metamorphosis is surprising. In field work a distinction between these two units is only possible, if the sandstones comprise dolomite components. The similarity is caused by the fact that the sandstone and graywacke are composed of the detritus of the crystalline, so that a similar material in connection with a corresponding metamorphosis (destructive in the crystalline, constructive in the Cretaceous graywackes) produces the same shape.

Stop 5.3. Schwarzsee

The Schwarzsee circus demonstrates the stratigraphy and tectonics of the Hochfeind nappe. Beyond the Upper Triassic the two main types of breccias, the Türkenkogel breccia of Lower Jurassic and the younger Schwarzeck breccia, appear. The sequence of the whole series rich in breccias with sedimentary blocks in the uppermost parts can be seen in the panorama of the crest south of the circus between Schwarzeck and Speikkogel (fig. 32—34).

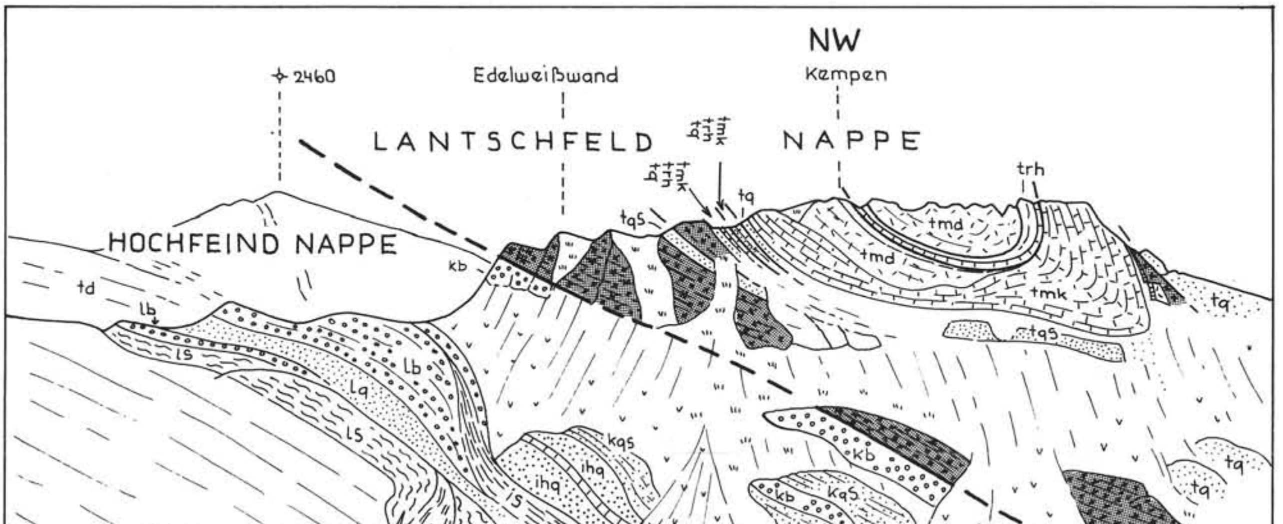


Fig. 33: View at the bordering zone of Hochfeind nappe (below) and Lantschfeld nappe (above) in the northern frame of the Fuchs circus, southern Radstadt Tauern (Original). Legend see fig. 27.

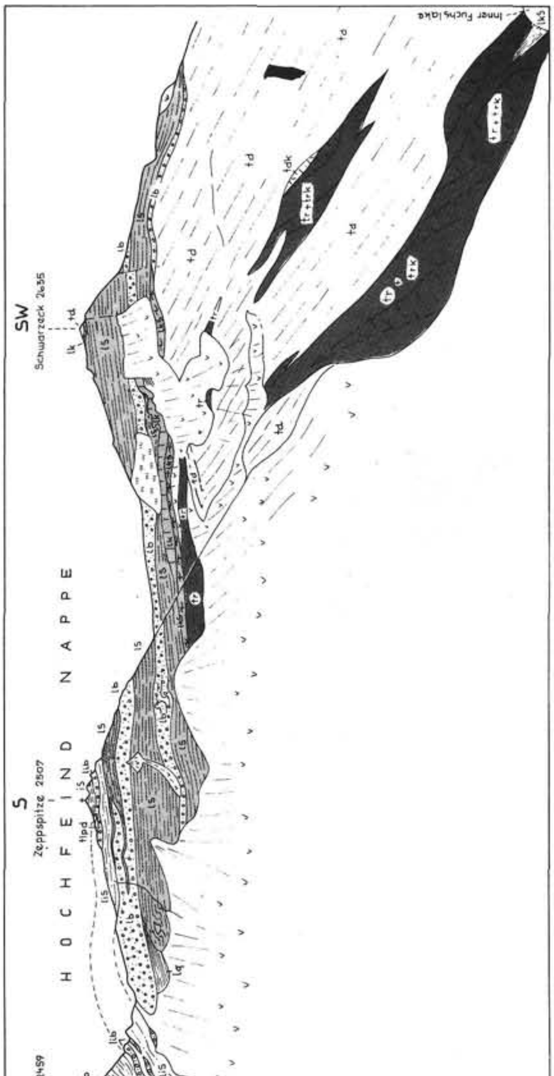


Fig. 34: View of the main range of the southern Radstadt Tauern in the section of the Schwarzeck (Original). Legend see fig. 27.

Day 6

Middle Austroalpine and Gurktal nappe east of the Tauern Window

(A. TOLLMANN)

R o u t e: Obertauern — Mauterndorf — St. Michael — Katschberg — Innerkrems — Eisentalhöhe — Karlbad — Innerkrems — Spittal/Drau — Villach — Hermagor. Provinces: Salzburg, Carinthia. Bus drive and a march near Innerkrems.

S u b j e c t: Eastern border of the Tauern Window. Prolongation of the Lower Austroalpine in the Katschberg zone. Middle Austroalpine crystalline and its sedimentary cover of the Stangalm Mesozoic. The western border of the Upper Austroalpine Gurktal nappe and the tectonic slice of Lician facies, representing an involuted Upper Austroalpine chip of the Drauzug near Innerkrems. Drauzug and Gailtal fault.

R e f e r e n c e s: N. ANDERLE: Geolog. Karte von Österreich 1 : 50.000, sheet 200 Arnoldstein; R. v. BEMMELEN (1961): Jb. Geol. B.-A., **104**, *213—237*, Wien; E. COLINS et al. (1979): Mitt. Ges. Geol. Bergbaustud. Österr., **25** (1978), 1—10, Wien; Ch. EXNER (1954, 1971): Jb. Geol. B.-A., **97,** 17—37; Ibid. **114** (1971), 1—119, Wien; E. KRISTAN-TOLLMANN et al. (1963): Mitt. geol. Ges. Wien, 56, 539—589, Wien; K. LIEGLER (1970): Carinthia II, **160**, 27—44, Klagenfurt; J. PISTOTNIK (1974): Mitt. geol. Ges. Wien, **66—67**, **127—141**, Wien; H. STOWASSER (1956): Jb. Geol. B.-A., **99**, 75—199, Wien; A. TOLLMANN: Mitt. Ges. Geol. Bergbaustud. Österr., **9** (1958), 57—73; N. Jb. Geol. Pal. Abh., **150** (1975), 19—43, Stuttgart; Geologie von Österreich, vol. **1** (Wien, Deuticke, 1977), p. 131 ff., 309—329, 588—643. — Topogr. maps: Österr. Karte 1 : 50.000, sheet 157, 182, 183!, 199, 200.

Introduction

This day gives insight into the situation along the eastern framework of the Tauern Window. It gives a review about the three nappe systems of the Austroalpine unit, which succeed one the other like the peels of an onion, visible here in consequence of the eastward dipping culmination of the Tauern.

The first part of the excursion route leads exactly along the narrow Lower Austroalpine zone at the eastern border of the Tauern Window. The nappe system of the Radstadt Tauern is prolongated in its Mesozoic series beyond Mauterndorf still to St. Michael, where is ends by tectonic lamination. Only the reversed highest unit, the Quartzphyllite nappe, continues with its monotonous phyllites and few lenses of Paleozoic dolomites and limestones (with conodonts of Upper Silurian) southward across the Katschberg pass to Rennweg and further on to Gmünd in Carinthia. This prolongation of the Lower Austroalpine is called the Katschberg Zone.

It is overthrust by the vast mass of Middle Austroalpine crystalline, which joins at the east. NE of Mauterndorf this Altkristallin consists mainly of paragneis-

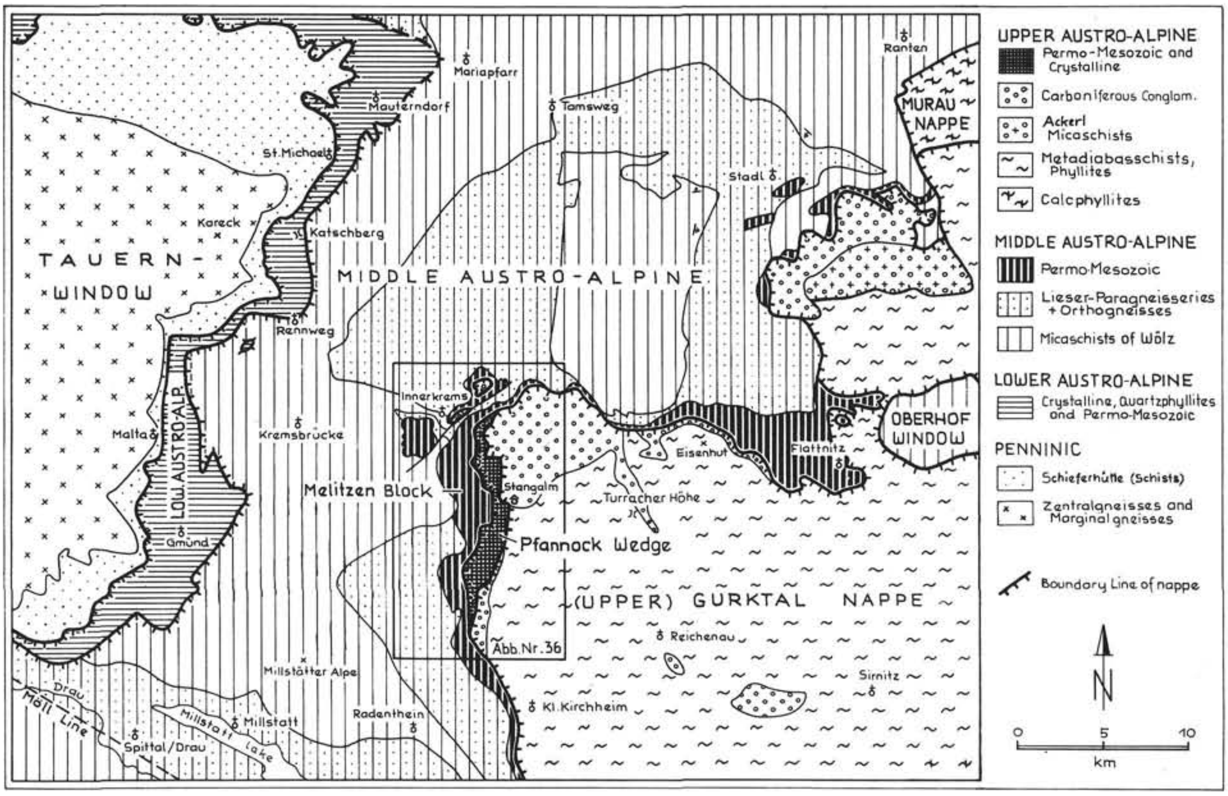


Fig. 35: General view of the region east of the Tauern Window (A. Tollmann, 1975).

ses. Southernmore, east of the Katschberg Zone micaschists with a diaphthoritic base dominate. In the upper part of this crystalline, i. e., further in the east, appears the Bundschuh para- and orthogneiss.

The Permotriassic in centralalpine facies (see fig. 6), belonging primarily to the Altkristallin, overlies this crystalline 15—20 km far eastern from the thrustplane, exposed in a meridional zone. It shows a slight metamorphosis and an intensive schuppen structure. This unit is called the Melitzen-mass. Beyond this unit another type of Mesozoic, the Upper Austroalpine Pfannock schuppe, rests upon with tectonic contact. Melitzen scholle and Pfannock schuppe together form the so called Stangalm Mesozoic (fig. 35). The Paleozoic of the Gurktal nappe rests above all along a significant thrust plane.

This impressive succession of Austroalpine units, divided by Mesozoic intercalations excited us in 1959 under the impression of the position, facies and metamorphosis of the Stangalm Mesozoic, to divide the Austroalpine system into the three main subunits mentioned above.

Like the Gurktal nappe in the east of Hohe Tauern, the Middle Austroalpine mass south of the Tauern culmination is also superimposed by the Upper Austroalpine: There is the Drauzug Mesozoic along Gail- and Drau-valley in the Gailtal Alps and its Paleozoic basement in the Goldeck massif. The Drauzug Mesozoic occupies by its Lician facies and its position a mediate position between the Northern Limestone Alps and the Southern Alps. Similarities with the Northern Limestone Alps in Tyrol are, for example, the Ladinian-Carnian Wetterstein limestone with its syngenetic lead-zinc-deposits, a specific Carnian sequence with a distinct rhythm of carbonates and shales, the Norian Hauptdolomit with its bituminous shales (Seefeld shales), Plattenkalk, Koessen beds and Upper Rhaetic Dachstein limestone. The similarities with the Southern Alps exist mainly in the Permian with Gröden sandstone, Werfenian, the Anisian with sand-bearing carbonates and a significant volcanism in the Middle Triassic. The morphologically most important formations of the Drauzug in the Gailtal Alps and Lienzer Dolomites are the Wetterstein dolomite (or limestone) with a thickness up to 1700 m and the 1200 m thick Norian Hauptdolomit. The tectonic style of this part of Upper Austroalpine near the main root zone of the Alps is characterized by a strong compression, expressed by a lot of narrow crested upright longitudinal folds, steep dipping strata and a strong fracturing by a conjugate joint system.

