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Excursion 034 A

Geology of the Eastern Alps

(An Excursion Guide)

by

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52 figures and 10 tables

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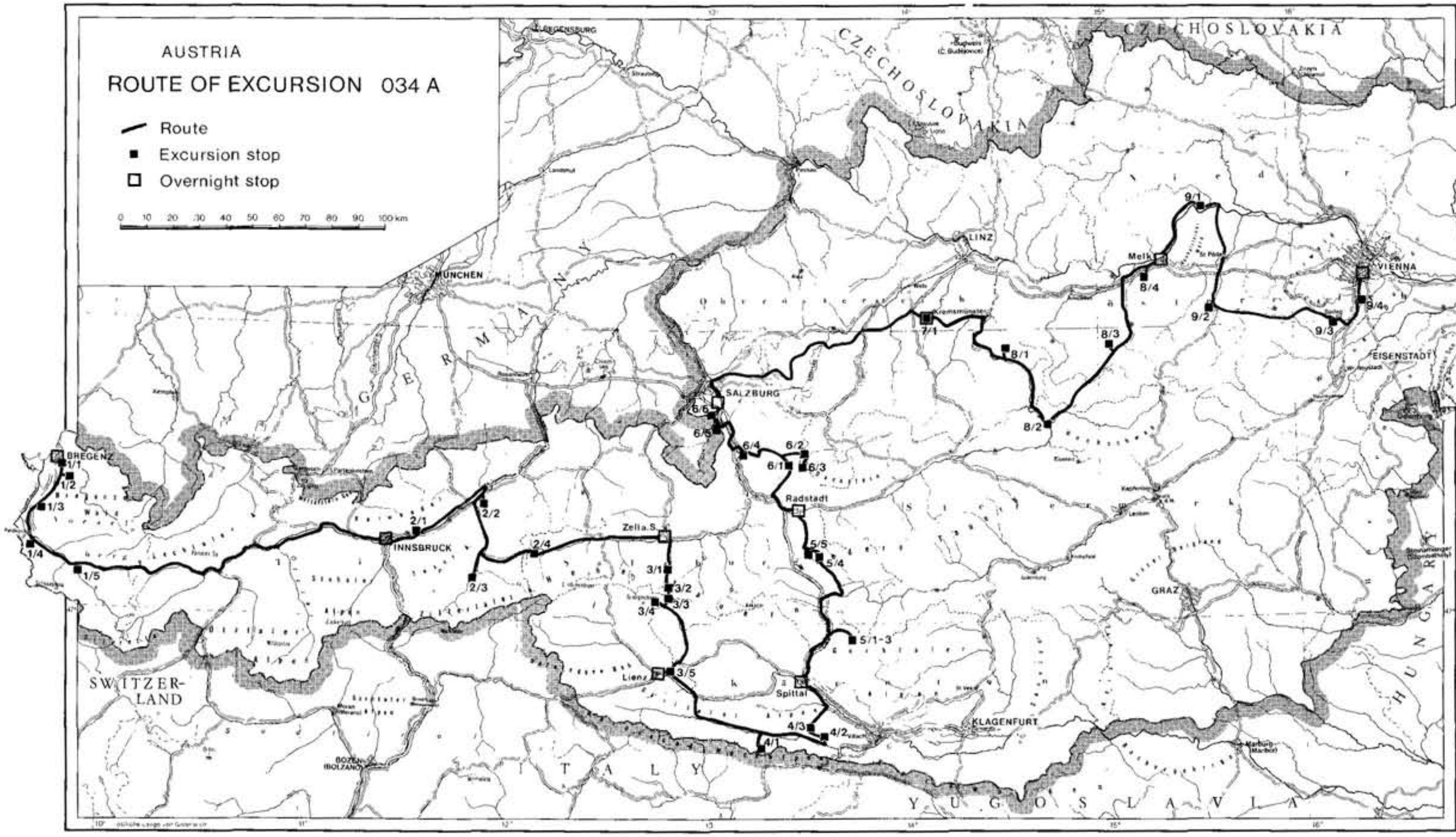

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A c k n o w l e d g m e n t s

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Day 1

Molasse Zone, Helvetic Zone, Flyschzone, Northern Calcareous Alps, regional pattern of Vorarlberg

Route: Bregenz — Gebhardsberg — Schwarzachtobel — Dornbirn — Götzis — Feldkirch — Frastanz — Lorüns — Arlberg Pass — Landeck — Innsbruck

Introduction

Vorarlberg is an appropriate area to introduce into the geological structure of the Eastern Alps. The section of the Rhine valley south of Bregenz between the Bodensee and the Principality of Liechtenstein can be taken as the topographic boundary between the Western and the Eastern Alps. Moreover, east of this line also the Austro-Alpine Unit begins and extends eastwards forming major parts of the Eastern Alps. The main geological units of the Western Alps (Helvetic and Penninic Zones) continue towards east as a relatively narrow zone along the northern boundary of the Eastern Alps.

The existing geological structure is the result of the Alpine orogenesis, a complex multiphase event. In Vorarlberg the main Alpine tectonic activity took place during the Palaeogene. As a consequence of regional compression with southward subduction of the foreland, areas of Mesozoic to Tertiary sedimentary series of different facial nature, in some places with slices of their basement, moved from their site of deposition in such a manner, that they overrode the neighbouring units in the north.

The main units from the top to the bottom are ordered as follows:

Austro-Alpine Unit (Northern Calcareous Alps and Silvretta crystalline complex)
Penninic Zone (Flyschzone)
Helvetic Zone
Foreland (Molasse Zone)

This corresponds with the paleogeographic order from south towards north.

The Molasse Zone forms the foreland. It comprises a thick succession of upper Eocene to Miocene clastic sediments composed of the debris of the rising Alps. The older portions of the Molasse sequence have been envolved by folding and thrusting (Subalpine Molasse) into the orogenic movements. From geophysical surveys and drillings we know that the Molasse sediments continue far below the Eastern Alps towards south. The crystalline complex of the Bohemian Massif with a thin Palaeozoic and Mesozoic cover forms the basement of the Molasse Zone.

The Helvetic Zone in Vorarlberg comprises Upper Jurassic to Upper Eocene rocks. The primary neighbourhood to the autochthonous Mesozoic is indicated by facial analogies. Small thickness, gaps, greensands and reefs in the northerly region, and the abundance of marls in the southerly region indicate depositional conditions at the shelf edge.

The Penninic Zone in Vorarlberg is mainly represented by Cretaceous to Lower Eocene Flysch sediments. In general these synorogenic successions are rather poor in fossils and have in many places been affected by synsedimentary movements. They have been deposited in different subsidiary troughs.

The Alpine movements did not only cause the complex internal structure of the Penninic Flyschzone; moreover, the northern front of the Flysch Nappe has been overthrust by the normally underlying Helvetic Nappe. At the surface we can distinguish therefore a northern and a southern Flyschzone in Vorarlberg. The boundary plane between the Helvetic Zone and the Penninic Zone is marked by a strongly deformed Schuppenzone.

The Falknis-Sulzfluh Nappe and the Arosa Schuppenzone which tectonically overlie the Flyschzone have also been allocated to the Penninic unit. Concerning their depositional facies the Upper Jurassic to Paleocene successions are different from the Flysch development and thought to come from a more southerly region. The strongly deformed rocks of the Arosa Schuppenzone directly underlie the Austro-Alpine Unit and mark its plane of overthrusting which can be traced from Südbünden (Switzerland) northwards as far as Vorarlberg along the western and further eastwards to the Allgäu (Bavaria) along the northern edge of the Austro-Alpine Unit. Moreover, the Arosa Schuppenzone appears in several tectonic windows in the westernmost area of the Northern Calcareous Alps as well as together with lower Penninic units in the window of Gargellen which is situated in the area of the Silvretta crystalline complex.

The Austro-Alpine Unit in Vorarlberg is chiefly represented by the Permomesozoic series of the Northern Calcareous Alps and by the Silvretta crystalline complex. The latter consists of paragneisses and micaschists and minor proportions of amphibolites and Early Palaeozoic orthogneisses. Mesozoics and crystalline complex are linked together by the narrow Phyllitgneis-Zone and a late Palaeozoic clastic succession which exhibits stratigraphic contact in the south against the Phyllitgneis-Zone and continues into the Mesozoic series in the north. The internal structure of the Northern Calcareous Alps is mainly the result of early Alpine

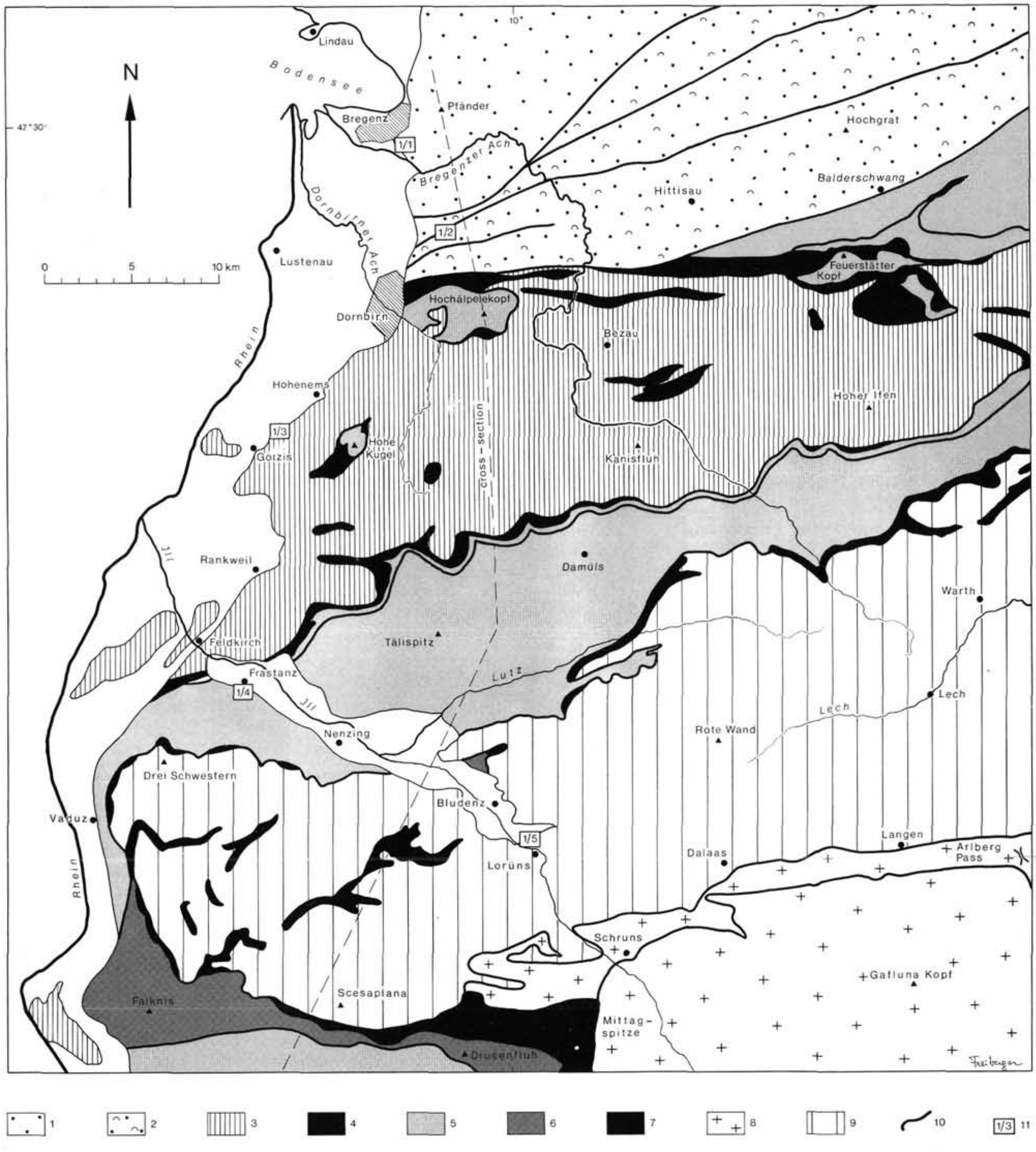

Fig. 1: Tectonic sketch-map of Vorarlberg (modified after M. RICHTER, 1978). 1 = Foreland Molasse; 2 = Subalpine Molasse; 3 = Helvetic Zone; 4 = Schuppenzone; 5—7 = Penninic Zone; 5 = Northern and southern Flysch Zone, Prätigau Flysch; 6 = Falknis-Sulzfluh Nappe; 7 = Arosa Schuppenzone; 8+9 = Austro-Alpine Unit; 8 = Crystalline basement (Altkristallin); 9 = Northern Calcareous Alps; 10 = Major thrust-plane; 11 = Excursion stop.

(Cretaceous) movements. Three major subsidiary nappes can be distinguished from the top to the bottom: the Inntal Nappe, the Lechtal Nappe and the Allgäu Nappe.

In Vorarlberg the influence of a very low-grade Alpine metamorphism is restricted to the southerly regions mainly resulting in a retrograde metamorphism of parts of the Silvretta crystalline complex.