Itinerary: Along the route from Obertauern to Mauterndorf we cross more and more the lower units of the Radstädter Tauern: from Obertauern to Tweng we remain in the Pleisling nappe, of which we cross the Anisian and Werfenian at the Twenger Talpass. South of Tweng the crystalline of the Lantschfeld nappe crosses the valley. The Hochfeind nappe reaches in Mauterndorf the bottom of the valley. The system of Radstadt Tauern nappes finally ends at St. Michael.

Stop 6.1. Katschberg

Driving up from St. Michael to the Katschberg pass the view towards west shows the units of the Penninic system: The thick Glockner nappe, consisting mainly of post-Triassic calcschists and greenschists, forms the slopes of the Zederhaus valley. The Schrovinkopf south of the end of this valley belongs to the Lower Schieferhülle nappe with its Brennkogel facies. Below this unit we see the Penninic Altkristallin Storz series along the bents of the Murtal. This crystalline also forms a nappe (Storz nappe), sheared off from its socle. The new Autobahn tunnel below the Katschberg pass crosses in its main part this migmatitic Storz crystalline. In the background of the upper course of the Murtal and again in the upper Lieser valley west of Rennweg one sees the core of the Penninic system, the centralgneiss dome of the Hafner massif.

The outcrops on the summit of the Katschberg pass show the strongly deformed Paleozoic quartzphyllites of the Lower Austroalpine Katschberg Zone, dipping eastward below the micaschists of the Middle Austroalpine unit.

Stop 6.2. Innerkrems

Leaving the Lieser valley at Kremsbrücke and turning to the Krems valley in the east one crosses first the micaschists, than a paragneiss zone and finally, at Innerkrems, the Bundschuh orthogneiss (with an radiometric age of 370—380 million years, i. e. Lower Devonian). To the south and est of Innerkrems the Stangalm Triassic rests unconformably on the crystalline (fig. 36). This Mesozoic zone strikes from the south, from the Melitzen peak, and runs to the east to Flattnitz and Murau. The meridional sector includes, in its lower part, in the Melitzenzone, a series with Permian sericite-quartzite and quartzkeratophyre, Skythian quartzites and Roet schists, Anisian cellular dolomite, banded limestone and dark and light dolomite and Ladinian Wetterstein dolomite. Upper Triassic and Jurassic join in the west-east striking zone of Flattnitz.

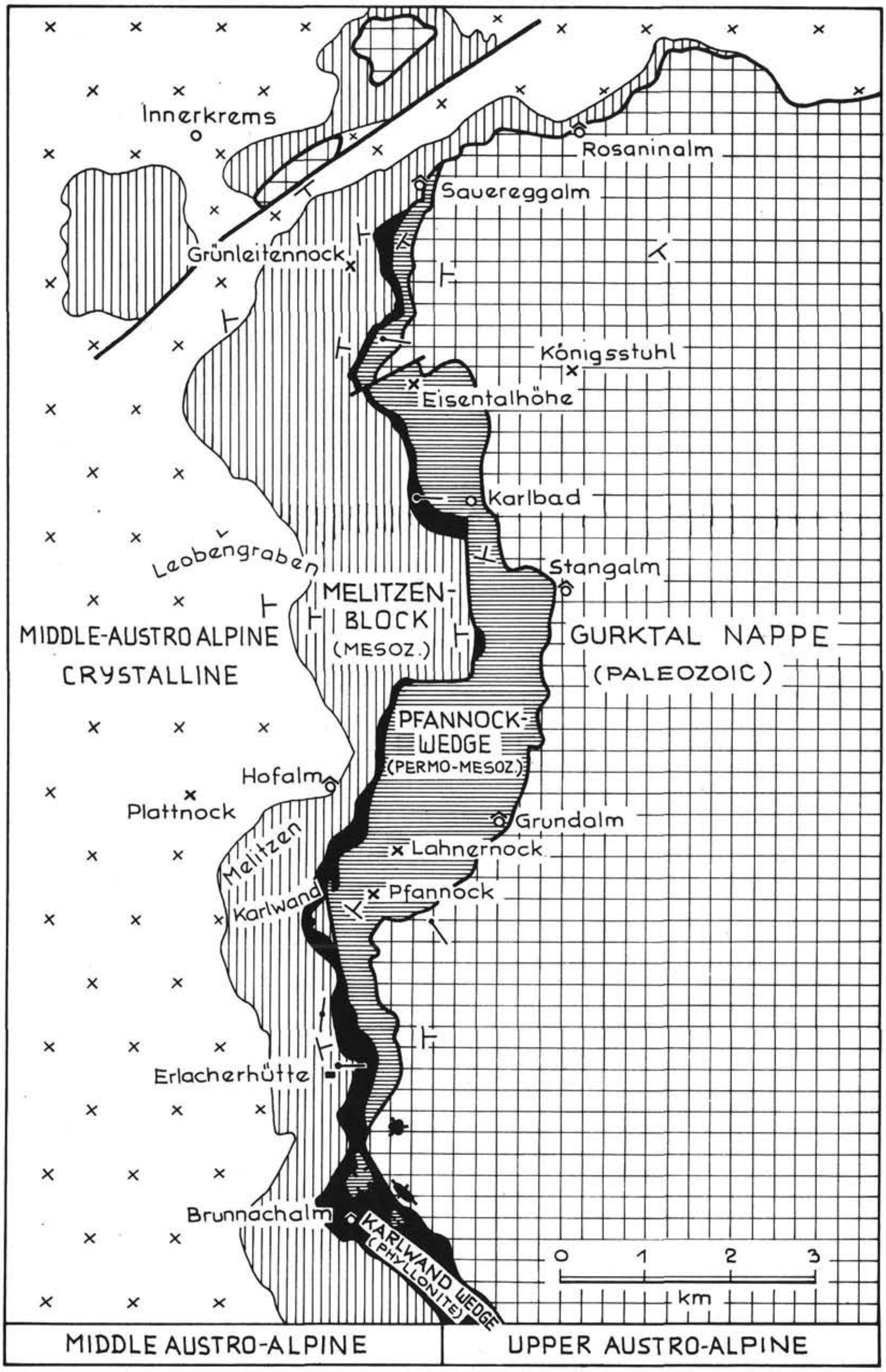
This series of Lower and Middle Triassic of the Melitzen zone exposes an imbricate structure along the Saueregg brook east of Innerkrems (fig. 36). South of the Saueregg alp this zone is superposed along a mylonite horizon of shales by an other series of Mesozoic with different facies and metamorphism, namely the Pfannock schuppe. In this region the Pfannock schuppe rests with non-reversed Upper Triassic (Hauptdolomit, Plattenkalk, Koessen beds) on the Middle Triassic of the basement and suggests a normal sequence (pseudoseries) seemingly joining these two different units. But the southern prolongation of the Pfannock schuppe, which shows a reverted position 6 km to the south prooves the tectonic independency of this higher unit. There, in the region of Pfannock, its facies with sandbearing fossiliferous Anisian and other features demonstrates the origin from the Drauzug mass with its Lician facies. Therefore this higher Mesozoic unit of Pfannock schuppe is part of the Upper Austroalpine system. The reversed position of the main part of this unit and also the reversed structure of the overthrust part of the Gurktal nappe with Upper Carboniferous conglomerates below Lower Paleozoic shales suggest an involution of the Pfannock slice below the bulk of the Upper Austroalpine (fig. 37). We meet here one of the most impressive examples for involution in the Eastern Alps!

Stop 6.3. Eisental Höhe — Königstuhl

The ascent from Saueregg alp to the Eisental summit and farther to the east in direction of Königstuhl (2332 m) shows the superposition of the Melitzen zone, of the zone of mylonitic shales, the Upper Triassic of the Pfannock schuppe and finally the Upper Carboniferous of the Gurktal nappe, demonstrated schematically in fig. 37. The Koessen beds of the Eisental summit have supplied a Rhaetic fauna: the basal part of the section includes molluscs of the Swabian facies with *Rhaetavicula contorta* (PORTL.), *Cardita austriaca* HAUER, *Dimyopsis intusstriata* (EMMR.) etc. The upper part of the section comprises a fauna with corals like *Astraeomorpha crassisepta* RSS., *Thamnasteria rectilamellosa* WINKL., *Oppelismilia zitteli* (FRECH) and *Thecosmilia,* furthermore *Isocrinus bavaricus* (WINKL.) and a poor microfauna with foraminifera.

In the past the Upper Carboniferous sandstones and conglomerates, were exploited for coal and from 1783 on have yielded rich floras of Westfalian D to Stefanian with *Neuropteries ovata* HOFFM., *Pecopteris arborescens* BRGT., *Calamites cruciatus* STERNBG., *Annularia stellata* SCHL., *Lepidodendron rimosum* STERNBG., *Sigillaria laevigata* BRGT. etc.

The view from the Eisental summit to the south shows clearly the superposition of crystalline and Mesozoic of the Middle Austroalpine, dipping toward east, above this the reversed Pfannock schuppe with the dark Pfannock crystalline on the top of this mountain, and above all the monotonous Lower Paleozoic mass of shales of the Gurktal nappe, forming the so-called "Nock landscape" of Carinthia.


Innerkrems
Rosaninalm
Sauereggalm
Grünleitennock
Königsstuhl
Eisentalhöhe
Karlbad
Leobengraben
Stangalm
MELITZEN-BLOCK
(MESOZ.)
MIDDLE-AUSTRO ALPINE
CRYSTALLINE
GURKTAL NAPPE
(PALEOZOIC)
PFANNOCK-WEDGE
(PERMO-MESOZ.)
Hofalm
Plattnock
Grundalm
Melitzen
Lahnernock
Pfannock
Karlwand
Erlacherhütte
Brunnachalm
KARLWAND WEDGE
(PHYLLONITE)
0 1 2 3
km
MIDDLE AUSTRO-ALPINE
UPPER AUSTRO-ALPINE

Upon returning to the L i e s e r v a l l e y the tour leads us in the direction of the Lieserbrücke, first across a zone of micaschists with garnet, comprising some lenses of dolomite and magnesite — which is exploited farther east, near Radenthein. The view from Gmünd towards NW in the Malta valley and to the Maltein Sonnblick shows the Penninic central gneiss.

Farther to the south, along the L i e s e r g o r g e, the route crosses the Lieser gneiss series of the Middle Austroalpine system. This paragneisss with a high grade of prealpidic metamorphosis has been overprinted in the alpidic era in its part near to the Tauern Window by the epidote-amphibolite facies. Here the Lieser gneiss includes staurolithe, apatite, tourmaline, epidote, oligoclase, albite etc. It exhibits an eminent infiltration of pegmatites, so that one can find here at the exit of the Lieser gorge an unique quarry of feldspar in Austria.

At Spittal/Drau we reach the wide D r a u v a l l e y. It follows a great faultline, running WNW-ESE, well visible on the satellite picture. The route leads near Villach around the eastern corner of the Gailtal Alps (Drauzug) to Hermagor in the Gail valley. This valley follows the P e r i a d r i a t i c L i n e, the most important fault line in the Eatsern Alps, along which we estimate a dextral wrench of about 150 km.

The D o b r a t s c h massif on the eastern termination of the Gailtal Alps is comprised of two wedges. The bulk of this mountain consists of the Ladinian-Lower Carnian Wetterstein Limestone, without regard to the interesting red Hallstatt facies and vulcanites in the Middle Triassic. During an earthquake in Venetia in 1348 a vast landslide came down from the southern flank of the Dobratsch massif, destroying 17 villages and forming a striking toma landscape.

North of the Dobratsch, beyond the Bleiberg fault are the lead-zinc mines of Bleiberg, probably already utilized by the Celts and citated in the year 1014. These mines have today a production of almost 400.000 tons of ore per annum. The metallization is of sedimentary origin and in conjunction with the upper part of Wetterstein limestone and with the Carnian Raibl beds.

West of the Dobratsch extend the famous Carboniferous outcrops of Nötsch. An 8 km long mass, tectonically isolated, was preserved from erosion. Already in the year 1829 *Productus* of the Lower Carboniferous was mentioned from this locality. The rich fauna documents an age of this section from Upper Tournai to Westfal. The youngest part of these formations can be considered as a marginal facies of the southalpine Hochwipfel formation with its flysch character.

South of the Gail valley the C a r n i c A l p s as the northernmost part of the Southern Alps rise up with series from Caradocian to Carboniferous and a trans-

Fig. 36: Tectonic division of the Stangalm Mesozoic near Innerkrems (A. Tollmann 1975).

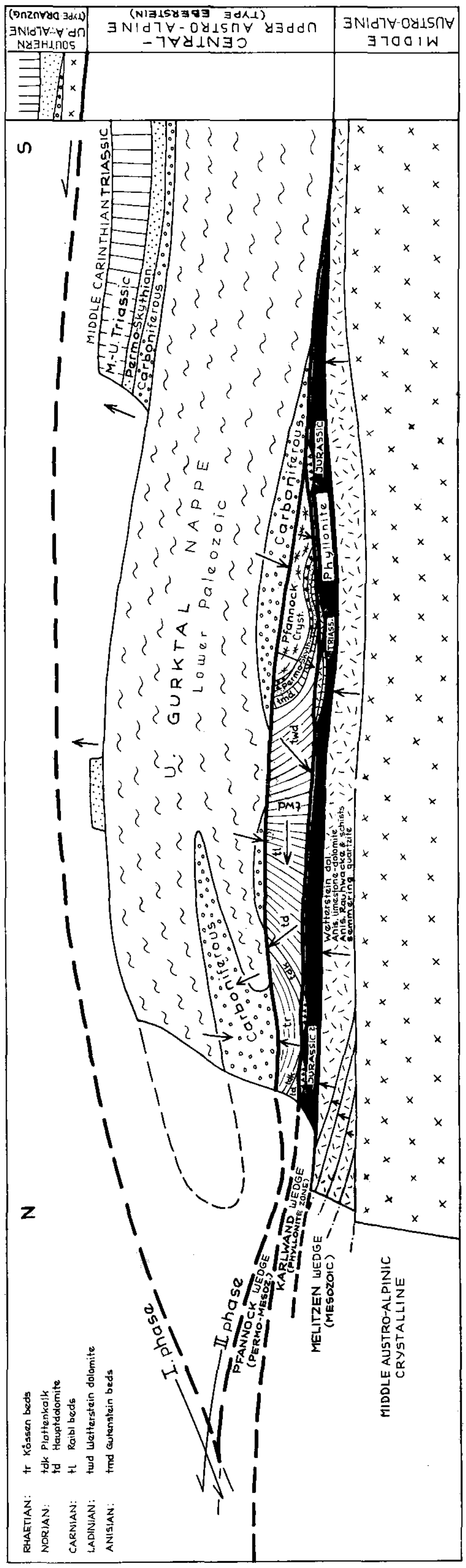


Fig. 37: Schematic section explaining the position and the structure of the Stangalm Mesozoic (A. Tollmann, 1975).

gressive second stage from uppermost Carboniferous to Triassic.