The Pleistocene history is proved by a broad variety of glacial phenomena. The glaciation attained a thickness of about 1000 m. The Rhine valley was a very prominent glacier bed. The Rhine glaciers extended as far as 40 km north of the Bodensee during the glacial maximum.

Stop 1.1. Gebhardsberg

Foreland Molasse
Top. sheet 111 Dornbirn

The locality Gebhardsberg (590 m above sealevel) lies about 190 m above the Bodensee. Beside the parking place the Eggenburgian sandstone-conglomerate-(Nagelfluh)-sequence (fig. 3, tab. 1) is exposed with low-angle north-north-west dip. The sandstones are overlain by several meters of conglomerates with thick crossbedding. The pebbles consist of yellowish more or less quartzose limestones thought to be derived from Flysch rocks. At some places the conglomerate contains oyster shells.

Regarding the tectonic position the locality is situated in the Foreland Molasse. Here at its southern end the Foreland Molasse was lifted by the northward push of the Alpine thrust sheets resulting in a northward slope of the beds.

The castle-like buildings of Gebhardsberg were established at the site of the former Bregenz Castle which has been built in the 11. century and destroyed during the Thirty Years War in 1647. Some remains of this castle are still preserved.

Scenic view from the panorama platform beside the restaurant: In the west the Bodensee with adjoining towns of Bregenz and Lindau; the glacial morphology of the hilly landscape on the German side towards north-west; from west towards south the Swiss Molasse mountains, the Säntis and Churfirsten mountains belonging to the Helvetic Zone and the northernmost mountains of Graubünden; in the background to the south on the Austrian side east of the Rhine valley the Rätikon as the westernmost part of the Northern Calcareous Alps; in front of it the eastern continuation of the Helvetic unit with the Flysch outlier of the Hohe Kugel; nearer towards south-south-east the Hochälpelekopf as part of the Northern Flyschzone; the adjoining mountains in the north belong to the Subalpine Molasse, which is rather narrow here, and the Foreland Molasse; below us the broad valley floor of the Rhine valley with the deltas of the Rhine and the Bregenzer Ache.

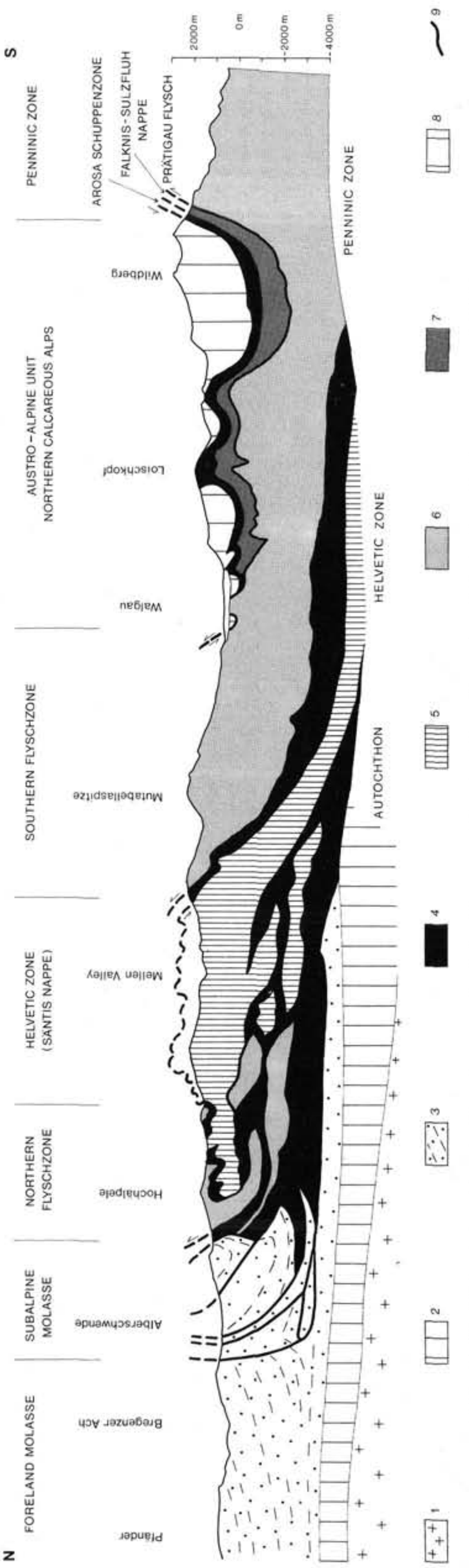

Fig. 2: Section across the northwestern end of the Eastern Alps in Vorarlberg (modified after R. OBERHAUSER, 1980). 1—3 = Foreland; 1 = Crystalline basement; 2 = Mesozoic basement; 3 = Molasse Zone, Oligocene to Miocene rocks; 4 = Schuppenzones with strongly deformed rocks; 5 = Helvetic Zone, Upper Jurassic to Palaeogene rocks; 6+7 = Penninic Zone; 6 = Flysch Zone (Rhenodanubian Flysch, Feuerstätter Zone, Liechtenstein-Prätigau Flysch), Cretaceous to Palaeogene rocks; 7 = Falknis-Sulzfluh Nappe, Upper Triassic to lower Eocene rocks; 8 = Austro-Alpine Unit, Northern Calcareous Alps, Mesozoic rocks; 9 = Movement planes.

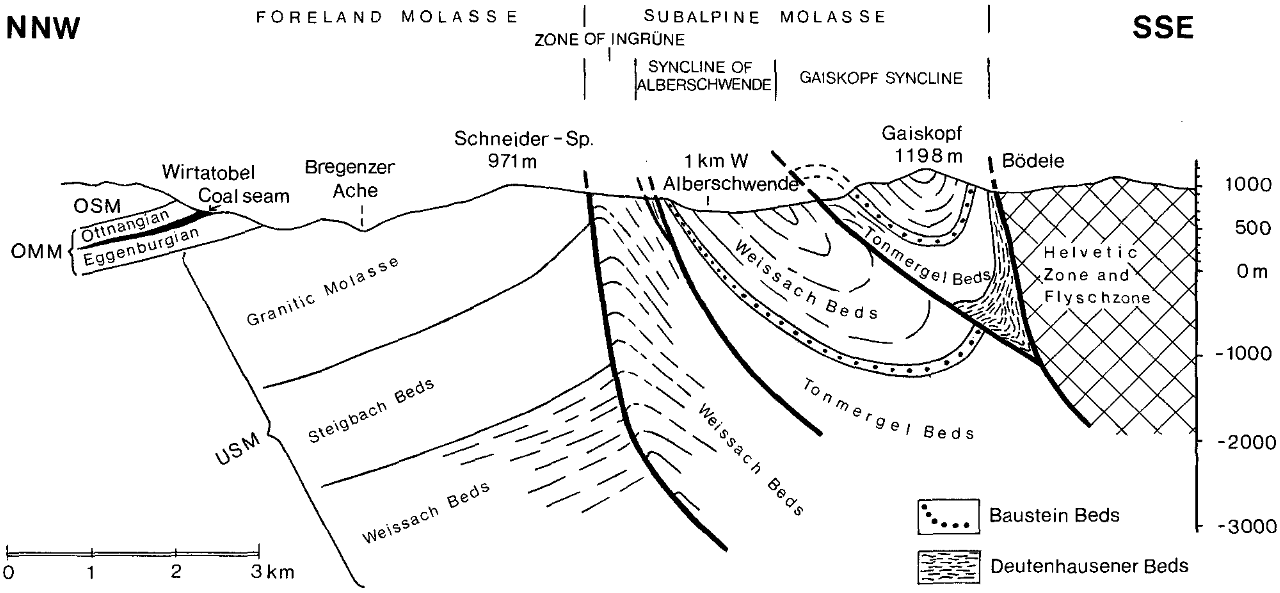

Fig. 3: Section across the western Molasse Zone of Vorarlberg (modified after W. RESCH, 1979). OSM = Upper Freshwater Molasse; OMM = Upper Marine Molasse; USM = Lower Freshwater Molasse.

Epochs	Stages	Formations	Lithologic Units
Oligocene	Badenian ?Karpatian	Upper Freshwater Molasse	**Silvana Beds,** coarse conglomerates, sandstones, and limnic marls, —700 m (Pfänder)
	Ottnangian	Upper Marine Molasse	Red conglomerates and glauconitic sandstones, —450 m
	Eggenburgian		Coal-seam 1.1. Conglomerates, sandstones (partly glauconitic), marls, ~ 250 m
Miocene	Egerian	Lower Freshwater Molasse	**Granitic Molasse,** sandstones, 1500 m **Kojen Beds** **Steigbach Beds,** sandstones and conglomerates, —1000 m **Weissach Beds,** red marls, sandstones, conglomerates, ~ 1200 m
	Rupelian	Lower Marine Molasse	1.2. **Baustein Beds,** calcareous sandstones, conglomerates, ~ 100 m
			Tonmergel Beds, grey marls, ~ 300 m
	Lattorfian		**Deutenhausen Beds,** grey marls, sandstones and sporadic conglomerates

Tab. 1: Stratigraphic correlation of the Molasse Zone in Vorarlberg (modified after M. RICHTER, 1978, and unpublished data of W. RESCH, Universität Innsbruck, and the IGCP Project 25 Working Group).

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Route description: We leave Gebhardsberg and Bregenz towards southeast via Wolfurt. Note the rockwalls at the southern side of the Gebhardsberg exposing a major section of the Eggenburgian "Upper Marine Molasse". At the southern end of the village of Wolfurt (Rickenbach) we enter the Subalpine Molasse. In Schwarzach the route turns eastwards into the Schwarzach valley.

Stop 1.2. Schwarzachtobel

Subalpine Molasse, Baustein Beds
Top. sheet 111 Dornbirn

The locality, an abandoned quarry, is situated within the northern limb of a subsidiary syncline (Syncline of Alberschwende) of the Subalpine Molasse (figures 3 and 4). The exposed well-bedded, grey and calcareous sandstones of approximately 25 m and a medium-angle southward dip represent the Baustein Beds which are part of the Oligocene "Lower Marine Molasse"

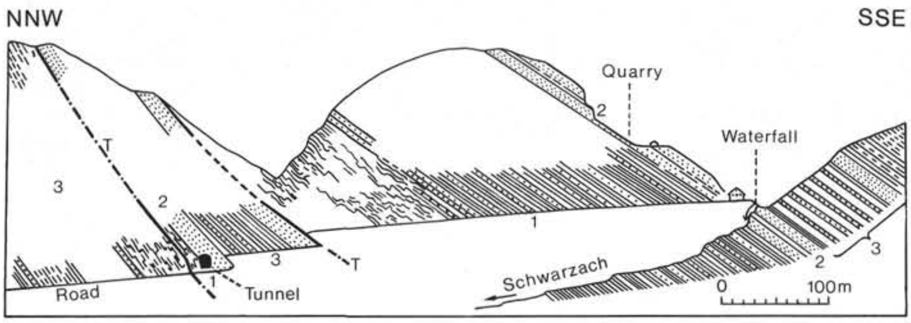

Fig. 4: Section across the "Lower Marine Molasse" in the Schwarzachtobel (modified after Arn. Heim et al., 1928). 1 = Tonmergel Beds; 2 = Baustein Beds; 3 = Weißach Beds; T = Thrust plane.

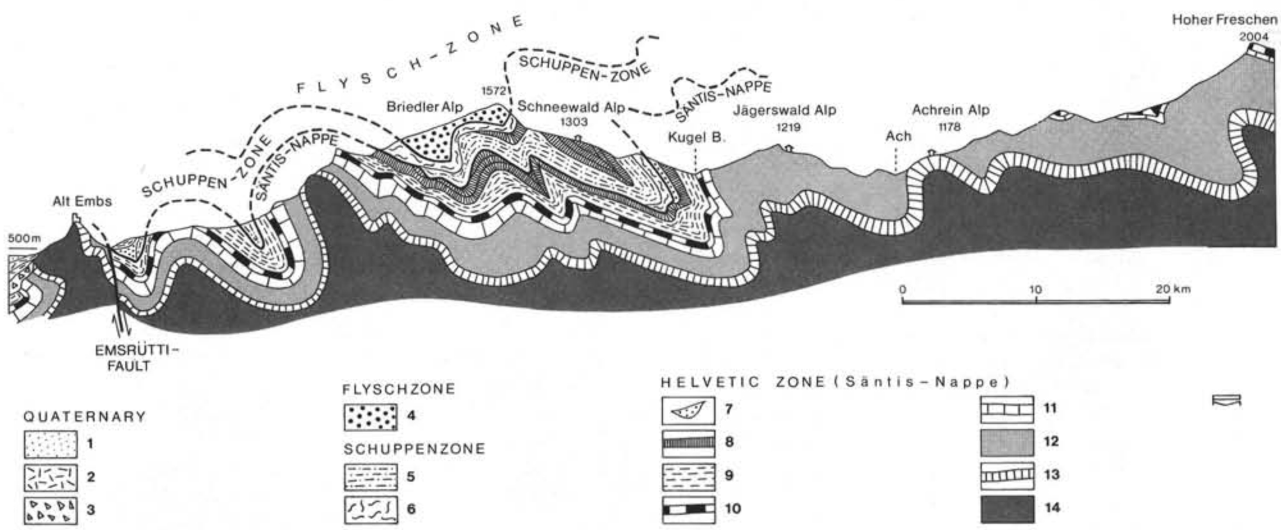

Fig. 5: Section across the Helvetic Zone (Säntis Nappe) south of Hohenems superimposed by remains of the Flyschzone (modified after R. Oberhauser, 1979). 1 = Lacustrine deposits of the Rhine valley lake; 2 = Alluvial fan; 3 = Talus; 4 = Reiselsberg Sandstone; 5 = Globigerina Beds; 6 = Leimern Marls; 7 = Nummulitic Beds; 8 = Wang Beds; 9 = Amden Marls; 10 = Seewer Limestone (Gault); 11 = Schratten Limestone; 12 = Drusberg Marl; 13 = Siliceous Limestone; 14 = Valanginian Limestones and Marls, Zementstein Beds a. s. o.

(tab. 1). Downwards the thickness of the layers is increasing. Rippelmarks with preferred orientation, pyritiferous layers, occasional clay galls and cross-bedding can be observed. There are hardly fossils (f. e. *Cardium* sp.) to be found. However, there are abundant plant remains and trace fossils. The tough sandstones have been worked for paving stones and whetstones.

At the valley floor below the quarry a section of the Baustein Beds and the basal parts of the overlying Weißach Beds is exposed. Note the sharp contact. The underlying Tonmergel Beds crop out at the road-side exposures close to the quarry.

Stop 1.3. Götzis, Kobelfelsen

Helvetic Zone, Götzis Anticline
Top. sheet 111 Dornbirn

The Barremian-Aptian Schratten Limestone crops out at the beginning of the geological-botanical instruction path. This place is situated in the inverted limb of a recumbent fold (Götzis Anticline) in which a Helvetic succession (tab. 2) from Valanginian marls to Coniacian-Santonian Amden Beds is involved (fig. 6).

This inverted limb of the Götzis Anticline extends as far as Sonderberg, a hill rising from the valley floor

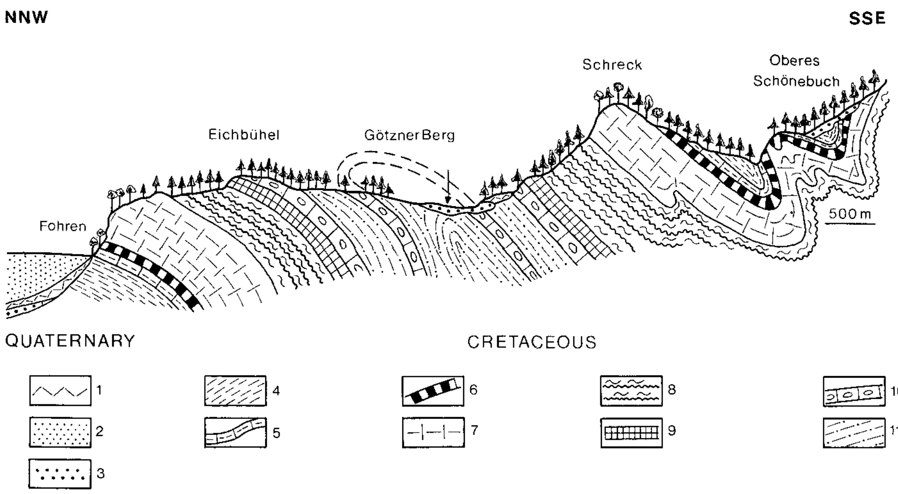

Fig. 6: Section across the Götzis Anticline (modified after R. OBERHAUSER, 1979). 1 = Lacustrine deposits of the Rhine valley lake; 2 = Talus; 3 = Moraine; 4 = Amden Marl; 5 = Seewer Limestone; 6 = Gault-Greensandstone; 7 = Schratten Limestone; 8 = Drusberg Marl; 9 = Siliceous Limestone; 10 = Valanginian oolitic limestone; 11 = Valanginian marl.

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Route description: After returning to Schwarzach the route continues southwards along the eastern edge of the floor of the Rhine valley. In the northern part of the town of Dornbirn we enter the Helvetic Zone. The valley flanks after Dornbirn show parallel escarpments of Schratten Limestone caused by the repetition of normal and inverted sequences of the folded Helvetic series (fig. 5). When passing the town of Hohenems pay attention to the famous Renaissance palace in the center of this town.

about 400 m north of stop 1.3. An inverted succession of quartzose-glauconitic thick-bedded limestone with oolithic domains, grey marls and Hauterivian siliceous limestones is exposed there, in a small abandoned quarry at the eastern end of this hill.

To the northeast there is again an impressive view of parallel escarpments mainly of Schratten Limestone on the valley flanks. The fold structure of this area is illustrated in fig. 5. Remains of the tectonically overlying Schuppenzone and Flyschzone are preserved in the core of some synclines.

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Palaeogene	Eocene	**Globigerina Marls,** —150 m **Nummulitic Limestone**
	Paleocene	***Fraxern Greensand***
Upper Cretaceous	Maastrichtian	**Wang Beds,** dark marly and siliceous limestones, —300 m
	Campanian Santonian Coniacian	**Amden Beds,** grey marls, —300 m
	Turonian	**Seewer Limestone,** pale, partly nodular limestone and marl, —100 m
	Cenomanian Albian	**Brisi Sandstone,** greensands and marls, —40 m
Lower Cretaceous	Aptian	**1.3.** **Schratten Limestone,** pale, thick-bedded limestone, —200 m
	Barremian	**Drusberg Beds,** dark marls and nodular limestones, —400 m
	Hauterivian	**Siliceous Limestone,** thick-bedded, interlayered by black, cherty beds, oolithes and fine breccias, —100 m
	Valanginian	**Valanginian Marl,** dark, interbedded with oolitic and reef limestone, —200 m
Upper Jurassic	Portlandian	**Zementstein Beds,** thin-bedded limestones and marls, —100 m
	Kimmeridgian	**Quinten Limestone,** thick-bedded, grey, —350 m
	Oxfordian	**Schilt Beds,** brownish marls, —120 m

Tab. 2: Schematic stratigraphy of the Helvetic Zone in Vorarlberg (modified after M. RICHTER, 1978).

R o u t e d e s c r i p t i o n: From the Rheintal Autobahn near Götzis view of the mountaineous landscape east of Götzis. The NE-striking folds of the Helvetic series are cut almost perpendicular by some peri-glacial dry valleys which have been shaped by glacial meltwater (fig. 7). One of them ends south of Götzis. At the town of Feldkirch the route leaves the Rhine valley and enters the Ill valley. Feldkirch stands near the southern boundary of the Helvetic Zone. The tunnel below the Schattenburg in Feldkirch and the narrow part of the Ill valley (Felsenau) immediately southeast of Feldkirch passes mainly Schratten Limestone. After this threshold the valley opens. This broad section of the lower Ill valley is called Walgau. After the melting of the Würm glacier this over-deepened basin has been filled by the drift of the Ill river. Near the village of Frastanz the route enters the Southern Flyschzone.

Stop 1.4. Samina Gorge near Frastanz

Flyschzone, Reiselsberg Sandstone
Top. sheet 141 Feldkirch

A section of the Cenomanian-Turonian Reiselsberg Sandstone (tab. 3) with a general medium-angle southward dip is exposed along a small road on a distance of about 500 m between the power station and the mouth of the valley. Near the power station limestones interbedded by marls are folded about steeply inclined axes. Downstream after a moraine exposure follow massive light mica bearing sandstones alternating with marl layers. Slump folds and drag marks indicating depositional transport from the east can be seen at the lower surface of one layer. This mica-sandstone-rich succession continues downstream as far as to the shed near the end of the gorge.

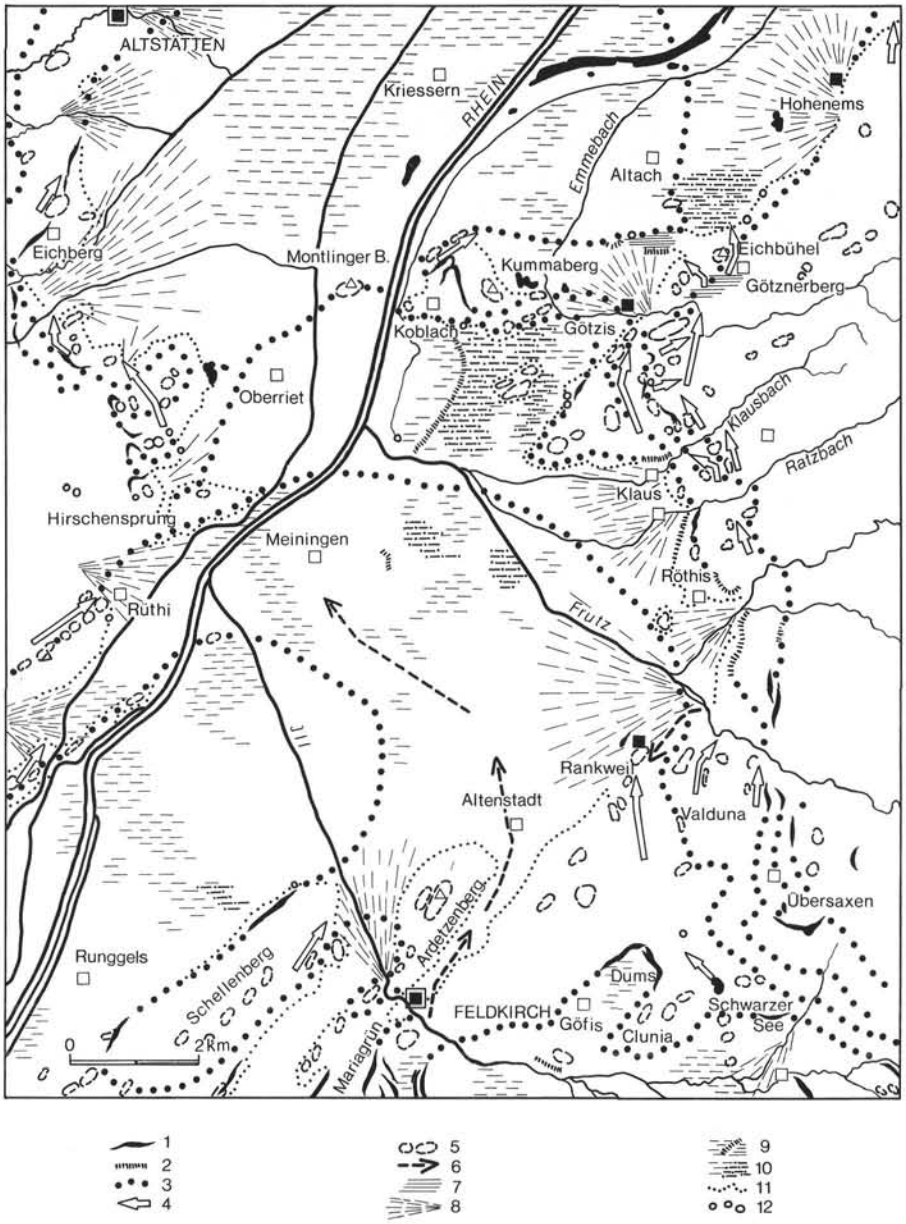

Fig. 7: Sketch-map of the Quaternary geology of the area around Götzis and Feldkirch (R. Hantke, 1979). 1 = Moraine rampart; 2 = Glacial terrace; 3 = Ice margin; 4 = Periglacial meltwater gully; 5 = Roche moutonnée; 6 = Former river bed; 7 = Ice marginal lake; 8 = Talus fan; 9 = Moor or lake terrace; 10 = Bog, peat; 11 = Valley margin; 12 = Springs.

Regionally the Reiselsberg Sandstone is of considerable thickness in the western part of the Flyschzone but of subordinate importance in the eastern part.

Reference

Oberhauser, R. (1979): Helvetikum, Südliche Flyschzone und Quartär am Rheintalrand und im westlichen Walgau (Exkursion F am 20. April 1979). — Jber. Mitt. oberrhein. geol. Ver., N. F. **61**, 57—70, Stuttgart.

Geological map

Heissel, W., Oberhauser, R. & Schmidegg, O. (1967): Geologische Karte des Walgaues, 1 : 25 000. — Geologische Bundesanstalt Wien.