Day 7

The Late Paleozoic of the Nassfeld Area in the Carnic Alps

(A. FENNINGER) *)

R o u t e: Hermagor — Nassfeld — Gugga, Flora, Garnitzenberg — Hermagor — Gailberg pass — Lienz.

S u b j e c t: The Late Paleozoic of the Carnic Alps shows its widest extent in the area around the Naßfeld and the Straniger Alm. The Carboniferous up to Westfalian B can not be studied within the scope of the excursion and is therefore not treated in this account.

On the one hand the area around the Naßfeld is known by the development of the Auernig Group containing the famous sections of Auernig, Garnitzen and Krone, on the other hand by Permian sections as Reppwand, Tressdorferhöhe, Grenzlandkamm and Schulter.

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Introduction

The A u e r n i g G r o u p transgresses over the Carboniferous flysch (Hochwipfel Formation) and represents the final-stage of the Variscan geosyncline in the form of a cyclothemic Molasse. At the Carboniferous/Permian boundary this environment changes to an in-

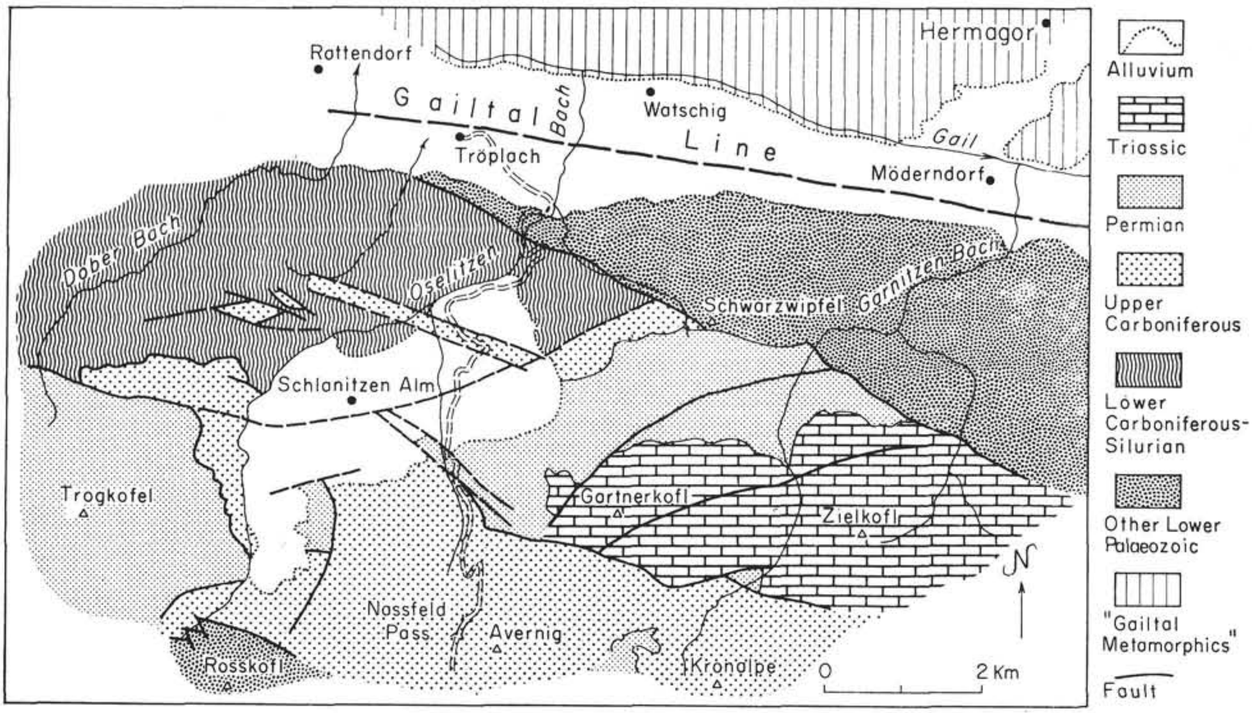

Fig. 38: Sketch map of the Naßfeld Area in the Carnic Alps (F. KAHLER & S. PREY, 1963; after E. R. OXBURGH, 1968).

ner-shelf facies which gradually passes into a carbonate platform (Rattendorf Group, Trogkofel Limestone and Tressdorf Limestone). Synsedimentary tectonic activities at the Lower/Middle Permian boundary lead to a destruction of this carbonate platform. Conglomerates and breccias were deposited in local depressions (Tarvis Breccia). The Alpidic cycle starts in the Middle Permian with the clastic Gröden Formation which in the Carnic Alps is mainly developed in marine facies. The increasing transgression during the Upper Permian results in the deposition of the basal evaporitic Bellerophon Formation (BUGGISCH et al. 1976) (Fig. 39).

The Auernig Group, up to 700 m in thickness, represents a sequence of shales, siltstones, sandstones, conglomerates, and different types of limestones and dolomites. Locally small coal seams are intercalated. The characteristic elements of fauna and flora are Dasycladacea, Rhodophycea, fusulinids, small foraminifers, Sphinctozoa, brachiopods, corals, conulates, lamellibranchs, gastropods, bryozoans, trilobites, and echinodermats. Elements of terrestrial flora are abundant in single layers, predominantly in finer-clastic rocks. In accordance to the frequency and thickness of carbonates the Auernig Group is divided into five formations (HERITSCH et al. 1934) (Fig. 40). SELLI 1963 registered these lithologic names and proposed formational designations based on local (topographic) names. The correlation is shown in the following table.

SELLI 1963	HERITSCH et al. 1934
Formazione del Carnizza	Upper kalkarme Formation
Formazione del Auernig	Upper kalkreiche Formation
Formazione del Corona	Middle kalkarme Formation
Formazione del Pizzul	Lower kalkreiche Formation
Formazione di Meledis	Lower kalkarme Formation

The Auernig Formations are partly retained as in German for the sake of brevity.

The Lower kalkarme Formation in the Naßfeld area is sparsely exposed. It is typically developed, however, in the area of the Straniger Alm (Waschbühel Section). There the Waidegger Fauna (GAURI 1965) has been famous for long times. The distinct development starts with the Lower kalkreiche Formation. The so called "Geröllschiefer", representing a contemporary development to the Lower kalkarme Formation and being deposited in depressions, are not exposed in the area of the Naßfeld. They transgressively overly the Variscan basement and are interpreted as continental debris flows and fluviatile sediments.

The Auernig Group may be subdivided into a series of cyclothems, the Lower kalkarme Formation representing a cyclothem with dominantly marine shales. The Lower kalkreiche as well as the Upper kalkreiche Formations are balanced cyclothems, whereas the Middle kalkarme Formation represents a cyclothem type with basal sandstones and conglomerates dominating. The Upper kalkarme Formation seems to claim a transitional position between balanced and shale-dominated cyclothems.

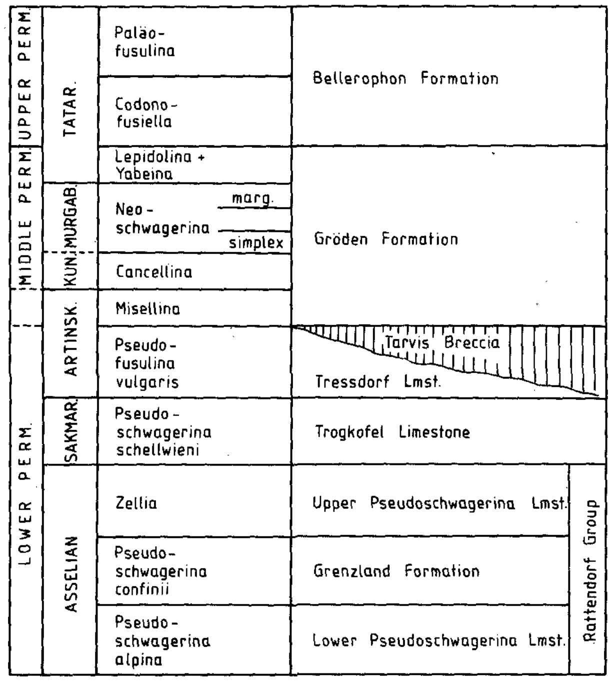

Fig. 39: Fusulinide stratigraphy of the Permian in the Naßfeld area, Carnic Alps (F. KAHLER, 1974, W. BUGGISCH et al., 1976).

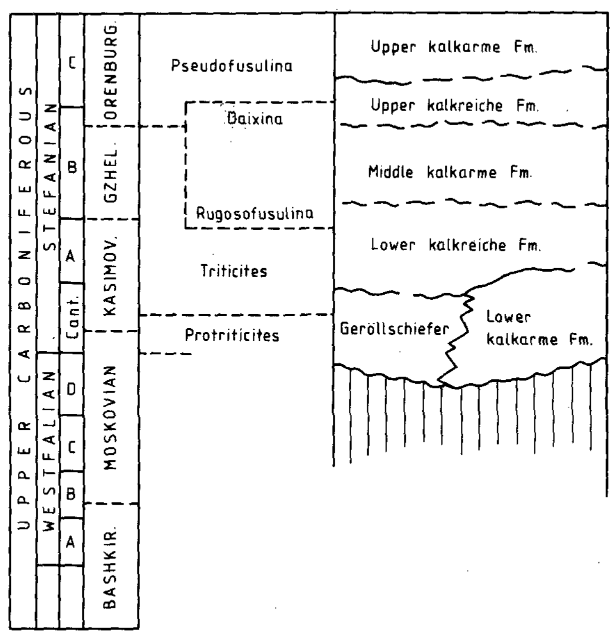

Fig. 40: Fusulinid stratigraphy of the Carboniferous Auernig Group (F. FRANCAVILLA & G. B. VAI, 1980).

Concerning biostratigraphy some items are not quite clear:

1. The Cantabrian is not definitely distinguished;
2. The Carboniferous/Permian boundary is open to question.

WATERHOUSE (1976) — referring to the worldwide correlation of brachiopod faunas — assigned parts to the Middle kalkarme Formation (?) and the upper Formations to the Asselian, putting them all into the Permian. Referring to fusulinid stratigraphy (KAHLER & PREY 1963, KAHLER 1974, FRANCAVILLA & VAI in press) the Carboniferous/Permian boundary is defined by the first appearance of *Pseudoschwagerina alpina*, and the first unit of Asselian thus in the Lower Pseudoschwagerina Limestone. The evolution of the flora corresponds with the fusulinid stratigraphy.

The excursion route is only crossing a part of the Garnitzen Section (Fig. 41), the Middle kalkarme Formation and the Upper kalkreiche Formation. Compared with other sections the great thickness of the Garnitzen Section is a remarkable phenomenon. It is caused by tectonic repetitions of the Middle kalkarme and the Upper kalkreiche Formation, which are clearly proved by mapping, fossil-bearing horizons and sedimentological parameters.

Stop 7.1. Road Junction Kötschach/Hermagor — Naßfeld

View of the Permian/Triassic section of the Reppwand and the Gartnerkofel.

Stop 7.2. End of chair-lift at Pt. 1902

The limestones and marls, which belong to the upper parts of the Lower kalkreiche Formation, can be devided into three horizons: a basal pebbly, sometimes dolomitic limestone, a middle layer consisting of marls, and an upper crinoidal breccia. The fauna was determined by WINKLER PRINS and comprises: Strophomenida indet., *Proteguliferina* ? sp., *Chaoiella* sp., Rhynchonellida indet., *Stenoscisma* sp., *Zaissania* ? cf. *coronae* (SCHELLW.), *Martinia karawanica* VOLGIN, "*Martinia*" cf. *carinthiaca* SCHELLW., *Duplophyllum* sp., *Amplexocarinia smithi* HERITSCH, *Wilkingia*? cf. *elegantissima* (STUCKENB.), *Annuliconcha* sp., *Conocardium* cf. *uralicum* de VERNEUIL, Gastropoda, *Colospongia* sp. A spinctozoan faunula was published by LOBITZER 1975: *Sollasia* ? sp., *Girtyocoelia* cf. *beedei* (GIRTY), *Girtyocoelia* ? sp., *Colospongia typica* (KING), *Colospongia* sp., *Colospongia* ? sp., *Amblysiphonella* cf. *barroisi* STEINMANN, *Amblysiphonella* sp., *Cystauletes* ? sp.