Route description: Returning back to the main road the route continues upstream the Ill valley towards southeast. After the village of Nenzing the route enters the region of the Austro-Alpine Unit repre-

		Lower Eocene Paleocene		
Cretaceous	Upper	Maastrichtian	**Bleicherhorn Series,** sandstones, fine breccias, calcarenites and marls, —700 m	
Cretaceous	Upper	Campanian	**Hällritzer (Plankner Brücke) Series,** calcarenites with black spongolites, —500 m	**Zementmergel Series,** marls, —700 m
Cretaceous	Upper	Santonian Coniacian	**Piesenkopf Series,** thin-bedded, pale limestones and marls, —500 m	
Cretaceous	Upper	Turonian	**(Upper) Mottled Marls,** —10 m	
Cretaceous	Upper	Turonian	**Reiselsberg Sandstone (Schwabbrünnen Series),** sandstones and marls, partly conglomeratic, —600 m	**1.4.**
Cretaceous	Upper	Cenomanian	**Ofterschwanger Beds,** thin-bedded limestones and marls, —300 m	
Cretaceous	Lower	Albian	**Quartzite Series,** —100 m	
Cretaceous	Lower	Aptian Barremian	**Tristel Series,** limestones, marls, breccias, —150 m	

Tab. 3: Schematic stratigraphy of the Flysch Zone in Vorarlberg (modified after M. P. GWINNER, 1978).

sented here by the Northern Calcareous Alps. The foothill of the Hoher Frasen mountain at the junction of the Große Walser valley consists of Norian Hauptdolomit, a prominent rocktype of the Mesozoic sequence of the Northern Calcareous Alps.

The village of Nüziders at the northeastern side of the Ill valley stands upon a tectonic window of the underlying Arosa Schuppenzone and the Falknis-Sulzfluh Nappe represented by Cretaceous and Tertiary rocks. It appears about 1 km behind the northern front of the Northern Calcareous Alps. Opposite to Nüziders road-sided outcrops in Ladinian Partnach Beds and Arlberg Beds occur.

Stop 1.5. Lorüns

Austro-Alpine Unit, Northern Calcareous Alps
Top. sheet 142 Schruns

The quarry of Lorüns stands at the western end of the mountain chain which separates the Montafon valley from the Kloster valley. The quarry is worked for cement production. A succession of uppermost Triassic to Upper Cretaceous is exposed. The beds are steeply dipping north. The succession is complicated by several faults. As the quarry is worked extensively the exposures are rapidly changing. Therefore we present a general model of the stratigraphy based on the studies of H. FURRER (1979) and illustrated in fig. 8. Some supplementary comments:

The basal "Oberrhätkalk" contains a characteristic Rhaetian fauna with *Rhaetavicula contorta* (PORTL.). In the uppermost portion grey and red marls and limestones with uneven bedding surfaces are dominating. Geopetal fabric can be observed in the light-grey and reddish calcareous filling of fissures and cavities cutting limestones and marls.

The Schattwald Beds, an alternating succession of red and green, often sandy marls and limestones, 5 to 6 m thick, are poor in fossils. The mud-cracked bedding surfaces show polygonal patterns.

The texture of the succeeding, 25 to 30 m thick, massive, grey limestone is characterized by oncolites and ooids which are visible at some weathered surfaces. This rock is correlated with the "Geiselstein Oolith". Fossils are rare.

Red or grey-green, nodular limestones follow. They correspond lithologically with the Adnet Limestone. Besides the first appearance of small belemnites plenty of ammonites can be found in some layers.

This nodular limestone grades into a thin-bedded, 25 to 30 m thick sequence of grey and red limestones and marls frequently containing nodules or layers of chert ("Liashornsteinkalk").

The basal part of the following "Condensed Succession" consists of variegated limestones with lens-shaped accumulations of ammonites and big nautiloids. The fossils are usually mantled by a 1 cm thick cover of stromatolites and sessile foraminifers, coloured red, green and black by a considerable content of iron and

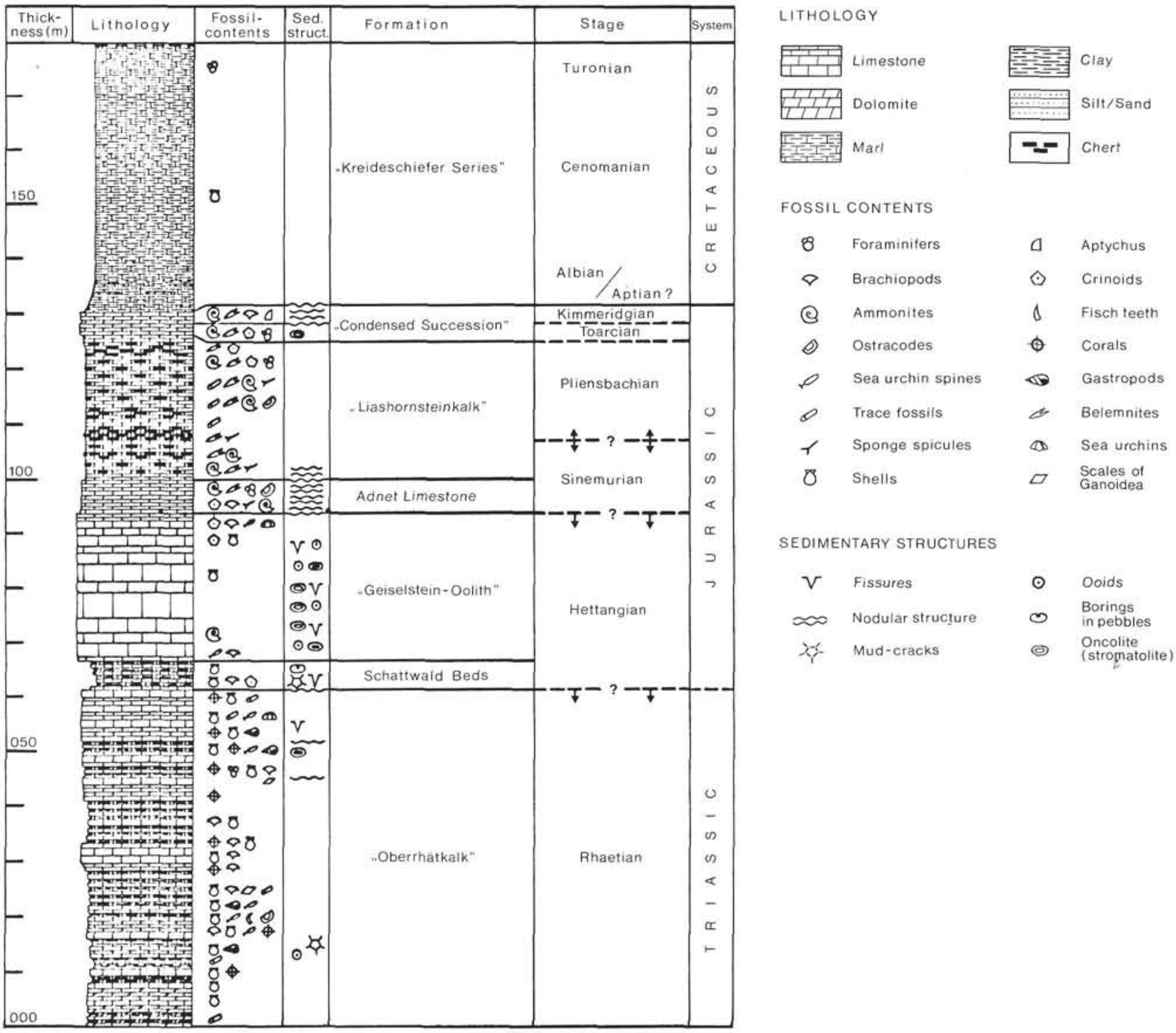

Fig. 8: The succession in the quarry of Lorüns (H. Furrer, 1979).

manganese. The upper part is formed by lightgrey, nodular limestones topped by a hardground with corroded ammonites.

The youngest part of the section is represented by the "Kreideschiefer Series" with a minimum thickness of 50 m and comprising dark-grey marls and laminated, sandy shales. Upper Cenomanian to Lower Turonian foraminifers were found in the upper part by R. Oberhauser (1963).

In Upper Turonian times the sedimentation has been stopped by the Alpine movements.

Geological map

Heissel, W., Oberhauser, R. Reithofer, O. & Schmidegg, O. (1965): Geologische Karte des Rätikon (Vorarlberg). — Geologische B.-A., Wien.

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Route description: About 2 km upstream the Ill valley (Montafon) near the eastern end of the village of Lorüns Norian Hauptdolomit is exposed along a side road which leaves the main road just before the bridge over the Ill river. The Hauptdolomit is a typical and prevailing rock type in the western part of the Northern Calcareous Alps.

We return to the Arlberg Pass road and continue eastwards upstream the Kloster valley. After the Arlberg Pass we descend through the Stanzer valley into the Inn valley which we meet at the town of Landeck and proceed downstream the Inn valley as far as Innsbruck. The route between the upper Kloster valley and Innsbruck follows the southern margin of the Northern Calcareous Alps. The mountains to the south of the route are made of crystalline rocks of the Austro-Alpine crystalline complex. The boundary between the Northern Calcareous Alps in the north and the Austro-Alpine crystalline complex in the south is almost vertical and chiefly of tectonic nature. The course of the broad, trough-shaped Inn valley downstream from Landeck is believed to be marked by a prominent fault line which is buried by thick glacial deposits.

Several kilometers before and after Landeck the so-called Landeck Quartz-Phyllites occur between the Northern Calcareous Alps and the Austro-Alpine crystalline complex.

At the junction of the Ötz valley the valley floor of the Inn valley is extensively covered by blocks of a gigantic mountain slide which came from the Tschirgant mountain in the north. This event was probably induced by the concussion of the same meteorite impact which is considered to have most likely caused the post-Pleistocene occurrence of rock glass at Köfels few kilometers upstream the Ötz valley.

Day 2

Quaternary, Grauwackenzone, Penninic Zone
Route: Innsbruck — Wattens/Fritzens — Brixlegg — Alpbach valley — Ziller valley — Mayrhofen — Gerlos Pass (toll road) — Krimml — Zell/See.

Introduction

The object of the second days program is a section from the Northern Calcareous Alps across the Western Grauwackenzone and the Innsbruck Quartz-Phyllite to the Penninic series of the Tauern Window (fig. 9).

The Western Grauwackenzone forms a belt joining the Northern Calcareous Alps in the south. In Tyrol it attains a maximum width of about 25 km. It largely consists of Early Palaeozoic phyllites. The contact between the Grauwackenzone and the Northern Calcareous Alps is of stratigraphic nature, although subsequently complicated by Alpine tectonic activity at many places. The Grauwackenzone is generally regarded as part of the Upper Austro-Alpine Unit.

Along the boundary between the Western Grauwackenzone and the underlying Innsbruck Quartz-Phyllite appears a row of isolated occurrences of the Caledonian Schwaz Augengneiss, a foliated, diaphthoritic, porphyritic granite gneiss. Whether this orthogneiss is separated or not from the underlying Innsbruck Quartz-Phyllite by an Alpine thrust plane is still a matter of controversy.

The Innsbruck Quartz-Phyllite represents an Early Palaeozoic assemblage of low-grade metamorphic rocks with certain lithological analogies to the adjacent Grauwackenzone and is considered as part of the Lower Austro-Alpine Unit. Appertaining Permomesozoic rocks occur in the Tarntal mountains at the southern margin of the Innsbruck Quartz-Phyllite zone.

The Penninic series of the Tauern Window have the deepest tectonic position. A narrow belt of highly deformed and tectonically repeated Palaeozoic and Mesozoic rocks is located between the Innsbruck Quartz-Phyllite and the Zentralgneis cores and represents the northern marginal zone of the western Tauern Window. The geology of the Tauern Window will be dealt more in detail on the next day.

R o u t e d e s c r i p t i o n: We are leaving Innsbruck eastwards downstream the Inn valley. Pleistocene terraces and periglacial dry valleys can be recognized in the lower part of the valley flanks. The mountains in the south are made of the early Palaeozoic Innsbruck Quartz-Phyllite; the opposite side in the north belongs to the Northern Calcareous Alps.

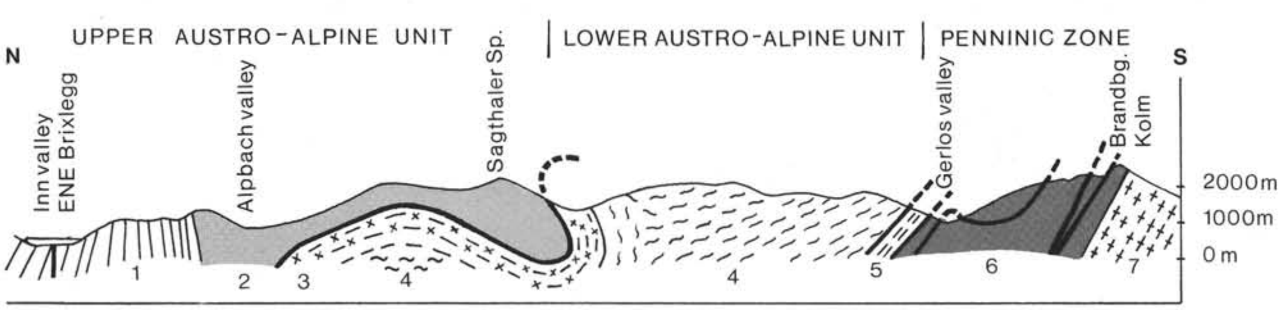

Fig. 9: Schematic section across the western Kitzbühel Alps (modified after O. THIELE, 1974, and A. TOLLMANN, 1977). The section is located appr. 5 km east of the river Ziller. 1 = Northern Calcareous Alps (Permomesozoic); 2 = Grauwackenzone (Palaeozoic); 3 = Schwaz Augengneiss (Caledonian); 4 = Innsbruck Quartz-Phyllite (Early Palaeozoic); 5 = Richbergkogel Series (Jurassic-Cretaceous); 6 = Penninic Schieferhülle (Palaeozoic and Mesozoic); 7 = Zentralgneis (Hercynian).

Stop 2.1. Baumkirchen NW Fritzens (Inn valley)

Pleistocene lacustrine clay
Top. sheet 118 Innsbruck

Besides the stratigraphy and the tectonic history of the Eastern Alps the glacial history is a prominent point of discussion. Regarding the repeated glaciation of the Alpine valleys only few intramontaneous localities give data on the glacial history. The results of investigations carried out since more than 100 years on the sites of Hötting and Baumkirchen near Innsbruck are the basis for understanding the mechanisms and successions of the Alpine glaciations. Hötting, not in our excursion program, is the type locality of the interglacial (Riß/Würm) *Höttinger Brekzie,* the most common building stone of Innsbruck. Sandy intercalations bear a rich flora described by Wettstein (1888). *Rhododendron sordellii* Tralau is used as indicator for a warmer interglacial climate than today. The collections are in care of the University of Innsbruck and the Museum of Natural History in Vienna.

The second place, the claypit of Baumkirchen gives an outstanding information about the dramatic event of the last glaciation. Several deposits of banded clay are known from the Inn valley between Imst and Kufstein. Their top strata are to be found in about 750 m altitude. The bottom is not known. The minimum thickness measures 110 m. The clay series is overlain by gravel and sand ("Vorstoßschotter") and at least by a ground moraine of the late Würmian glacier.

Recent investigations lead to following conclusions: the whole series of clay was sedimented in a shallow freshwater lake within a short timespan (fig. 10). The banding is not the result of seasonal changing of organic content. Research on pollen shows, that the annual sedimentation rate is several centimetres a year and spans over 2—5 bedding cycles. The thin individual beds reflect the changing depositional conditions of the river depending on rainfall and melting. The banded clay ("Bänderton") of Baumkirchen is deposited in a natural lake, dammed by the coarse material from a side valley downstream.

Radiocarbon analysis on fossil wood (tab. 4) between 655 m and 681 m indicate absolute ages between 30.600 ± 1.300 and 26.800 ± 1.300 years B. P. Deuterium analysis give evidence for an average temperature of 5° less than today. This is supported by a pollen diagram (tab. 5) typical for a poor *strauchsteppe* vege-

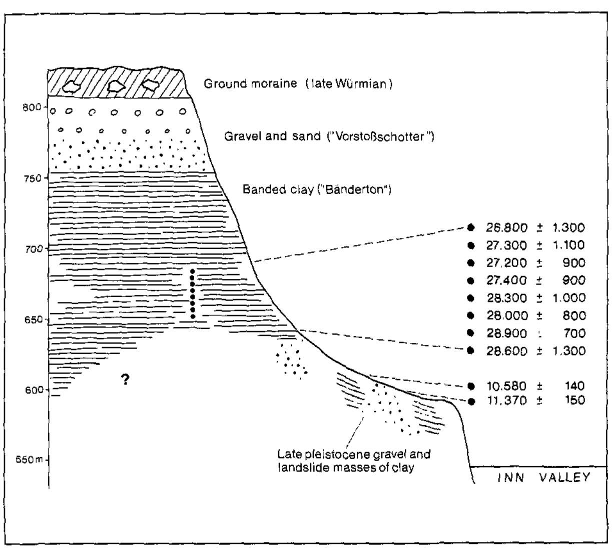

Fig. 10: Section through the Late Würmian Gnadenwaldterrasse near Innsbruck (modified after Fliri, 1978).

Metres above sea level	Wood	Age B. P.
655	Bark (Pinus)	30.600 ± 1.300
660	Hippophae rh.	28.900 ± 700
661	Pinus mugo	31.000 ± 1.300
		29.700 ± 1.100
		32.370 ± 600
661	Hippophae rh.	28.000 ± 1.000
661	Pinus sylv.	25.500 ± 600
663	Hippophae rh.	28.100 ± 800
667	Alnus viridis	28.300 ± 1.000
671	Hippophae rh.	27.400 ± 900
675	Alnus viridis	27.200 ± 900
678	Root (Conifer)	27.300 ± 1.100
681	Pinus mugo	26.800 ± 1.300
Resedimented clay	Wood (Conifer)	11.370 ± 150
		11.200 ± 170
	Pinus sylv.	11.200 ± 150
	Pinus sylv.	10.900 ± 160

Tab. 4: Radiocarbon analysis of fossil wood from Baumkirchen (after Fliri, Felber & Hilscher, 1972).

Pollen of trees and bushes		Pollen of herbs	
Pinus	11,6	Artemisia	28,7
Betula	5,3	Gramineae	9,4
Alnus	0,9	Cyperaceae	9,2
Salix	0,6	Chenopodiaceae	5,3
Juniperus	0,6	Rosaceae	3,6
Hippophae	0,5	Apiaceae	1,3
Picea	0,4	Achillea T.	1,3
Larix	0,06	Thalictrum	1,2
		Helianthemum	1,1
		Senecio T.	0,9
		Rumex	0,9
Spores		Caryophyllaceae	0,7
Dryopteris	0,9	Cichoriaceae	0,6
Selaginella sel.	0,4	Ephedra dist. T.	0,4
Botrychium	0,2	Ephedra alt. T.	0,4
		Filipendula	0,2

Tab. 5: Pollendiagram after Bortenschlager (1978).

tation dominated by herbs. Interpolation of 70 m unproved overlying clay, gravel and sand and data from other localities support the idea, that the Inn valley was overwhelmed by the late Würmian ice not earlier than 20.000 B. P. Absolute data from the Lanser swamp, also close to Innsbruck, show, that the area again was covered with vegetation at 13.230 ± 190 B. P. Data from Baumkirchen prove forest vegetation at 11.370 ± 150 B. P. (conifera). Therefore the time interval for glaciation (Late Würmian) of the Inn valley is restricted to approximately 6.000 years.

The high standard of botanical, geological and radiocarbon investigations brings the claypit of Baumkirchen into a keyposition for the understanding of the late Pleistocene history of the Eastern Alps.

The mineralogic composition of the clay indicates crystalline as well as carbonate source areas due to its depositional location between the Northern Calcareous Alps and the crystalline rocks of the Central Alps. The bedding planes show an enormous amount of ichnofossils caused by bottomnear swimming fish and suggest the assumption of extreme shallow water.

Divergent from the results of FLIRI, BORTENSCHLAGER, RESCH, FELBER, HEISSEL and HILSCHER is the opinion of F. MAYR (1976). He suggests an age of at least 46.000 years, probably 100.000 B. P. He correlates paleomagnetic data from Baumkirchen with the Blake Event and thinks of falsification of the radiocarbon dates by extreme radiocarbon concentration in the atmosphere. In his opinion the rhythmic banding indicates seasonal "warving". For further discussion of this point of view see FLIRI (1976).

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Route description: Leaving Fritzens the route continues downstream the Inn valley on the Autobahn. As far as the town of Schwaz the southern flanks are formed by the Innsbruck Quartz-Phyllite. At Schwaz basal parts of the Northern Calcareous Alps cross the Inn valley and afterwards appear on the southern flanks. However, between the underlying Innsbruck Quartz-Phyllite and the Mesozoics on top, the Schwaz Augengneiss and the narrow western end of the Western Grauwackenzone is exposed in the slope southeast of Schwaz.

The Lower Devonian Schwaz Dolomite is a typical member of the Western Grauwackenzone. In the westernmost part of the Grauwackenzone it forms an almost continuous body of about 20 km east-west extension. The considerable pre-Triassic fahlore mineralization of the Schwaz Dolomite in this region was object of famous and productive silver mining activity during the fifteenth and sixteenth century. This period had an important bearing upon the economic and cultural prosperity of this region at that time and is still evident in the architectural character of towns such as Bad Hall, Schwaz, Brixlegg and others. Besides the fahlore also siderite and barite were mined here. Nowadays all these ore deposits are of low economic importance and are worked only in few places.

The rock walls on both sides of the valley mouth of the Ziller valley, which appears on the southern side consist of Schwaz Dolomite.

Near Brixlegg the route leaves the Inn valley southwards passing the town of Brixlegg and the village of Reith and crossing steeply inclined basal part of the Northern Calcareous Alps.

Stop 2.2. Reith-Alpbach

Grauwackenzone
Top. sheet 120 Wörgl

Along the road connecting the villages Alpbach and Reith three prominent rock types of the Grauwackenzone (Lower Wildschönau Phyllites, porphyroid, Schwaz Dolomite) and the stratigraphic contact between Grauwackenzone and the Permian basis of the Mesozoic succession of the Northern Calcareous Alps are exposed (fig. 11). The whole complex displays strong folding and faulting and high angle dip of bedding planes, partly dipping northwards, partly overturned dipping southwards. These structural features are mainly due to Alpine tectonic events but also, regarding the Grauwackenzone, partly caused by Variscan movements. The rocks of the Grauwackenzone underwent a very low-grade metamorphism; their stratigraphy is illustrated in fig. 12.

The southernmost part of the section shows Lower Wildschönau Phyllites ranging from the deeper Ordovician to Caradocian. The alternation of silty slates and layers of subgreywackes is characteristic for the Lower Wildschönau Phyllites in which fossils have not yet been found. Besides prevailing quartz the subgreywackes consist of plagioclase (albite to oligoclase), light mica, altered biotite; alkali feldspars are rare; accessory minerals: zircon, tourmaline, apatite and rutile. In general the clastic texture is very well preserved.

An upper Ordovician steeply northwards dipping porphyroid overlies the Lower Wildschönau Phyllites. The contact is exposed and appears to be complicated by tectonic activity. This porphyroid represents a characteristic and rather persistent stratigraphic level throughout the whole Grauwackenzone and is derived from quartz porphyries and related tuffs. A number of facts, such as extensive occurrence, fragments of rock glass, relics of eutaxitic fabrics, the formation of soil on top of the porphyroid, indicate the nature of a rhyolitic ignimbrite and its subaerial deposition. The stratigraphic position of the porphyroid is established on the ground of lithological

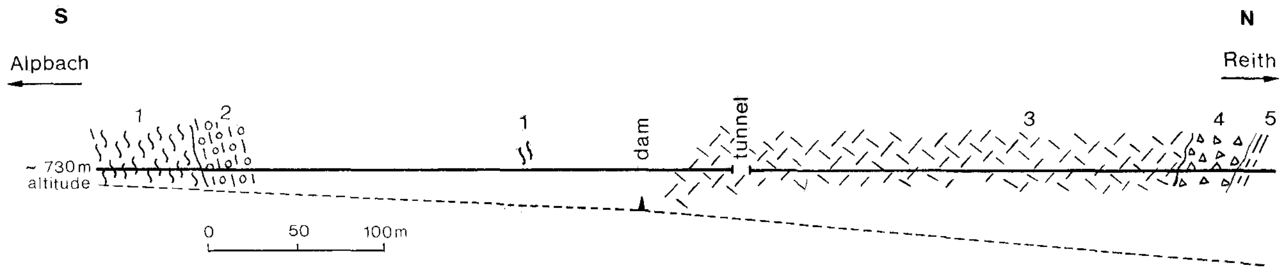

Fig. 11: Schematic section across Early Palaeozoic rocks of the Grauwackenzone and the Permian basis of the Northern Calcareous Alps along the road Alpbach-Reith south of Brixlegg. 1 = Lower Wildschönau Formation (Ordovician); 2 = Porphyroid (Upper Ordovician); 3 = Schwaz Dolomite (Lower Devonian); 4 = Basal Breccia (Lower Rotliegend); 5 = Red, sandy shales (Permian).

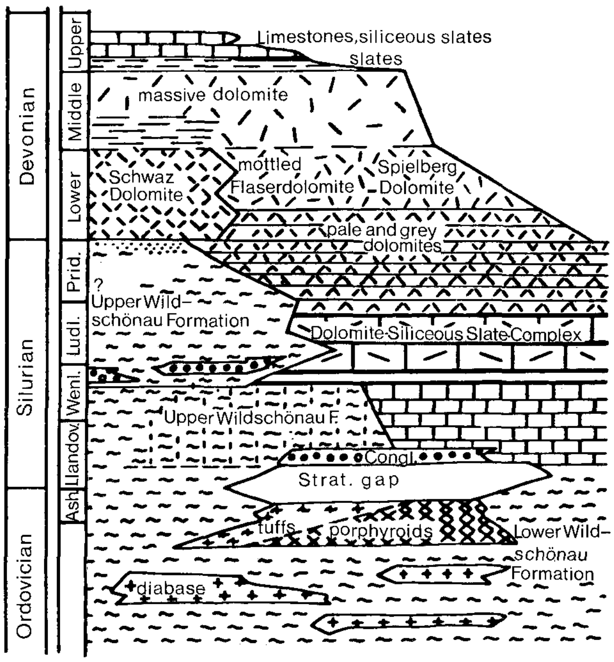

Fig. 12: Schematic facies diagram of the Grauwackenzone in Tyrol (after H. Mostler, 1968, modified by H. P. Schönlaub, 1979).

correlation with the "Blasseneck Porphyroid" of the eastern section of the Grauwackenzone, where fossils have been found.