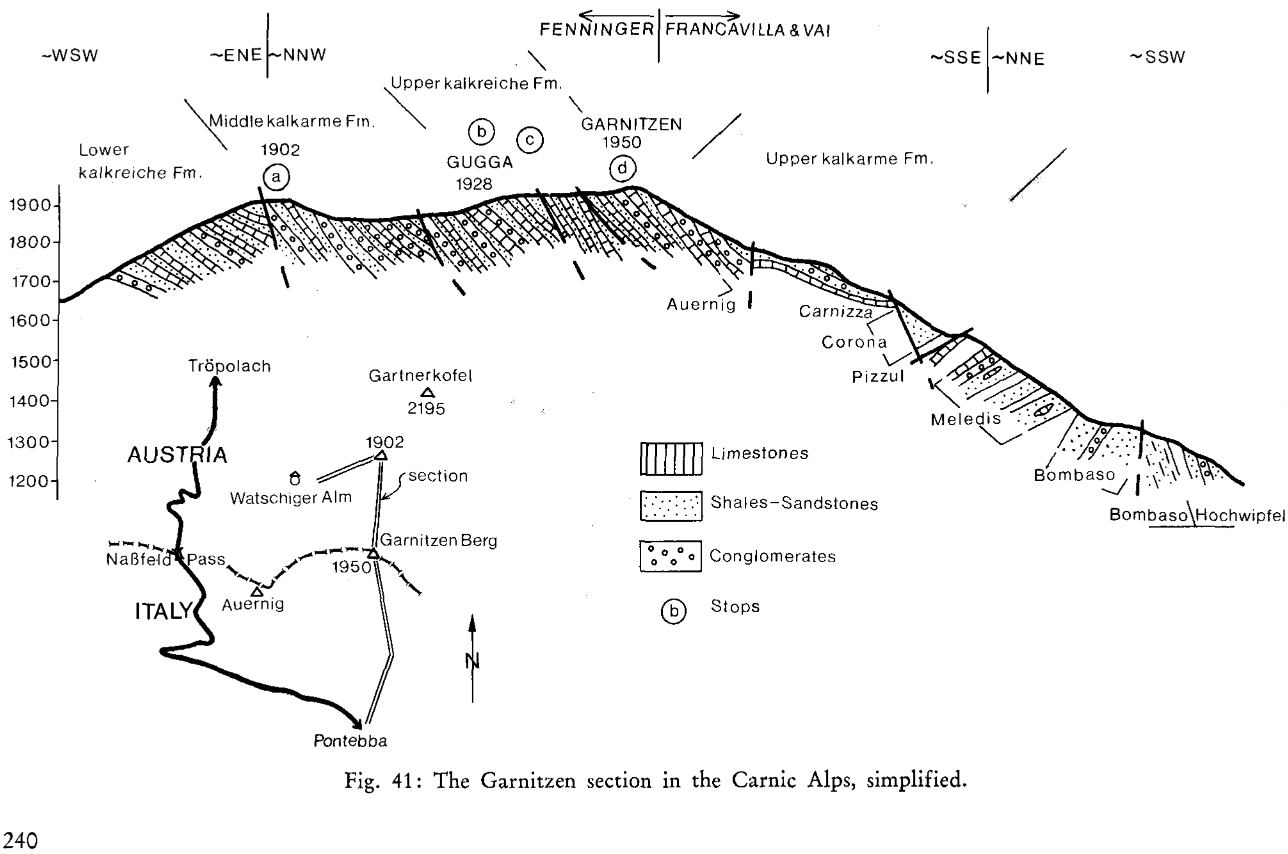

Fig. 41: The Garnitzen section in the Carnic Alps, simplified.

Shales with *Isogramma paotechowensis* CHAO:
The limestones and marls mentioned above are overlain by partly carbonatic sandstones and mica-rich shales containing *Isogramma paotechowensis*. Beside *Isogramma paotechowensis* one can find: Orbicuolidea, *Derbya* sp., *Linoproductus* sp., *Brachythyrina* sp. *Isogramma paotechowensis* can be found in different places of the Naßfeld area and is thus useful for local correlation. In Eurasia this species ranges up to the Permian. GORTANI 1924 described *Orthotethes expansus* which seems to be a younger synonym of *Isogramma paotechowensis*.

First we cross the Middle kalkarme Formation one part of which shows a tectonic repetition. The outcrops are sometimes rather sparse, especially along the path.

Stop 7.3. Gugga

Beginning with the Upper kalkreiche Formation the conditions of exposure are better. In this part the Garnitzen Section shows a tectonic repetition of the whole Upper kalkreiche Formation. The limestone horizon of Gugga gradually passes into marls rich in fusulinids (*Quasifusulina tenuissima* (SCHELLW.)) and contains a brachiopod-fauna with: Rhynchoporacea indet., *Phricodothyris* sp., Strophomenida indet., *Urushtenia?* sp., *Proteguliferina?* sp., *Kozlovskia* sp., *Karavankina* cf. *praepermica* RAMOVS, *Karavankina* sp.

The overlying sandstones with brachiopods and conulariids are characterized by: Orthida indet., *Linoproductus* cf. *cora* (d'ORB.), Rhynchonellida indet., *Phricodothyris?* sp.

Stop 7.4. Pt. 1914

After a fault the section begins with pebbly sandstones and conglomerates and is overlain by a sandstone horizon passing into shales and siltstones with a rich flora of Middle and Upper Stefanian age: *Pecopteris polymorpha, P. unita, P. hemitelioides, P. (?) obliquenervis, Crossotheca* sp., fructifications comparable *Acitheca, Odontopteris brardii, Alethopteris subelegans, Cordaites* cf. *borassifolius, Cordaites* sp., *Rhabdocarpus* sp., ? *Frigonocarpus* sp., *Annularia sphenophylloides, Sigillariophyllum* sp.

Stop 7.5. Garnitzenberg

Following the path to the Garnitzenberg we cross algae-rich marls (mainly with *Anthracoporella spectabilis* and phylloid algae). Beside the algae one can find: *Enteletes lamarckii* (FISCHER v. WALDH.), Strophomenida indet., *Urustenia* sp., *Proteguliferina* ? sp., *Avonia (Quasiavonia)* cf. *echinidiformis* (CHAO), *Avonia* ? cf. *curvirostris* (SCHELLW.), *Kozlowskia* sp., *Alexnia* cf. *gratiodentalis* (GRABAU), *Cancrinella* sp., *Karavankina praepermica* RAMOVS, Rhynchonellida indet., *Stenoscisma* cf. *alpina* (SCHELLW.), *Cleiothyridina* cf. *pectinifera* (SOW.), *Brachythyrina* cf. *carnica* (SCHELLW.), *Neospirifer* sp., *Zaissania* ? cf. *coronae* (SCHELLW.), *„Martinia"* *carinthiaca* SCHELLW., *Phricodothyris* sp., *Lophocarinophyllum* sp., *Annuliconcha* sp., *Conocardium* cf. *uralicum* VERNEUIL, *Trachydomia* sp., *Straparollus lutugini* JAKOW.

After a fault the Upper kalkreiche Formation sets in again. Along the path once more above mentioned marls occur with: *Heteralosia* sp. ?, *Urushtenia* ? sp., *Proteguliferina* ? sp., *Kozlowskia* sp., Rhynchonellida indet., *Cleiothyridina* cf. *pectinifera* (SOW.), *Neospirifer* sp., *Spiriferella* ? sp., *„Martinia"* cf. *carinthiaca* SCHELLW., *Phricodothyris* ? sp., *Conocardium uralicum* VERNEUIL, *Trachydomia* sp., *Microdoma* sp.

Day 8

The Penninic System along the Großglockner Road

(W. FRANK) *)

Route: Lienz — Heiligenblut — Großglockner Road — Zell am See.

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Topogr. maps: Alpenvereinskarte 1 : 25.000, Bl. 40, Großglockner; Österr. Karte 1 : 50.000, Bl. 153, 154.

Introduction

Along the route a complete section through the Penninic Tauern Window is studied. Coming from the south (Lienz) one has first to cross the Middle Austroalpine Crystalline of the Schobergruppe. The internal pre-Alpine structures of this medium grade metamorphic Crystalline (paragneisses, micaschists, amphibolites, eclogites and orthogneisses of different origin, partly with proved Caledonian metamorphism) have been well preserved in general. But whereas Hercynian mineral ages are known from the southern and tectonically higher levels, a pronounced heating during the Cretaceous is proved in deeper levels (cf. BRACK 1978). This heating took place when the Austroalpine was still south of the

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Pennine and the metamorphism interfered with the consumption of the Penninic ocean. The existence of this paired metamorphic belt (high pressure, Pennine — intermediate pressure regime) was most probably terminated as a result of large scale overthrusting of the Austroalpine onto the Pennine in the Upper Cretaceous (80—76 my). In this section the same pre-Alpine Crystalline was only at its immediate base and much less affected by the Tertiary metamorphic and structural events, intensely developed in the underlying Penninic schists. At the northern side of the Tauern cupola the continuation of this Crystalline is missing and the window is separated by a steep mylonitic fault from the Upper Austroalpine Grauwackenzone.

Tauern Window: Lithostratigraphy and Paleogeography:

The pre-Mesozoic sequences are developed in the lower tectonic units in the western and eastern part of the window. They comprise a strongly overprinted pre-Alpine polyphase metamorphic Crystalline which has partly a close relationship with the usual western Austroalpine Crystalline. Also few early Paleozoic orthogneisses are incorporated here. An early Paleozoic geosynclinal sequence with large volumes of mainly basic, but also intermediate and acid volcanic material is another important rock series. Paleozoic carbonates are essentially missing, some Paleozoic sequences with a pronounced sedimentary graded bedding (e. g. parts of the Greiner schists in the west) possibly represent Late Paleozoic flysch deposits. The typical Carboniferous Molasse type gravel sediments are missing. All these Paleozoic series are intruded by large Hercynian metagranitoids and metatonalites. Partly they are associated with high grade Hercynian metamorphism and deformation. However, the magmatic activity continued until

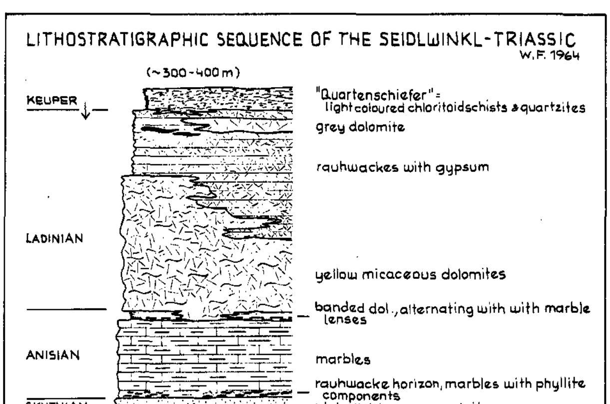


Fig. 42: The sequence of the Seidlwinkl Triassic in the area of the Glockner road.

the Upper Permian. From this respect, the basement in the Tauern Window can be regarded as one of the youngest tectonically active zones in the Varican orogen.

These pre-Mesozoic rock series are only developed west and east of the excursion route, which entirely lies in the N—S striking Großglockner axial depression zone of Permomesozoic sediments.

Permoscytian: East of the Hochtor on top of the Großglockner road is the type locality of the Permoscythian Wustkogelserie (Frasl 1958). The lower member consists of arcosic gneisses with boulders of the older basement and from acid volcanics. A high amount of the clastic material was derived from acid volcanics respectively shallow granitic intrusions. The higher member (probably mostly Scythian) is a uniform quartzite horizon. Fig. 42 shows also the Middle Triassic carbonate rocks of the Seidlwinkltrias, which exhibits the typical Germanic Keuper facies. The Seidlwinkltrias is stratigraphically overlain by the so-called Brennkogel Series, one of the different evolutions of Bündnerschiefer. The Brennkogel Series is characterized by a alternation of black phyllites and different quartzites with several horizons of reworked Triassic carbonates; also few prasinites are incorporated.

This Triassic — Jurassic sequence of the later Seidlwinklnappe was deposited south of the gneiss cores exposed today. The rifting, which led to the opening of the Penninic ocean started in the Liassic and caused a marked change in sedimentation and a pronounced facies variation. South of the Brennkogel Bündnerschiefer with their clastic terregeneous influence the main mass of Bündnerschiefer of the Glocknernappe developed. They are composed of a several km thick sequence of marls alternating with some pelites and large masses of basaltes (mainly tuffs, some pillow lavas ...) deposited mostly on oceanic crust (e. g. the Heiligenblut serpentinites). The stratigraphy is uncertain, generally it is assumed that Upper Jurassic to Lower Cretaceous rocks are exposed in the Glockner region. Still further in the south the so-called Fuscher facies of Bündnerschiefer developed, characterized again by a distinct terregeneous influence: mainly pelites and some flysch type sediments derived from a metamorphic crystalline basement covered by Triassic carbonates. They obviously developed along the southern margin of the Penninic ocean close to the well known breccias of the Lower Austroalpine.

Detailed geochemical investigations (Höck & Miller 1980) have shown that the ophiolites of the Glockner facies resemble closely to midocean ridge basaltes, whereas the variable basic intrusions and volcanics in the Fuscher facies show close affinities to withinplate basaltes.

On the northern margin of the Penninic ocean two more post-Triassic sequences are developed in the western Hohe Tauern on the Hercynian basement which corresponds to the Briançonnais of the Western Alps. They are the Hochstegenseries, an Upper Jurassic — Lower Cretaceous carbonate zone transgressing on the basement and the Lower Cretaceous Kaserer series (FRISCH, 1980) with partly very coarse clastic influence from the underlying basement. They are not exposed in the Glockner area. But it is assumed that a uniform pelitic sequence south of Fusch represents the post-Triassic cover north of the Brennkogelschists.

Tectonic and structures:

The N—S sections in the Glockner region (Fig. 43) clearly show the north-vergent transport in the Schieferhülle. The main feature is the giant recumbent fold of Glockner- and Seidlwinklnappe which developed at the base of the Glocknernappe after the Seidlwinklnappe was overridden. Although the southern part and especially the inverted limb is extremely thinned, the core and both limbs of the fold can be traced more than 25 km to the SE.

The base of the Glocknernappe can be regarded as a tectonic mélange horizon with lenses of serpentinites and Triassic rocks. Overlying the giant arch of the Glocknernappe s. str. we find a tectonically higher complicated wedge system: the thick Fuscher Schieferhülle, which forms a part of the Glocknernappe system in the north. In the south the highly tectonized Matreier Zone corresponds at least partly with this unit.