The lower Devonian Schwaz Dolomite mainly appears pale and massive, consisting of dolomitized organodetrital limestones with orthoceratites, crinoids, corals, bivalves. Few meters of dark, fossiliferous dolomites form the southernmost part of the exposed Schwaz Dolomite. *Syrinaxon zimmermanni* (Weissermel), *Thamnopora* cf. *reticulata* (De Blainville) and *Coenites* (?) *volaicus* (Charlesworth) were reported by H. Pirkl (1961) from the basal portion. Some indistinct layers indicate a general high angle northward dip.

The lower Permian Basal Breccia overlies the Schwaz Dolomite with a well-exposed roughly vertical sedimentary contact. This breccia mainly consists of angular to subangular, pale components of Schwaz Dolomite. The marginal or full red staining of the dolomite components is probably of secondary origin. In the lower parts the matrix is mainly dolomitic and of yellowreddish to grey colour. Upwards it gradually becomes sandy-clayey and achieves brown-reddish colour.

Only few metres of the succeeding red Permian sandy shales are exposed. The lithological change between the Basal Breccia and the red shales is rather quick. The position of the red shales is overturned and thus the beds are steeply dipping southwards.

Geological map

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Route description: Returning to Brixlegg and from there to the junction of the Ziller valley the route continues upstream the Ziller valley in southward direction. We are moving across the east-west striking regional structures towards the updomed central zone of the Eastern Alps (fig. 9). After the Grauwackenzone we are crossing the Schwaz Augengneiss between Fügen and Kaltenbach and then we enter the Innsbruck Quartz-Phyllite. Passing Zell am Ziller the route enters the Penninic Schieferhülle not far from the village of Mayrhofen.

Stop 2.3. Hochstegen near Mayrhofen

(W. FRISCH) *)

Penninic Zone, Tauern Window
Top. sheet 150 Zell am Ziller

The place is situated in the Tauern Window. Here, below the pile of Austro-Alpine nappes, the Penninic Zone as the deepest tectonic unit became exposed at the end of the Alpine orogeny by updoming and contemporaneous erosion of the central axial zone. Two subsidiary tectonic units of fundamental difference in structure and lithology can be distinguished in the western part of the Tauern Window.

The lower unit, the Venediger Nappe (Middle Penninic), consists of Hercynian basement including the Permocarboniferous Zentralgneis (granitoid gneisses), Lower Palaeozoic metasediments and metavolcanics, and a thin Mesozoic cover. The latter is characterized by only sporadic and thin Triassic, the Jurassic (to early ?Cretaceous) Hochstegen Formation (mainly pelagic marbles), and the Lower (to ?middle) Cretaceous Kaserer Formation (a clastic, partly turbiditic sequence).

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The higher unit, the Glockner Nappe (South Penninic), consists of thick Jurassic to Cretaceous Bündnerschiefer and Tauernflysch Formation which is, at least in part, a turbiditic deep water sediment deposited in a basin floored by oceanic crust. The base of the Glockner Nappe is formed by highly deformed Permotriassic strata (Permoskythian clastic terrestrial deposits, Middle Triassic shallow-water carbonates, Upper Triassic Keuper Formation) which, in places, are associated with basal Bündnerschiefer and ophiolites and thus attain the appearance of an ophiolitic mélange (f. e. southern flank of the Tauern arch).

The Hochsteg ("High bridge" over the gorge of the Zemm Bach) is the type locality of the Hochstegen Formation. The bridge joins the basement of the Venediger Nappe (Zentralgneis, here as phyllonitized porphyric granite gneiss) with its sedimentary cover, the Hochstegen Marble. The strata are vertical. Between Zentralgneis and Hochstegen Marble a graphitic quartzite bed, appr. 10 m thick, is scarcely exposed and forms the base of the Hochstegen Formation.

The quarry of Hochstegen, now abandoned, in 1939 furnished the imprint of *Perisphinctes* sp. which has been determined as Upper Jurassic, probably Oxfordian, by v. KLEBELSBERG and QUENSTEDT. Recently, findings of radiolarians, sponge spicules, and a belemnite were made in the quarry and confirm the post-Triassic age of the formation. The rocks of the quarry are predominantly dolomite marble with a certain content of H_2S.

The rocks underwent greenschists metamorphism.

The panoramic view to the west is illustrated by fig. 13. Note the complex isoclinal folding of the Hochstegen Marble forming here the front part of a northward diving recumbent fold (synform with an antiform as hinge). This complex structure is evident by some wedge-shaped lamellae of Palaeozoic schists diving from above into the Hochstegen Marble. A subsidiary nappe of the Venediger Nappe, the Wolfendorn Nappe, and finally the Glockner Nappe follow upon to the north.

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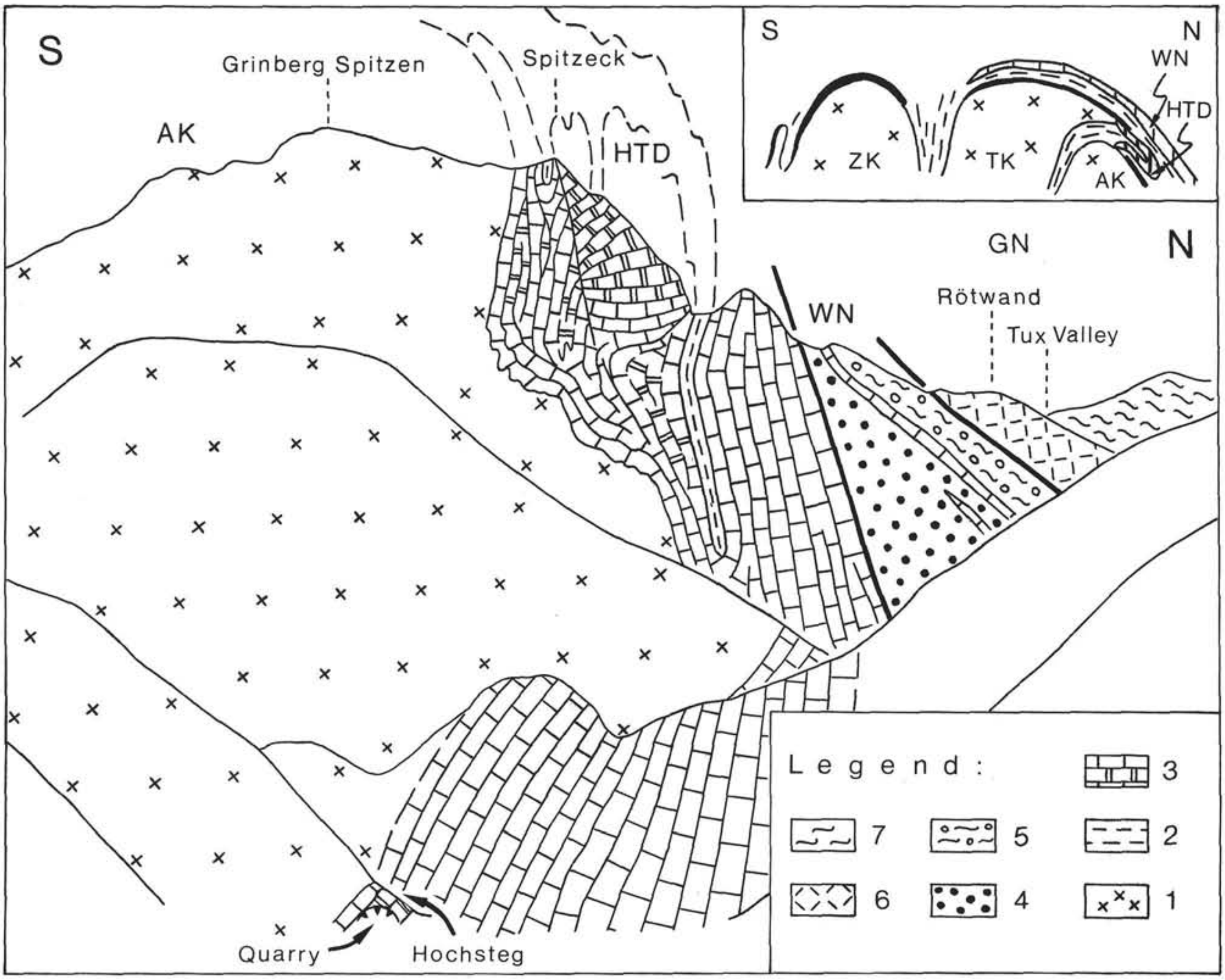

Fig. 13: View from Mayrhofen to the west showing the eastern main ridge of the Tux mountains (W. FRISCH). AK = Ahorn Kern (Ahorn Zentralgneis Core); HTD = Höllenstein-Tauchdecke (Höllenstein Diving Nappe); WN = Wolfendorn Nappe; AK, HTD and WN are parts of the Venediger Nappe; GN = Glockner Nappe; 1 = Porphyric granite gneiss; 2 = Palaeozoic schists; 3 = Hochstegen Marble (double lines for dolomite); 4 = Palaeozoic volcanoclastic formation; 5 = Kaserer Formation; 6 = Middle Triassic carbonate rocks; 7 = Bündnerschiefer and Tauernflysch Formation.
Inset: Tectonic section across the western Tauern Window. Crosses = Zentralgneis; dashed lines = Palaeozoic schists; black = autochthonous Mesozoic cover; bold vertical lines = parautochthonous Mesozoics; vertical lines = allochthonous Mesozoics.

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Route description: We return to Zell am Ziller into the Innsbruck Quartz-Phyllite and from there ascend the Gerlos valley towards east. About 7 km after Zell am Ziller we again enter the Penninic Zone. Until the next stop the road, proceeding almost parallel to the regional strike, remains within the Penninic Schieferhülle.

On the Gerlos Pass the road is crossing a high bog which is approximately four meters thick. Radiocarbon dating of the base yielded an age of about 12 200 years.

Stop 2.4. Krimml

Penninic Zone, Zentralgneis
Top. sheet 151 Krimml

The parking place in 1170 m at turn 2 of the Gerlos Toll Road stands within Penninic Zentralgneis. There are exposures of "Augen- and Flasergranitgneis", a two-mica granite gneiss with augen of feldspar and flasers of grain aggregates, between 0,5 to 2 cm in size and composed of alkali feldspar, plagioclase (albite) and quartz. Aplitic veins are common. For the Augen- and Flasergranitgneis a Rb/Sr whole rock age of 246 m.y. was reported by E. JÄGER & al (1969).

Among different varieties of the Zentralgneis the Augen- and Flasergranitgneis is believed to be the oldest followed by a tonalitic-granitic generation and by aplite granites (F. KARL, 1959).

From the structural point of view stop 2.4. is situated in the northern flank of the parautochthonous "Krimmler Gneiswalze" (Krimml Cylindric Gneiss Anticline) which itself is subdivided into the northern and southern "Sulzbachzungen" (Sulzbach Subsidiary Anticlines) by a narrow zone of epidote-amphibolites and paragneisses (Knappenwand Syncline). The structural situation to the north of stop 2.4. is illustrated by fig. 14.

To the south there is an excellent view of the entrance of the Krimmler Ache valley with famous waterfalls.

Geological map

KARL, F. & SCHMIDEGG, O. (1979): Geologische Karte der Republik Österreich 1 : 50.000, 151 Krimml. — Geol. B.-A. Wien.

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Route description: The road descends into the broad glacial west-east trending Salzach valley. It follows an important longitudinal fault system (Salzach Longitudinal Fault or Tauernnordrand Fault) which terminates the Tauern Window series to the north. This late Alpine fault system is associated with mylonites of appr. 200 m thickness.

There are road-side exposures of Triassic dolomites at the eastern end of the village of Krimml. Whether they are allocated either to the Penninic complex or to the Lower Austro-Alpine Unit is a matter of discussion. The Obersulzbach, Untersulzbach and Habach valleys which appear several kilometers after Krimml to the right side in the south are famous because of considerable occurrences of emerald and epidote crystals.

At the village of Mittersill the Innsbruck Quartz-Phyllite is wedging out on the northern side. Along the following section of the Salzach valley the Grauwackenzone is directly neighbouring the Penninic series.

Day 3

Penninic Zone, Tauern Window, Austro-Alpine Crystalline Complex

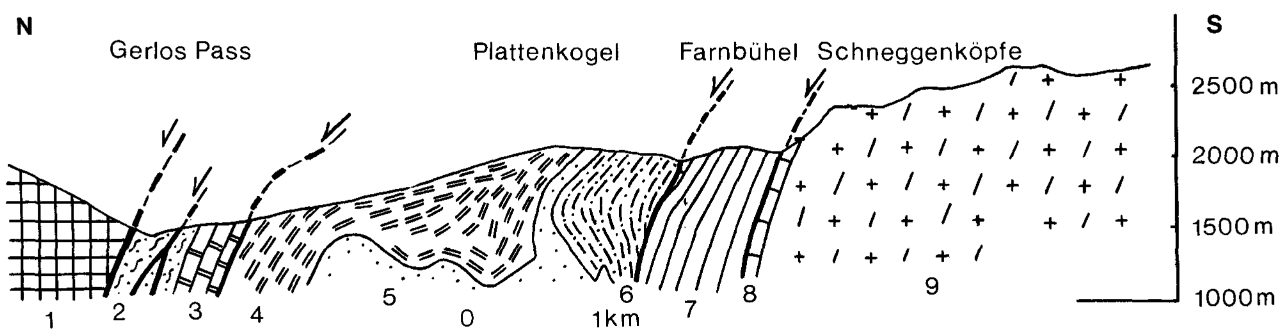

Fig. 14: Cross-section through the northern margin of the Tauern Window in the area of the Gerlos Pass (after O. THIELE, 1974). 1—3 = Lower Austro-Alpine Unit; 1 = Innsbruck Quartz-Phyllite; 2 = Richbergkogel Series (Jurassic to ?Cretaceous); 3 = Triassic carbonate rocks; 4—6 = Penninic Zone, Upper Schieferhülle Unit (synonym of Glockner Nappe); 4 = Bündnerschiefer (Jurassic to Cretaceous); 5 = Green arcose gneiss and quartzite (?Permoskythian); 6 = Habach Phyllite (Palaeozoic); 7—9 = Penninic Zone, allochthonous schuppen of the Lower Schieferhülle Unit and Parautochthon (synonym of Venediger Nappe); 7 = Hochstegen Marble (Jurassic); 8 = Volcanoclastic formation (Palaeozoic); 9 = Augen- and Flasergranitgneis (Zentralgneis); bold contours = boundaries of nappes and schuppen.

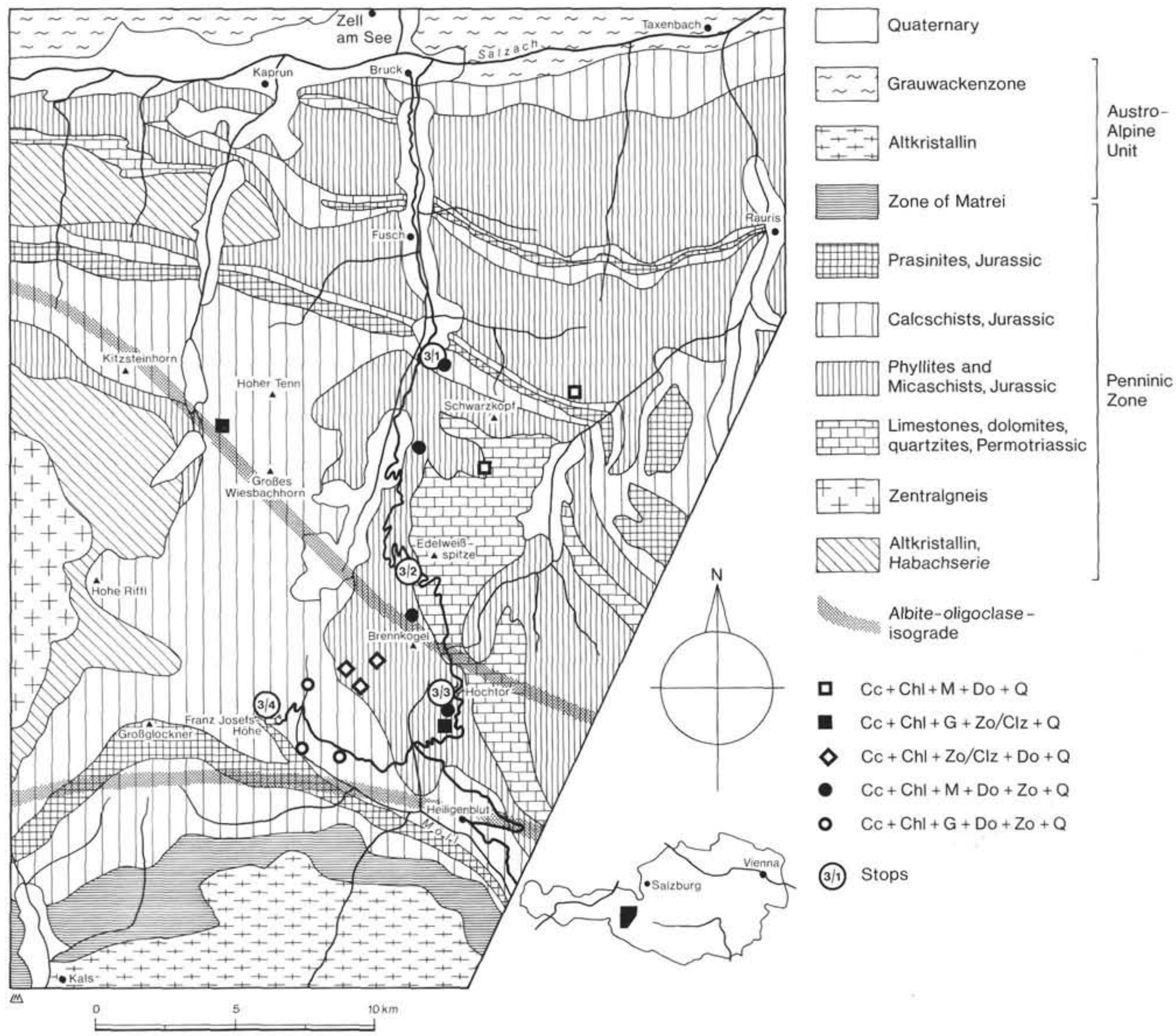

Fig. 15: Geological sketch-map of the middle part of the Tauern Window (V. Höck). The distribution area of garnet and oligoclase is limited by the stippled stripes (albite-oligoclase-isograde).

Route: Zell/See — Großglockner-Hochalpenstraße (toll road) — Heiligenblut — Iselsberg — Lienz

Introduction

(V. Höck) *)

Topographically, this day's excursion will travers the Hohe Tauern between the Salzach valley in the north and the Drau valley in the south. The Hohe Tauern represent the main ridge of the Eastern Alps and contain a considerable number of summits exceeding an altitude of 3000 m. The pass section of the route is traversed by the Großglockner-Hochalpenstraße, a magnificently engineered road, which was begun in 1930 and completed in 1935. The Hochtor (2505 m) is one of the highest passes in Europe.

Geologically, the excursion will display a section across the middle part of the Tauern Window and the Austro-Alpine crystalline complex (fig. 15).

The Penninic assemblage of the Tauern Window comprises a polymetamorphic crystalline basement, as well as metamorphosed Palaeozoic and Permomesozoic rocks. Based on the classical surveys by H. P. Cor-

*) Doz. Dr. Volker Höck, Institut für Geowissenschaften, Universität Salzburg, Akademiestraße 26, A-5020 Salzburg.

NELIUS and E. CLAR (1939) the recent concepts on the stratigraphy in the middle part of the Hohe Tauern were developed by FRASL (1958) and were refined by G. FRASL and W. FRANK (1964, 1966). The stratigraphy and the ideas on the tectonic position of the Penninic complex exposed within the Tauern Window is based mainly on lithological correlation of related series.

The pre-Hercynian Palaeozoic portion is correlated with stratigraphically well known rocks in the Grauwackenzone north of the Tauern Window, the Jurassic-Cretaceous portion with the Penninic Bündnerschiefer in the Western Alps. They disappear below the Austro-Alpine Unit at the western end of the Eastern Alps and are believed to reappear further to the east in some tectonic windows, the largest of which is the Tauern Window. Moreover, fossil occurrences, despite their poor quality and scarcity, provide evidence for the Mesozoic age of rocks within the Tauern Window.

The internal structure of the Penninic system of the Tauern Window is very complex. During the Alpine movements a group of regional thrust-sheets were piled up, each having been transported northwards relatively to ist subadjacent unit. Finally, the whole suite has been arched, forming the central area of culmination (fig. 16). All proposed explanations of this structure are based mainly on facies differences within the Jurassic-Cretaceous Bündnerschiefer and the inferred paleogeographic order of the facies types, as well as on the general attitude of folds. According to FRASL and FRANK (1966) four different facies zones can be distinguished. The original site of the first one, the Hochstegen facies (which was seen already at stop 2.3), is believed to have been north of the Brennkogel facies (subject of stop 3.3.), and the Glockner facies rocks (subject of stop 3.1. and 3.4.), which therefore occupy a higher tectonic position now. The Fusch facies situated originally in the southernmost part of the Penninic geosyncline is described in more detail on page 125.

A considerable part of the route traverses a regional transverse depression, the Glockner syncline, which is associated with complex folding about N-S-axes. In the north, however, these cross-folds are overprinted by younger longitudinal west-north-west axes.

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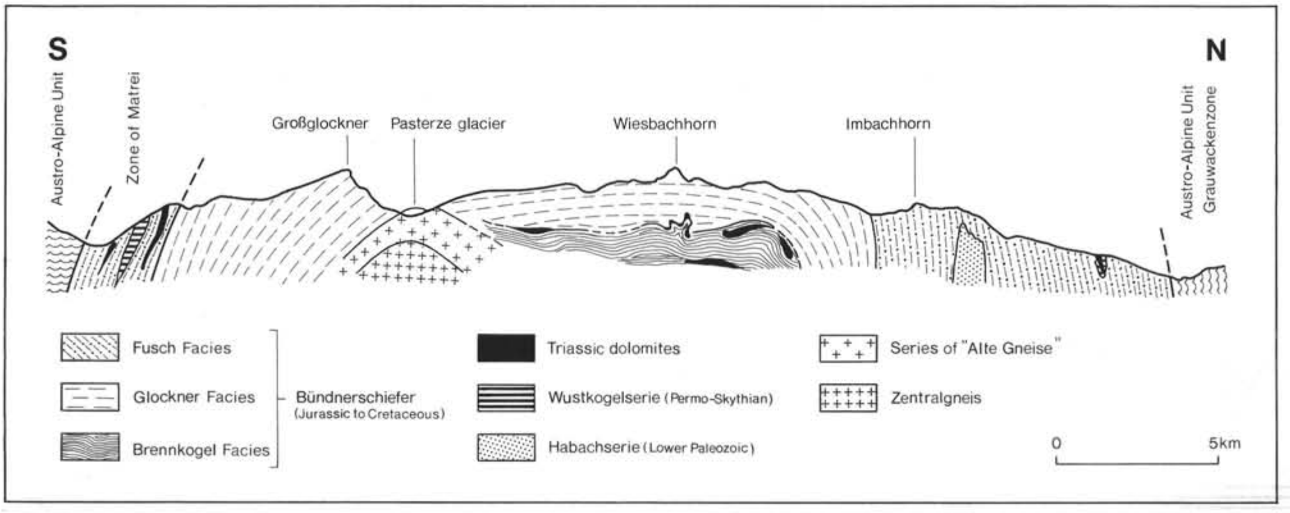

Fig. 16: Geological cross-section of the middle part of the Tauern Window (after W. FRANK, 1965).

On Alpine Metamorphism and Metamorphic Zoning in the Middle Part of the Tauern Window

(V. HÖCK)

The Penninic assemblage of the Tauern Window underwent Alpine syn- to posttectonic greenschist facies metamorphism. The grade of metamorphism increases towards the central parts. Concerning the metamorphism in the middle part of the Tauern Window, four significant rock-types of the Permomesozoic sequence are of interest:

1) Metabasic and ultrabasic rocks
2) Metapelites and metapsammites
3) Almost pure calcareous rocks and siliceous dolomites including dolomite-breccias and carbonate-quartzites
4) calcschists

Plagioclase is a common mineral in carbonate-free rocks. Based on increasing An-content an "oligoclase zone" can be delineated, bordered on both sides by an "albite zone" (fig. 15). Oligoclase (An 21—24) partly mantles albite, partly coexisting as distinct grains with almost pure albite (An 0—2) similar to that discribed by CRAWFORD (1966) and STRECKEISEN and WENK (1974). These plagioclases are covering the peristerite gap and their coexistence may serve as an isograde.

The increase of An-content can be attributed mainly to a breakdown reaction of epidot in all areas (HÖCK and ZIMMERER, 1978). The contribution of amphibole to the oligoclase formation in prasinites is not yet clear; preliminary investigations by HÖCK and ZIMMERER (1978) indicate neither systematic core/rim variation of amphibole composition with respect to their Na_2O and CaO content nor significant changes in modal abundance of amphibole and plagioclase. In pelitic rocks kyanite is widely distributed and often associated with chloritoid. It is not restricted to the area of higher temperature i. e. the field of garnet (see below) and oligoclase. Pyrophyllite, as the potential precursor of kyanite, has not yet been detected as a constituent of the country rock. Chloritoid is found all over the Tauern Window whereas stilpnomelane is restricted to some rocktypes in the northernmost part of the Tauern Window.

The most interesting feature is the first appearance of garnet in pelitic schists in the middle part of the Hohe Tauern. The shape of the area of garnet occurrence ("garnet zone") is very similar to the distribution field of oligoclase in metabasic rocks (fig. 15), especially in the northern part. Because of the complex composition of the garnet and its large chemical variability (CLIFF et al, 1971; HÖCK, 1974) no reaction leading to the formation of garnets expressing a "garnet isograde" in pelitic rocks has been formulated so far. The distribution pattern of garnet, however, indicates the existence of such an isograde.