The three-dimensional structure of the whole system is very complicated. The northwestern end of the large-scale recumbent fold is overprinted by a pronounced N-S fold zone which caused also the N-S trending axial Glockner-depression. These N-S striking fold axes, mineral lineations and elongations exhibit a very distinct preferred N-S-orientation in the middle part and opens to fan structures in the north and in the south, where the neighbouring gneiss cores have no more influence. The author thinks that this "cross folding" developed contineously over a considerable time span (some 10 my). The first event probably was a elongation by simple shear in connection with subduction and formation of eclogites. Later then, when the oceanic sediments were thrust on the sialic basement, the elongation of this basement in the E-W direction caused the intense N-S folding in the inner part of the Glockner axial depression (fig. 44). We recognize also a remarkable Stockwerkstektonik as the N-S structures are developed from the southern margin of the window only to the northern border of the Glocknernappe s. str. The overlying Fuscher Schieferhülle show no relics of these N-S lineations, only E-W striking, gently west-dipping structures, which overprinted the whole outer part of the internal cupola.

Alpine metamorphism:

Two main metamorphic events can be distinguished. The relatively older high pressure event is preserved as relics of eclogites and glaucophaneschists (e. g. Gamsgrube NW Franz-Josefs-Höhe) at or near the southern base of the Glocknernappe and as form relics of lawsonite, widespread in higher horizons of the same unit (HÖCK 1976). MILLER 1977 was able to distinguish five stages in the evolution of the eclogites to the prasinite mineral assemblages in the southern Venediger area which are also valid in the Glockner region. The formation of the high pressure event at 8—10 kb and up to 500° C is correlated with subduction during the closure of the Penninic ocean. Due to widespread Ar^{40} overpressure no really conclusive radiometric data exist about the time of formation of the HP-event. In analogy to the results of HUNZIKER in the Western Alps and from the existing data a Cretaceous age is assumed.

The present mineral assemblages show the metamorphic zonation of the Early Tertiary Tauernkristallisation. In the outermost parts of the Schieferhülle this metamorphism had its thermal peak around 30—40 my, whereas biotit cooling ages in the neighbourhood cluster around 20—17 my. In general the Tertiary metamorphism show a concentric pattern (HÖCK 1980) with low grade stages in the outermost horizons of the Schieferhülle (stilpnomelane NE Fusch) and highest grade greenschist facies in the central part. Only east of the Großglocknerroad a single occurrence of staurolite was reported (EXNER 1964). The characteristic white mica is phengite, biotite is usually absent or rare in metasedimentary rocks due to chemical reasons. Useful isogrades are the albite/oligoclase boundary in prasinites and the incoming of garnet and margarite in calcareous metasediments which have been studied by HÖCK & HOSCHEK 1980. Tremolite is common in the Triassic dolomites. From this mineral distribution metamorphic conditions of 500° C and approximately 5 kb can be deduced in the central part of the section especially in the Hochtor area.

In the whole central part of the Tauern Window the crystallisation postdated the deformation, whereas in the outer parts, especially in the north crystallisation and deformation took place simultaneously.

Stop 8.1. Kasereck, north of Heiligenblut

Antigorite-serpentinite and ophicalcite together with calcmicaschists at the base of the Glockner nappe. View on the geology of upper Möll valley.

Stop 8.2. Franz-Josefs-Höhe

Foot walk to Gamsgrube. Prasinites; highest metamorphic Bündnerschist of Glockner nappe with grossular, margarite, eclogites and glaucophaneschists and their retrograde equivalents in the Gamsgrube.

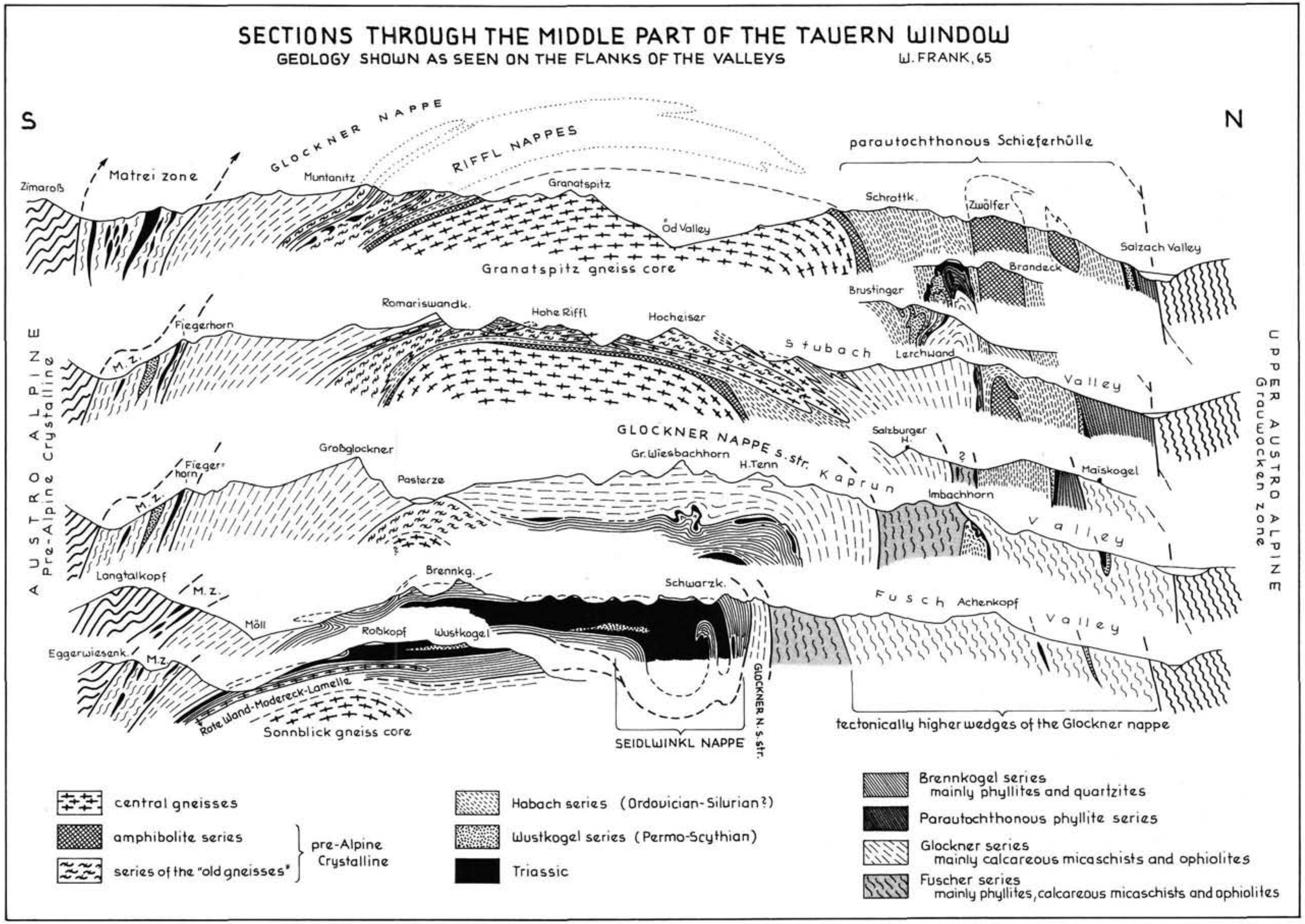
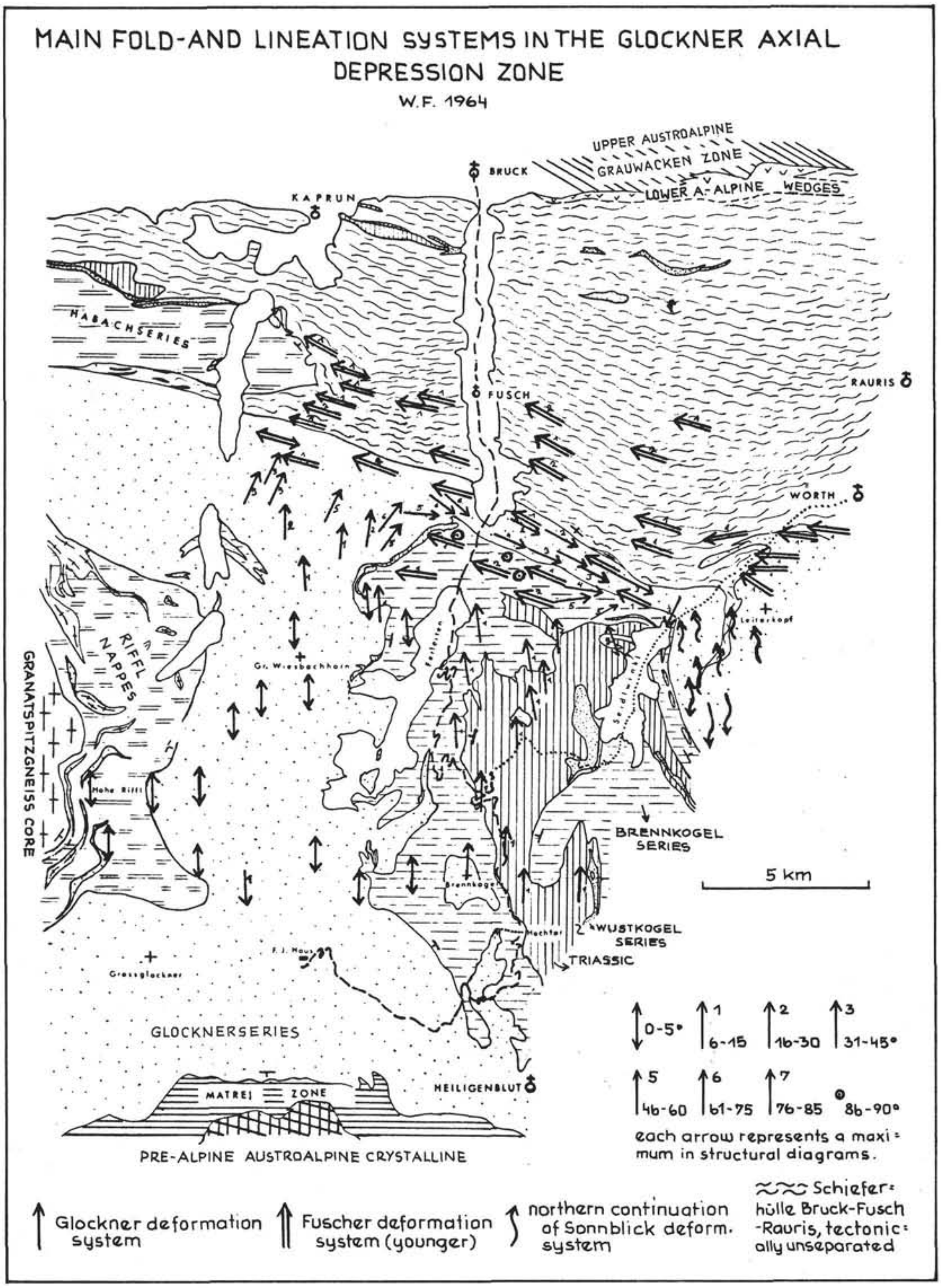

SECTIONS THROUGH THE MIDDLE PART OF THE TAUERN WINDOW
GEOLOGY SHOWN AS SEEN ON THE FLANKS OF THE VALLEYS
W. FRANK, 65
S
N
GLOCKNER NAPPE
RIFFL NAPPES
Matrei zone
parautochthonous Schieferhülle
Zimaroß
Muntanitz
Granatspitz
Öd Valley
Schrottk.
Zwölfer
Brandeck
Salzach Valley
Brustinger
Granatspitz gneiss core
Romariswandk.
Hohe Riffl
Hocheiser
Fiegerhorn
M. Z.
Stubach
Lerchwand
Valley
AUSTRO ALPINE
Pre-Alpine Crystalline
UPPER AUSTRO ALPINE
Grauwacken zone
GLOCKNER NAPPE s. str.
Großglockner
Gr. Wiesbachhorn
H. Tenn
Salzburger H.
Kaprun
Imbachhorn
Maiskogel
Fiegerhorn
Pasterze
Valley
Langtalkopf
Brennkg.
Schwarzk.
Fusch
Achenkopf
Valley
Möll
Roßkopf
Wustkogel
Eggerwiesenk.
Rote Wand-Modereck-Lamelle
Sonnblick gneiss core
SEIDLWINKL NAPPE
GLOCKNER N. s. str.
tectonically higher wedges of the Glockner nappe
central gneisses
amphibolite series
series of the "old gneisses"
pre-Alpine Crystalline
Habach series (Ordovician-Silurian?)
Wustkogel series (Permo-Scythian)
Triassic
Brennkogel series
mainly phyllites and quartzites
Parautochthonous phyllite series
Glockner series
mainly calcareous micaschists and ophiolites
Fuscher series
mainly phyllites, calcareous micaschists and ophiolites

Fig. 43



MAIN FOLD-AND LINEATION SYSTEMS IN THE GLOCKNER AXIAL DEPRESSION ZONE
W.F. 1964
UPPER AUSTROALPINE
GRAUWACKEN ZONE
LOWER A.-ALPINE WEDGES
BRUCK
KAPRUN
HABACHSERIES
FUSCH
RAURIS
WÖRTH
RIFFL NAPPES
GRANATSPITZGNEISS CORE
Gr. Wiesbachhorn
Hohe Riffl
Leiterkopf
BRENNKOGEL SERIES
5 km
Brennkogel
WUSTKOGEL SERIES
TRIASSIC
Grossglockner
GLOCKNERSERIES
HEILIGENBLUT
MATREI ZONE
PRE-ALPINE AUSTROALPINE CRYSTALLINE
0-5°
1 6-15
2 16-30
3 31-45°
5 46-60
6 61-75
7 76-85
86-90°
each arrow represents a maximum in structural diagrams.
Glockner deformation system
Fuscher deformation system (younger)
northern continuation of Sonnblick deform. system
Schieferhülle Bruck-Fusch -Rauris, tectonically unseparated

Fig. 44

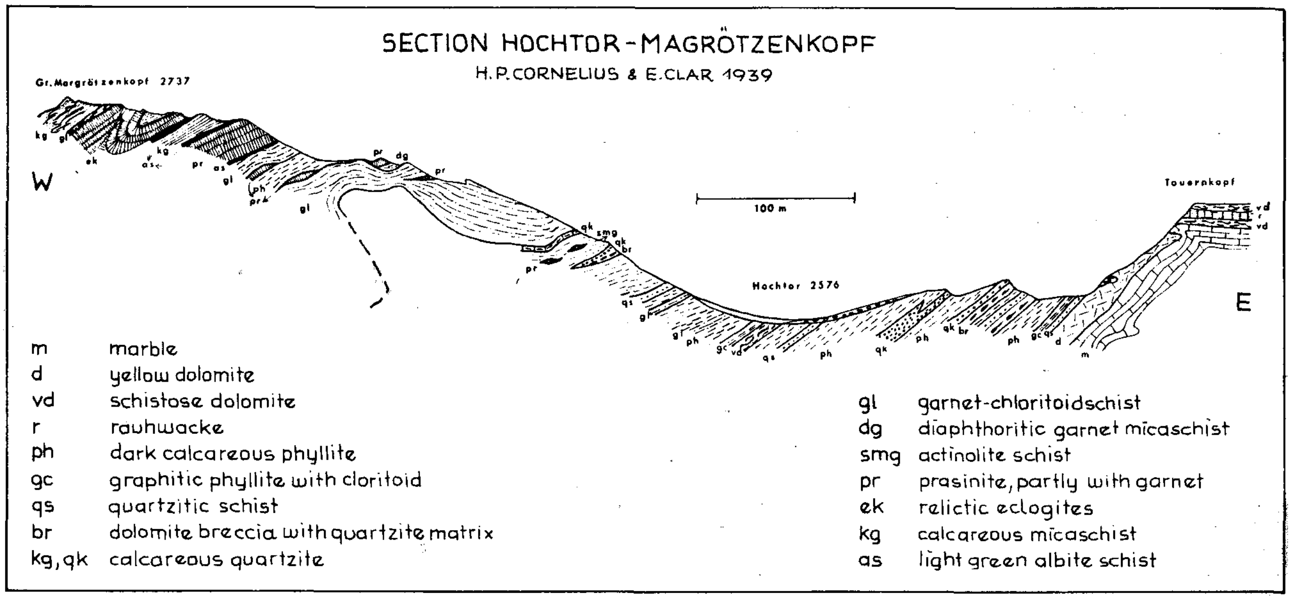


Fig. 45: Section Hochtor-Margrötzenkopf near the top of the Glockner road (H. P. CORNELIUS & E. CLAR, 1939).

Stop 8.3. Hochtor

Bündnerschists in Brennkogel facies, dark garnetmicaschists partly with chloritoid, quartzites, prasinites, breccias with highly deformed Triassic carbonate components in a quartzite matrix (fig. 45); remnants of Roman road.

Stop 8.4. Elendgrube

Brennkogel antigorite serpentinites as a part of the tectonic melange at the base of the Glockner nappe.

Stop 8.5. Fuscher Törl

Dolomites, rauhwackes and gypsum together with light chloritoidschist and quartzite ("Quartenschiefer", Keuper); Seidlwinkltrias.

Stop 8.6. Edelweißspitze

Geology similar to stop 5. Panorama view (FRASL & FRANK, 1969); discussion of the general tectonic and structural evolution of the Permomesozoic series in the Glockner axial depression.

Day 9

The Graywacke Zone and the Northern Limestone Alps in Salzburg

A) The Graywacke Zone in Salzburg

Josef-Michael SCHRAMM & Gottfried TICHY *)

Route: Zell am See — Taxenbach — Dienten valley — Filzen pass — Mühlbach am Hochkönig — Bischofshofen — Werfen.

Subject: Stratigraphy, facies, metamorphosis and tectonics of the Graywacke Zone in Salzburg and the contact between this unit and the Northern Limestone Alps.

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Topographical maps: Österreichische Karte 1 : 50.000, sheet 124 (Saalfelden), sheet 125 (Bischofshofen).

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Introduction

The Graywacke Zone (part of the Upper Austroalpine Unit) is completely detached from its original crystalline basement and thrust over deeper Austroalpine units and the Penninic belt to the north. Therefore, deeper tectonic units border the Graywacke Zone on its southern side, whereas in the north rocks of the overlying Northern Limestone Alps are adjacent (see tectonic sketchmap, fig. 46). Compared with the Graywacke Zone in Tyrol and Styria the western part is simpler tectonically, has a more monotonous lithology and has fewer fossils. Stratigraphic details concerning the excursion route may be understood from figure 47. The stratigraphy is based mainly on conodonts and lithologic correlation. The base of the Northern Limestone Alps was affected by Alpine metamorphic events, and the Graywacke Zone additionally by Variscan metamorphism. Due to equal intensities of metamorphism the Alpine stage cannot be distinguished from the older ones. Metamorphic minerals such as chloritoid, paragonite and pyrophyllite, and illite crystallinity values below 4.0 (index sensu KUBLER) indicate low to very low grade metamorphism. The intensity decreases northwards. Thus, very low grade alterated Werfen beds can be detected as far as twenty kilometers north of the border between Graywacke Zone and Northern Limestone Alps (illite crystallinity values between 7.5 and 4.0).

The area visited is an old mining region. Iron ores have been exploited near Dienten and Werfen, crystalline magnesite in the areas of Goldegg, Dienten, and Hintertal, and copper ore at Mühlbach am Hochkönig. All mines are abandoned now.

Stop 9.1. Road cut in the southern part of the Dienten valley

Driving eastward through the Salzach valley we pass the narrow portion of Taxenbach and the slide area of Embach and reach the confluence with the Dienten Bach. The E-W running Salzach Valley Fault which determines the course of the Salzach valley, separates the Penninic Schieferhülle (S) from the Graywacke Zone (N). The fault was active at least up to Miocene and is manifested as a more or less wide zone. Therefore, the rocks of the southernmost part of the Graywacke Zone were strongly strained again after their tectonism during Variscan and Alpine orogenesis.

The cross section shows a typical sequence of Lower Wildschönau schists (Ordovician). Grey coloured phyllites and sericitic quartzites pass into calc-phyllites and also greenschists. The latter rocks represent syngenetic intercalations of formerly fine-grained diabases, fine layered diabasic tuffs and tuffites. Blastoids of stilpnomelane (near Ferolisäge; visible only in thin section) and green biotite (S of Mühlwirt) in those rocks indicate greenschist facies. This corresponds with data from the metasediments. The intensity of metamorphism is similar to that of the Bünden schists of the Penninic Tauern window. Minute folding, mainly steeply northward dipping s-surfaces, and gently WNW plunging B-axes determine the tectonic feature (figure 48). The course of the Dienten valley follows a NNW-SSE running system of Alpine faults.

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Stop 9.2. Road cut N of inn "Ronachbäck"

We drive northward to Ronachbäck, where a series of lenticular crystalline magnesite bodies cross the Dienten valley. The banded grey magnesite and the adjacent dark phyllites strike WNW and the s-surfaces dip steeply northward. Probably the magnesites are of Upper Silurian (Ludlovian-Přidolian) age. However, their stratigraphical position could not be determined in detail. Fine-grained layers change to coarsely-crystalline pinolite (at the northern part of the outcrop). Based on investigations of the structure HADITSCH supposed a postdiagenetic and metasomatic origin of the magnesite. A system of fissures (partly infilled with younger dolomite, and quartz) dissects the magnesite body.

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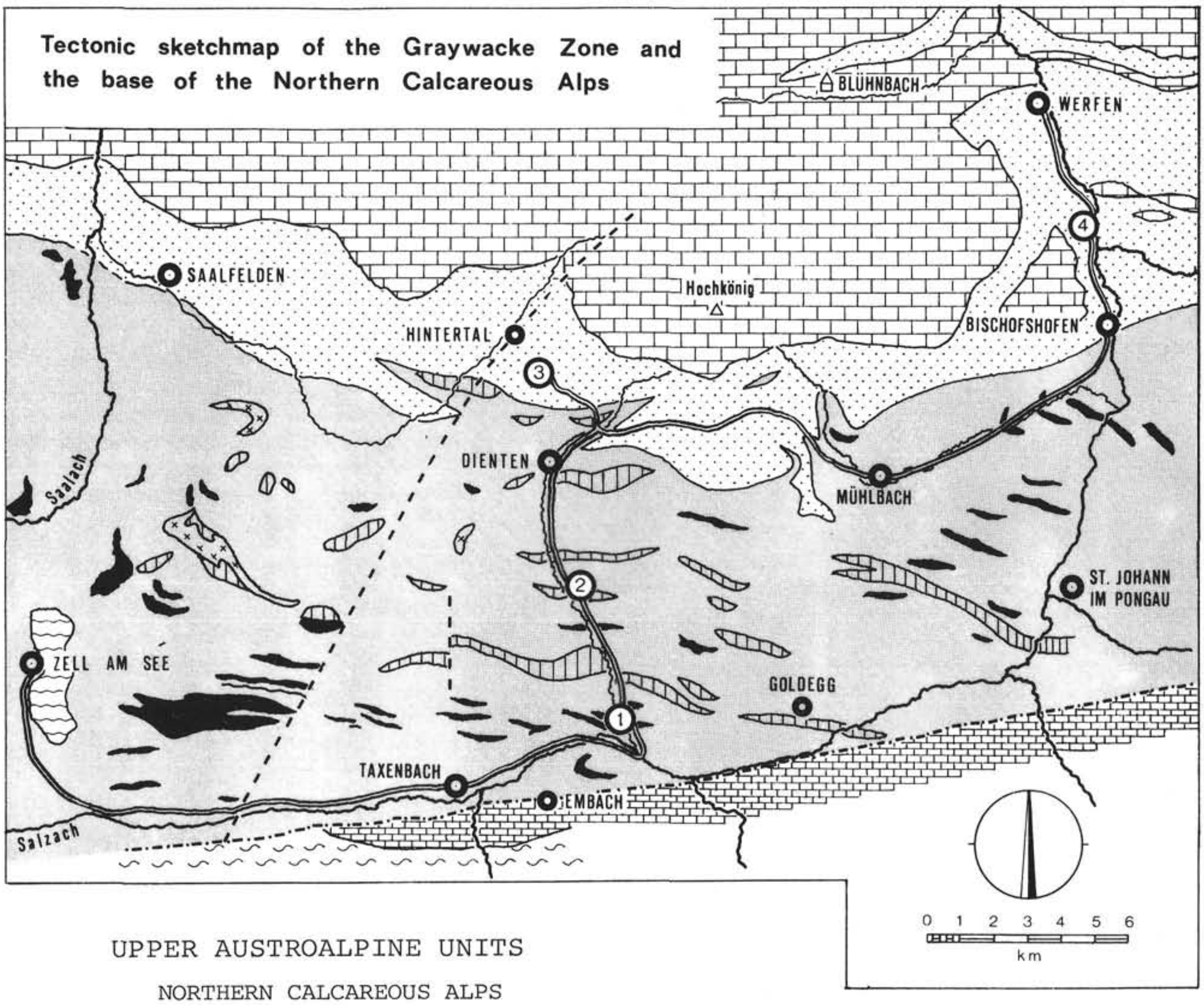
Stop 9.3. Road cut at the western ascent to the Filzensattel

Continuing the excursion we pass the village Dienten, whose church hill is underlain by Dienten schists (Silurian). North of Dienten we enter the Northern Limestone Alps.



UPPER AUSTROALPINE UNITS

NORTHERN CALCAREOUS ALPS

Carbonate Triassic

Clastic Permoskythian (Gainfeld Conglomerate, Hochfilzen Beds, Violet and Green Series, Werfen Beds)

GRAYWACKE ZONE

Lower Paleozoic carbonate sediments (Black Limestone, Grey Dolomite and Magnesite, "Sauberg Limestone")

Porphyroids and related tuffs

Lower and Higher Wildschönau Schists (calc-phyllites, Siliceous Schists, and Dienten Schists included)

Metadiabases and greenschists

PENNINIC UNIT

Klamm Limestone

Bünden Schists

Salzach Valley Fault

Faults

Excursion route with stops

Fig. 46

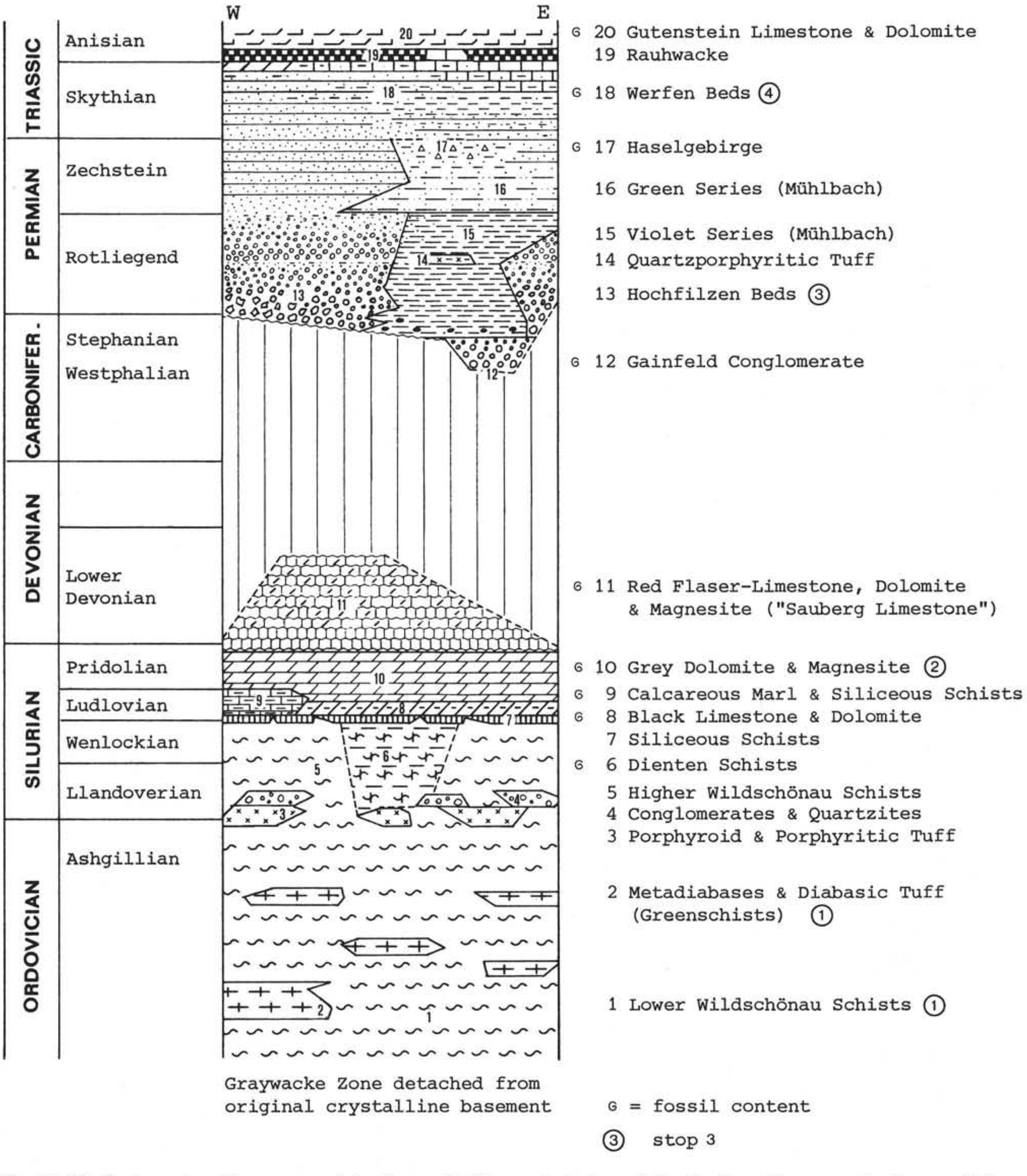


Fig. 47: Idealized stratigraphic sequence of the Graywacke Zone and the base of the Northern Limestone Alps between Zell am See und Werfen (Salzburg). Not according to any scale. Sensu F. K. Bauer et al. (1969), G. Gabl (1964), H. Mostler (1968, 1972), H. P. Schönlaub (1979), J.-M. Schramm (1973).

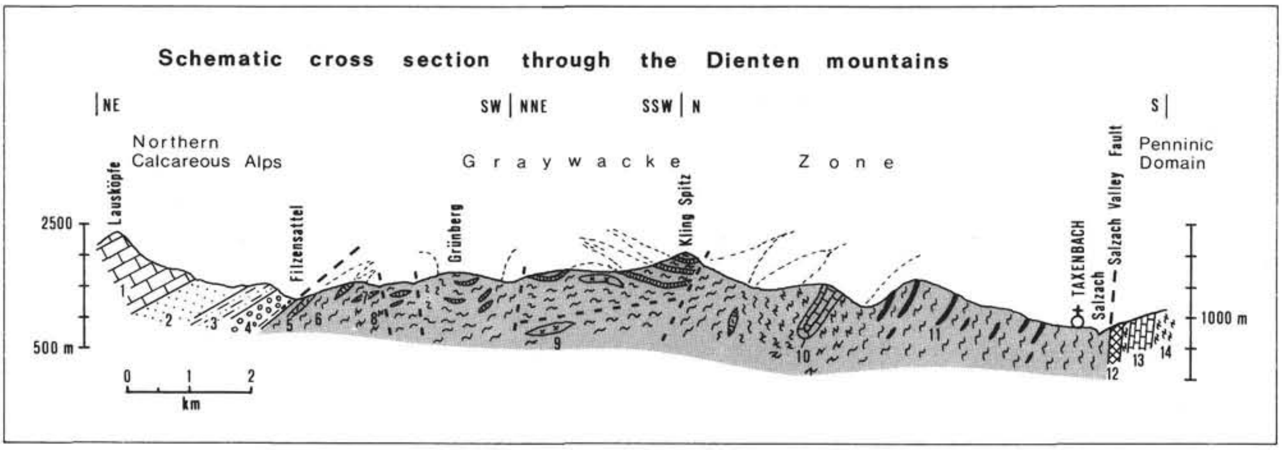


Fig. 48: 1 = Carbonate Triassic, 2 = Werfen Beds, 3 = Green Series, 4 = Hochfilzen Beds and Violet Series (with carbonate concretions); 5 = Grey Dolomite and Magnesite, 6 = Wildschönau Schists, 7 = Variegated Carbonate Rocks and Siliceous Schists, 8 = Dienten Schists, 9 = Porphyroids and related tuffs (mainly of quartzkeratophyric composition), 10 = Black Limestone, 11 = Metadiabases and greenschists; 12 = Mylonite (Salzach Valley Fault); 13 = Klamm Limestone, 14 = Bünden Schists. Sensu F. K. BAUER et al. (1969) and J.-M. SCHRAMM (Original).

The Alpine sedimentary cycle of the Northern Limestone Alps, overlying the Graywacke Zone, begins with coarse-grained sediments, the Lower Permian Hochfilzen beds (TOLLMANN). These breccias and conglomerates contain clastic components of a local source area, i. e. the Graywacke Zone. Quartzites, siliceous schists, dolomites, limestones, and crystalline magnesites were deposited as subangular, even to well rounded pebbles in a typical claret-coloured sericitic matrix. The sediments represent a transitional facies between the shallow-water deposits of Tyrol and the basin sediments of Mitterberg.

The evidence of entirely clastic components of crystalline magnesite in the Hochfilzen beds from the Enterwinkel (about 5 kilometers W) helped to answer the controversial question of genesis. Thus, the crystalline magnesites of the western part of the Graywacke Zone were formed by a pre-Alpine Mg-metasomatism.

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Stop 9.4. Road cut near deviation 2,5 km NNW of Bischofshofen

Driving eastward we pass the southern foothills of the Hochkönig massif and reach the Salzach transverse valley near Bischofshofen. The contact between Graywacke Zone and Northern Limestone Alps is characterized by intensive and complicated scaly structures with axial planes dipping northward. At the southern side of the Hochkönig the scaly structures never exceed about 500 meters in lateral extent, whereas in the zone of Werfen — St. Martin they reach a width of five kilometers. Whether the imbrication structures are northerly or southerly overturned is still being debated.

Variegated grey, green, and red quartzites and sandstones of deeper stratigraphic parts of Werfen beds will be studied at this site. They are thin-bedded, with clay flakes occurring on the bedding planes, and thin layers of slates are intercalated. Structural features are local faults, overfaults, and flexure folding. A very well exposed fossiliferous, and undisturbed cross section through Werfen beds is situated in the Blühnbach valley 6 kilometers west of Werfen. That section is currently under investigation, but lack of time permits no visit.

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B) The Northern Limestone Alps in Salzburg

B. PLÖCHINGER *)

R o u t e: Werfen — Golling — Hallein — Gartenau/ St. Leonhard — Adnet — Salzburg.

S u b j e c t: Stratigraphy and tectonics of the Northern Limestone Alps, Malmian-Lower Cretaceous series, intra-Malmian gliding of a Hallstatt outlier, Liassic Adnet Limestone.

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Geological maps: Hallein—Berchtesgaden (A. BITTNER, E. FUGGER) 1 : 75.000, Geol. R.-A. Wien, 1906; Adnet und Umgebung (M. SCHLAGER) 1 : 10.000, Geol. B.-A. Wien, 1960; Umgebung der Stadt Salzburg (S. PREY) 1 : 50.000, Geol. B.-A. Wien, 1969.

Topographic maps: Österr. Karte 1 : 50.000, sheet 94 (Hallein), 125 (Bischofshofen).

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Introduction

The miogeosynclinal marine series of the Northern Limestone Alps were deposited during the general subsidence of the shelf environment in the Upper Austroalpine sedimentation area. Upon the evaporitebearing Permian sediments Triassic sediments in different facies are developed. According to their position there are mainly sediments of the lagoonal, reef or open sea environment. The sedimentation area of the Jurassic is characterized by the existence of more accentuated and differentiated longitudinal depressions and elevations. From the Jurassic up to the Middle Cretaceous important olistolithic glidings occurred. During the Intra-Cretaceous orogeny the sediments of the Northern Limestone Alps together with their normal Paleozoic base — the Grauwackenzone — were detached from the basement and moved towards north over the Lower Austroalpine and Penninic Zones. At the same time they were folded and divided into nappes. The Cenomanian sediments, especially the Senonian to Eocen Gosau Beds are overlying unconformably the folds and thrust slices. The nappes from the bottom to the top are ordered into three major systems, the Bajuvarikum, the Tirolikum and the Juvavikum (fig. 49). During the older Tertiary, in Oligocene, the pile of nappes was brought over the Flysch and the Helvetikum.

I t i n e r a r y

After the visit of the locus typicus of the Werfen Formation, Werfen, the excursion route enters the "W e r f e n S c h u p p e n l a n d", where ridges of Middle Triassic limestones and dolomites alternate with Werfen Beds. The route follows the Salzach valley and crosses the nappe of Staufen-Höllengebirge (Tirolikum), which here reaches almost to the northern border of the Limestone Alps. It forms the "Tirolian arc". Within or upon this dish-shaped Tirolikum Juvavian masses are embedded (figs. 49, 50).

The thick carbonate-sequence of the H a g e n g e b i r g e in the west and the T e n n e n g e b i r g e in the east are separated by the narrow gorge of the Salzach (Salzachöfen). From Golling towards the north the valley is widening. During the Mindel-Riß Interglacial it was filled by a lake. Close to Golling the route crosses the E-W striking zone of the L a m m e r m a s s (Lower Juvavikum) which in its extent and position is not yet explored completely. To this mass belong outliers with Hallstatt facies in the Lammer valley region and in the zone of the Torrener Joch (H. ZANKL, 1962), moreover the series with normal facies of the Gollinger Schwarzenberg (A. TOLLMANN, 1976 a, b, H. HÄUSLER, 1979) and the Hohe Göll (PLÖCHINGER).

The syncline north of the front of the Hohe Göll is filled by the 380 m thick Neocomian Schrambach- and Roßfeld Formations. Small Hallstatt outliers are overlying the Roßfeld Beds as olistoliths. Towards the north

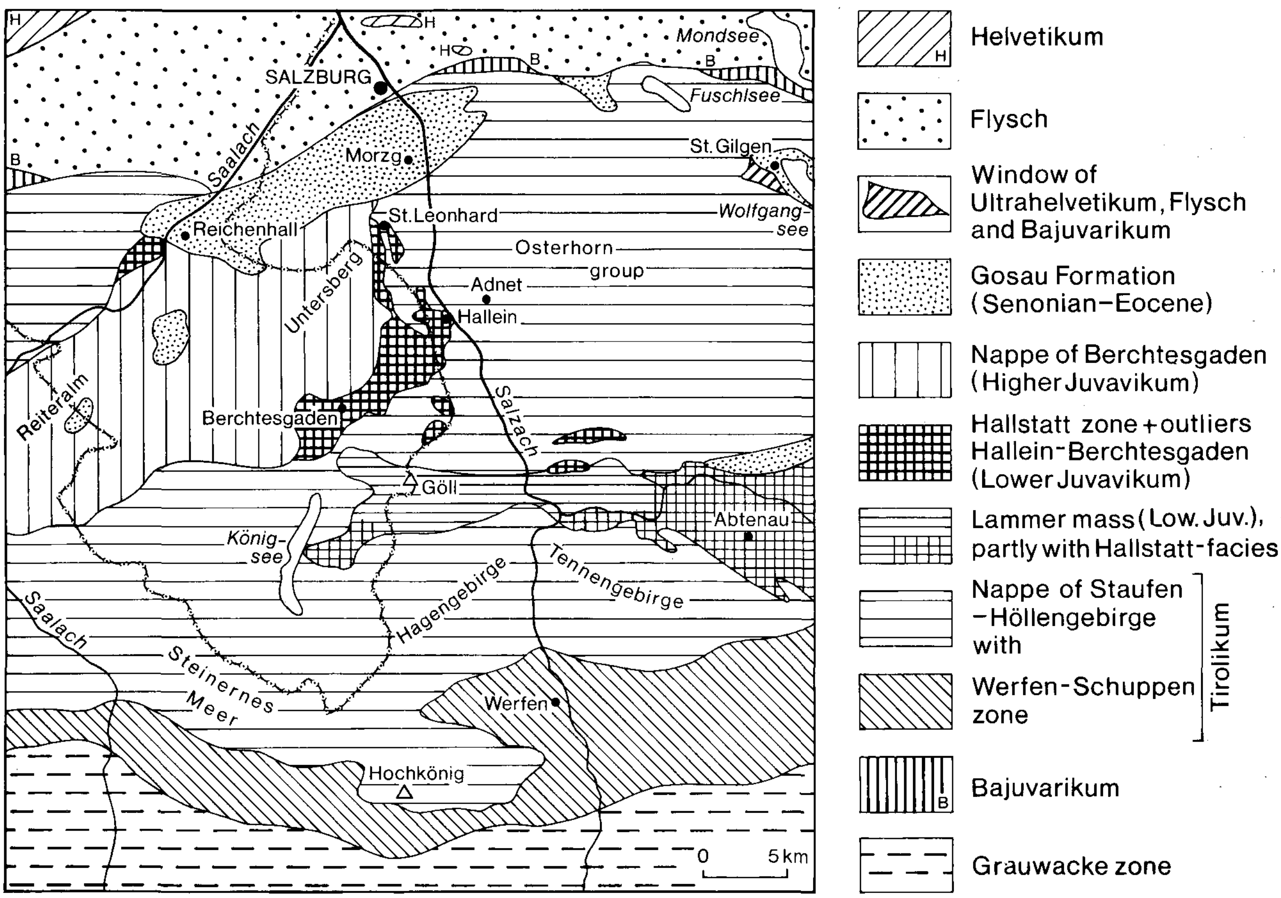

Fig. 49: Sketch map of the excursion area in the Northern Limestone Alps of Salzburg.

this syncline is followed by about thousand metres thick Permotriassic mass with Hallstatt facies, the H a l l s t a t t z o n e o f H a l l e i n - B e r c h t e s g a d e n. After recent investigations this mass can not be considered as a post-Neocomian thrust sheet (O. AMPFERER, W. E. PETRASCHEK, 1947, W. MEDWENITSCH, 1960, 1962, B. PLÖCHINGER, 1955 and others); it has a sedimentary contact with the Upper Jurassic Oberalm Formation. The steep to overturned Oberalm Beds which form the frame of the Hallstatt mass, are not dipping under the Hallstatt mass but overly it stratigraphically; both, surface outcrops as well as drilling data support the supposition of an intra-Malmian gliding process during which the entire mass slid into the Malmian sediments (B. PLÖCHINGER, 1976, 1977).

The U n t e r s b e r g situated close to the city of Salzburg is part of the highest nappe along the route. It is allocated to the Berchtesgaden nappe belonging with its Dachstein Limestone facies to the Higher Juvavikum. Possibly it is a post-Neocomian gliding-mass, which dragged a garland of Hallstatt outliers at its base (A. TOLLMANN, 1973, 1976). Both Juvavic units are overlying the Neocomian sediments of the Staufen-Höllengebirge nappe (Tirolikum).

East of the Salzach valley the O s t e r h o r n g r o u p (Osterhorn-Tirolikum) is extending. It comprehends the following generally flat-lying members: Hauptdolomit, Platten Limestone, Kössen Beds, Rhaetian reef Limestone, Liassic marls and limestones, up to 350 m thick siliceous, radiolarite-bearing strata (Malmbasis Formation, Tauglboden Formation) and finally the up to 800 m thick Oberalm Formation.

On the southern border of the Osterhorn group a submarine uplift with Dachstein reef Limestone was developed during the late Kimmeridgian cycle. The uplift is believed to be the main source of the olistostromatic and olistolithic material in the siliceous Tauglboden Formation of the Inner Osterhorn group (W. & M. SCHLAGER, 1973).

Stop 9.5. Quarry of the Gartenau Portland cement work "Gebrüder Leube" (fig. 51)

Within the only 60 m thick series of Oberalm Formation (Tithonian-Berriasian) of the quarry one can observe a NNW-SSE striking anticline, in the center of which a 1 km long body of Haselgebirge (Upper Permian) could be mapped. This Haselgebirge characterizes the beginning of a cyclothem, which reaches over allodapic limestones (Barmstein Limestone) to a pelagic limestone (clayey Oberalm Limestone). The two higher cyclothems in the Oberalm Formation begin with a coarse allodapic sediment (Tonflatschen breccia) which shows a striking content of components of Upper Permian Haselgebirge and of Malmian shallow-water limestones. Thus, the cyclothems consist of mud-current breccia (Tonflatschen breccia), fluxoturbidites and turbidites. They indicate a rhythmic decrease of allodapic material towards the more pelagic sediments of the clayey Oberalm Formation in the coccolith-tintinnid-radiolarian facies.

A deep-drilling project proved the assumption that the Haselgebirge-body, which is to be found now in the center of the anticline, once glided into the Malmian sediment (B. Plöchinger, 1969). An intercalated body of Triassic-Liassic rocks found by the drilling shows Hallstatt development. The process of synsedimentary gliding of Hallstatt outliers obviously began in the Tithonian and ended with the outliers of the Roßfeld mountain which are overlying the Upper Roßfeld Formation. The allodapic components indicate, that this process began with an undersea-updoming caused by a salt diapirism (fig. 53).

The Schrambach Formation (Lower Valanginian) in the quarry consists of aptychus- and ammonite-bearing gray limy marls and marly limestones. Above a thin layer of reddish marly limestones (Anzenbach Formation) the Lower Roßfeld Formation is developed by gray sandy marls (Upper Valanginian — Lower Hauterivian). The sandstone member of the Lower Roßfeld Formation is missing here. Above the reduced sandy marls the conglomerate-(olistostrome-)rich Upper Roßfeld Formation of the higher Hauterivian is beginning. The Roßfeld Formation can be interpreted as a proceeding deep sea channel facies, the coarse-grained sediments of the Upper Roßfeld Formation as a small fan-deposit and slump-deposit (P. Faupl & A. Tollmann, 1979).

Stop 9.6. Liassic Adnet Limestone (Adneter Kalk) in the Plattenquarry of Adnet (fig. 52)

On the western border of the Osterhorn group, at the village of Adnet, the Adnet Limestone has its type locality. Here the Adnet Limestone with its varieties follows the Rhaetian Limestones after a stratigraphic gap (M. Schlager, 1960, map). The ammonite content proves its Lower Liassic to Middle Liassic age. The red

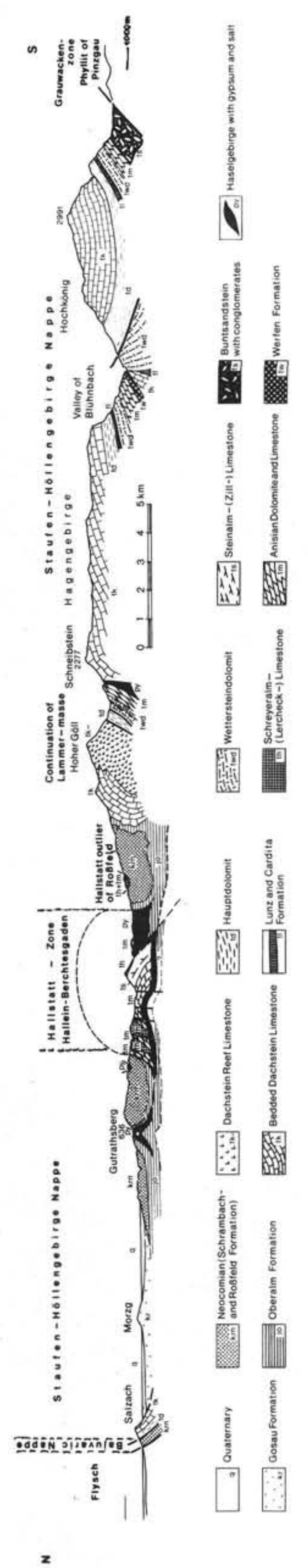

Fig. 50: Section through the Northern Limestone Alps of Salzburg.

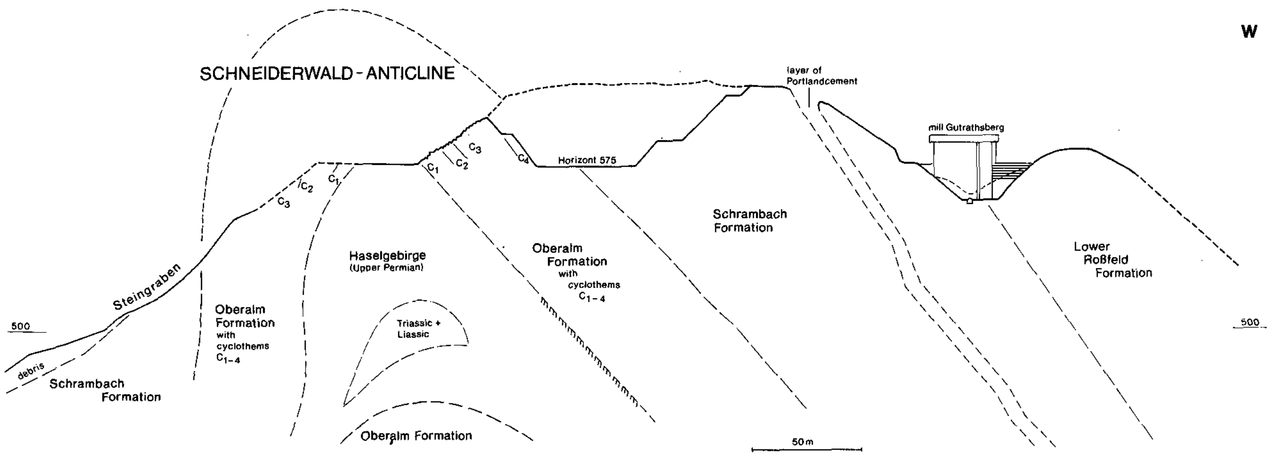

Fig. 51: Section through the area of the cement-quarry Gutrathsberg south of St. Leonhard in the Salzach-valley.

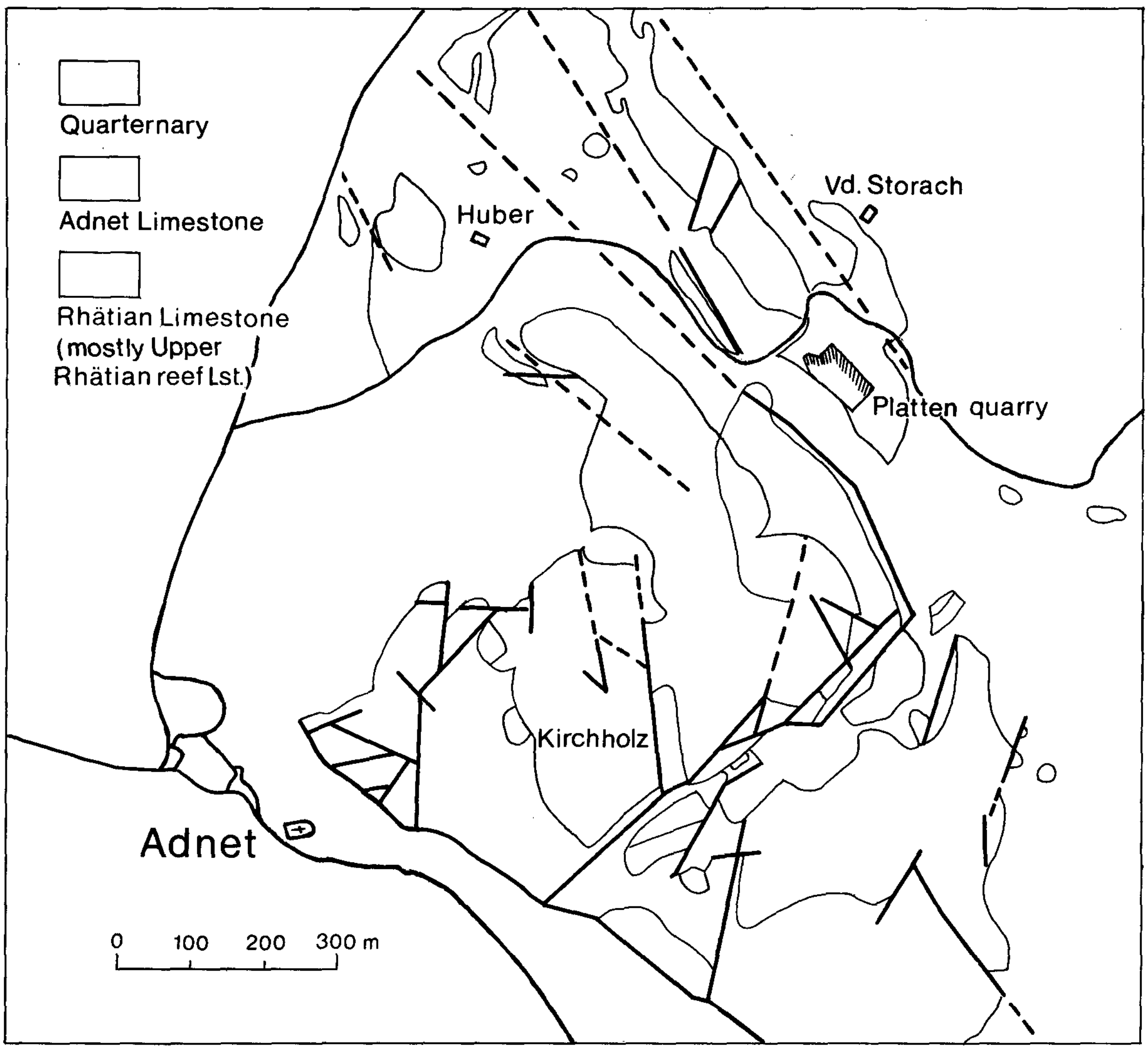

Fig. 52: Sketch map of the Adnet area with the excursion point 9.6. (Platten quarry). After M. SCHLAGER, 1960.

nodular Adnet Limestone s. str., up to 15 m thick, belongs to the Sinemurian and Lower Pliensbachian and may have been deposited in a relatively flat sea. Subsolution which may have influenced the formation of the red Liassic Limestone certainly is also due to the condensation of the sediment. It is supposed, that the nodules were already present when the sediment was still unconsolidated. The nodules are considered as products formed by gliding during the diagenesis.

The up to 6 m thick overlying conglomeratic rock (Knollenbrekzie) of the Upper Pliensbachian contains fragments of different rock types: the Adnet Limestones and the crinoidal Hierlatz Limestone of the same age; the matrix is a pink crinoidal calcilutite (J. D. HUDSON & H. C. JENKYNS, 1969). The highest sediment of the quarry is formed by the so-called about 2 m thick "Scheck", which belongs to the Middle Liassic. It consists almost entirely of ovoid clasts of red calcilutite, cemented by white calcspar. After HUDSON & JENKYNS it may be considered as a resedimented conglomerate in a continuously subsiding region.

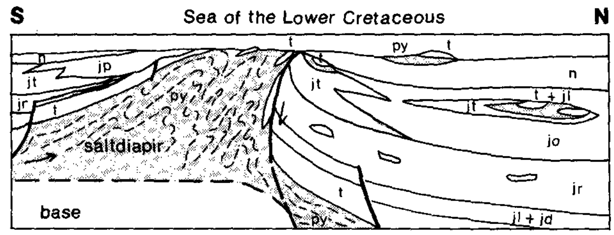

Fig. 53: Schematic section through a laterally deformed submarine salt-diapir, which caused olistolithic gliding during the Jurassics and the Lower Neocomian; n= Neocomian deposits, jo = Oberalm Formation, jp = Plassen Limestone, jr = siliceous radiolarite bearing Formation of the Lower Malmian, jd = Dogger deposits, jl = Liassic deposits, t = Triassic deposits in general, tw = Werfen Formation (Skythian), py = Haselgebirge (Upper Permian) with salt-diapirism.