Triassic dolomites and siliceous carbonate rocks within the Bündnerschiefer Series, like carbonate-quartzites and dolomite breccias often contain the assemblage tremolite + quartz + calcite + dolomite, accompanied by zoisite or clinozoisite. This indicates a low XCO_2 during metamorphism. Diopside occurs in some carbonaceous rocks around several serpentinite bodies together with tremolite/actinolite, dolomite and calcite. This assemblage can be stable at the same temperature as tremolite + quartz + dolomite + calcite, but only with a gas phase poor in CO_2, which may be caused by the adjacent serpentinite bodies, acting as external reservoir for a water-rich gas phase (HÖCK, 1977).

The metamorphism of the calcschists in the middle part of the Hohe Tauern can be described within the six-component system CaO — Al_2O_3 — MgO — SiO_2 — CO_2 — H_2O by the six-phase assemblage calcite + dolomite + chlorite + margarite + zoisite (clinozoisite) + quartz — the "margarite-isograde" and the assemblage calcite + dolomite + chlorite + garnet + zoisite (clinozoisite) + quartz, which is the so called "garnet-isograde" (HÖCK and HOSCHEK, 1980).

Biotite is almost completely missing in the calcschists here, but is ubiquitous in the western and eastern part of the Hohe Tauern. The temperature of metamorphism is estimated to have reached about 500° C, based on the calcite-dolomite geothermometry (BICKLE and POWELL, 1977). A minimum pressure of 4—6 kb is inferred from the abundant occurrence of kyanite according to the experimental results by ALTHAUS (1967), RICHARDSON et al. (1969) and HOLDAWAY (1971).

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The following comments regarding the route and the excursion stops within the Tauern Window are given by V. HÖCK.

Route description: Zell/See stands near the southern margin of the Grauwackenzone. The slopes east and west of Zell/See show black phyllites of early Palaeozoic age with minor intercalations of diabases. In Bruck an der Glocknerstraße the route crosses the Salzach Longitudinal Fault and the associated mylonite zone which is responsible for the east-west trending course of the upper Salzach valley. Then the route continues southwards upstream the Fusch valley and enters the Penninic realm of the Tauern Window.

The northernmost part of the Tauern Window culmination consists of Bündnerschiefer of Fusch facies type, i. e. dark phyllites, metaarcoses, calc-schists, quartzites, dolomite breccias, basic metavolcanic rocks and occasionally serpentinites. The lithology of the Fusch facies is similar to the Brennkogel facies. Only metabasic rocks are much more widespread. Magmatic relics of clinopyroxene and sometimes brown amphiboles are common. Chemical composition of some meta-volcanics reveals affinities to alkalibasalts (tab. 6). Approximately 4,5 km south of Bruck an old abandoned talc mine is related to a serpentinite body.

	Fusch Facies		Glockner Facies		
	54/70	109/76	50/71	143/70	99/74
SiO_2	48,24	43,70	49,36	46,11	50,23
TiO_2	1,79	1,29	1,30	1,17	1,66
Al_2O_3	18,45	14,66	16,20	16,63	15,77
Fe_2O_3*)	10,22	8,69	8,81	9,18	10,05
MnO	0,13	0,20	0,15	0,16	0,15
MgO	6,12	5,28	7,27	6,67	7,10
CaO	7,13	12,53	11,40	13,04	9,66
Na_2O	4,01	3,88	2,40	2,29	3,88
K_2O	0,06	0,01	0,07	0,22	0,07
P_2O_5	0,23	0,21	0,12	0,11	0,16
H_2O**)	n. d.	9,06	2,44	5,19	1,92
Total	96,38	99,51	99,52	100,77	100,65

*) Fe_2O_3 as total iron; **) Ignition loss; 54/70 Wolfbach valley; 109/76 Großarl valley; 50/71 Heiligenblut; 143/70 Franz Josef Haus; 99/74 Möll valley.

Tab. 6: Chemical composition of some meta-basic rocks of the middle part of the Tauern Window.

Stop 3.1. Bärenschlucht south of Fusch

Penninic Zone, Bündnerschiefer, Glockner Facies
Top. sheet 153 Glockglockner

Calc-schists of the Glockner facies are exposed in an old quarry (960 m). They represent the northern part of the huge mass of calc-schists which make up the western slope of the Fusch valley. S-planes dip generally steeply to the north, but are sometimes overturned to the south. Calcite, dolomite, chlorite, phengite, paragonite, margarite, quartz and zoisite are the most characteristic minerals. Unfortunately most of them are very small, thus they cannot be detected with the naked eye. From a petrological point of view the coexistence of phengite + paragonite + margarite should be noted here. The six-phase assemblage dolomite + calcite + quartz + margarite + zoisite + chlorite may serve as an isograde within the calc-schists (margarite isograde, cf. HÖCK and HOSCHEK, 1980) (fig. 15). Frequently observed black dots (1—2 mm in diameter) consist of zoisite, calcite and sometimes chlorite filled with graphite. They are interpreted as pseudomorphs after lawsonite (cf. HÖCK, 1974).

More information about Bündnerschiefer of Glockner facies type will be given at stop 3.4.

Geological map and references (see stop 3.4.)

Route description: At the toll station in Ferleiten the road leaves the bottom of the valley and winds uphill on the west facing slope. This slope consists mainly of Bündnerschiefer of Brennkogel facies type, dark, sometimes calcareous phyllites intercalated with white and grey quartzites. Between the curves 8 and 9 of the road at an elevation of approximately 2000 m we are entering an area called "Hexenküche", which means "kitchen of a witch", because of strange forms caused by a landslide of Upper Triassic to Liassic tourmaline- and fuchsite-bearing quartzites and chlorite-chloritoid schists.

Approaching the summit of the Fuscher Törl the road crosses Triassic dolomites, marbles and rauhwacke with occasional gypsum.

Stop 3.2. Fuscher Törl — Edelweißspitze

Penninic Zone, Seidlwinkl Triassic, Panoramic View
Top. sheet 153 Gloßglockner

The upper part of the Seidlwinkl Triassic can be studied her (fig. 17). The dolomites, marbles and associated rocks of the Seidlwinkl Triassic represent the largest occurrence of Triassic rocks within the Penninic Zone of the Tauern Window. They are named after the Seidlwinkl valley next to the east. It is in stratigraphic contact with the underlying Permoskythian Wustkogel Series and with the overlying Jurassic Bündnerschiefer of Brennkogel facies type described at stop 3.3. The whole assemblage is considered to be an individual thrust-sheet forming a recumbent fold with an amplitude of about five kilometers (fig. 16). This so-called Seidlwinkl nappe is allocated to the Lower Schieferhülle Unit. Sporadic occurrences of dolomite pieces (?Triassic) at the boundary to the overlying Bündnerschiefer of Glockner facies type (cf. stop 3.4.) are believed to indicate

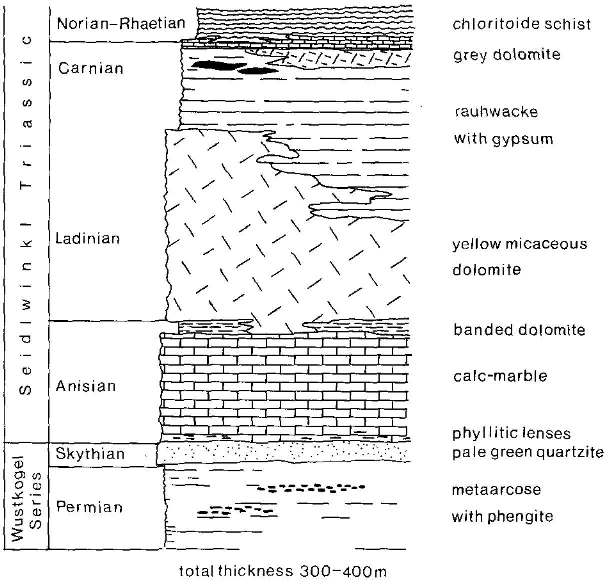

Fig. 17: Columnar section of the Wustkogel Series and the Seidlwinkl Triassic (after W. FRANK, 1964).

a tectonic level separating the underlying Seidlwinkl nappe from the overlying Upper Schieferhülle Unit.

Stop 3.2. is situated at the eastern side of the Glockner transverse depression. Complex folding about N-S-axes can be observed. In the carbonate rocks sometimes synclines of chloritoid schists or dark kyanite quartzites and quartzitic schists can be found. Quartzites interbedded with thin layers of chloritoid schists are exposed immediately below the Dr. Franz-Rehrl-Haus at the Fuscher Törl. These quartzites consist of chlorite, bluish-grey chloritoid, quartz, magnetite and hematite. The trail from the Fuscher Törl parking place up to the Edelweißspitze (sometimes called Leitenkopf, 2577 m) is crossing the middle-Triassic yellow dolomite.

Immediately north of the Edelweißspitze black quartzites and quartzitic schists with black needles of kyanite ("Rhätizit") and dark chloritoid are exposed. The black colour of kyanite and chloritoid is caused by graphitic inclusions. Those quartzites represent parts of the Upper Triassic to Liassic cover of the Middle-Triassic dolomites and limestones of the Seidlwinkl-Triassic.

The panoramic view from the Edelweißspitze offers a magnificent insight to the tectonic structure of the Seidlwinkl nappe and the Upper Schieferhülle Unit. Looking to the east, both limbs of the large recumbent fold of the Seidlwinkl nappe are exposed on the west-facing flanks of the Seidlwinkl valley. The central parts of this fold, consisting of the Permoskythian Wustkogel-Series, is enveloped by the Seidlwinkl Triassic and Bündnerschiefer of Brennkogel facies type. The light-coloured carbonate rocks of the Seidlwinkl Triassic occupy the adjacent summits north of the Edelweißspitze and are visible to the south in the area of the Wustkogel and as far as to the ridge east of the Hochtor. The Brennkogel in the south gives the name to the mentioned Bündnerschiefer facies type. The section of the road between the Fuscher Törl and the Hochtor can be roughly taken as the boundary between the Seidlwinkl Triassic and the Bündnerschiefer of Brennkogel facies type. The valley head of the Fusch valley in the southwest and the upper part of the western flank of the Fusch valley are mainly occupied by calc-schists of the Bündnerschiefer of Glockner facies type forming here the Upper Schieferhülle Unit (fig. 16). The axis of the Glockner transverse depression can be assumed roughly to follow the impressive mountain rigde Fuscherkarkopf — Gr. Wiesbachhorn — Hoher Tenn in the west the summits of which almost each exceeds the elevation of 3000 m. The lower parts of the western flanks of the Fusch valley consist of Bündnerschiefer of Brennkogel facies type. To the north the calc-schists of the Upper Schieferhülle Unit gradually steepen and finally reach the valley floor at the Bärenschlucht (stop 3.1.).

G e o l o g i c a l m a p and r e f e r e n c e s (see stop 3.4.)

R o u t e d e s c r i p t i o n: From the Fuscher Törl the route continues southwards passing by the Brennkogel. Above the road level the slope of Brennkogel consists of black phyllites with calcite, dolomite, zoisite, margarite, paragonite, chlorite and chloritoid, intercalated with quartzites. The serpentinite body in the eastern flank of the Brennkogel can be clearly distinguished from the country rock by its green colour. Near the Fuscherwegscheide the sign "Knappenstube" indicates the entrance to an old, medieval goldmine tunnel.

Stop 3.3. Hochtor Pass

Penninic Zone, Bündnerschiefer, Brennkogel Facies
Top. sheet 154 Rauris

From the parking place north of the Hochtor tunnel we ascend to the Hochtor Pass (2575 m) where a section of the Bündnerschiefer of Brennkogel facies type can be studied (fig. 18).

The Brennkogel facies is characterized by abundant clastic rocks. The prevailing dark phyllites and mica-schists (often with garnet) are frequently interbedded by white or grey quartzites, carbonate quartzites, highly deformed dolomite-breccias with elongated components and either quartzitic or carbonatic matrix, and meta-arkoses (also "Bündnerschiefergneise", G. FRASL, 1958). Calc-schists and metabasic rocks are of minor importance. Most of these rock-type can be found in the Hochtor Pass area.

The light-coloured carbonate rocks of the Tauernkopf east of the Hochtor Pass represent the top of the Seidlwinkl Triassic, upon which the westwards dipping sequence of Brennkogel facies rocks is following. Note the appearance of garnet-mica-schists instead of phyllites on the ridge ascending westwards to the Gr. Magrötzenkopf (2737 m). There are also several garnetiferous prasinite drift blocks on the Hochtor saddle. As already mentioned above, the presence of garnets in pelitic schists indicates a garnet field similar to the distribution of the oligoclase zone (fig. 15).

Stop 3.4. Franz Josefs-Haus

Penninic Zone, Bündnerschiefer, Glockner Facies
Top. sheet 153 Gloßglockner

Calc-schists and green meta-basic rocks, both of remarkable thickness, are the significant and prevailing rock types of the Glockner facies assemblage. Minor

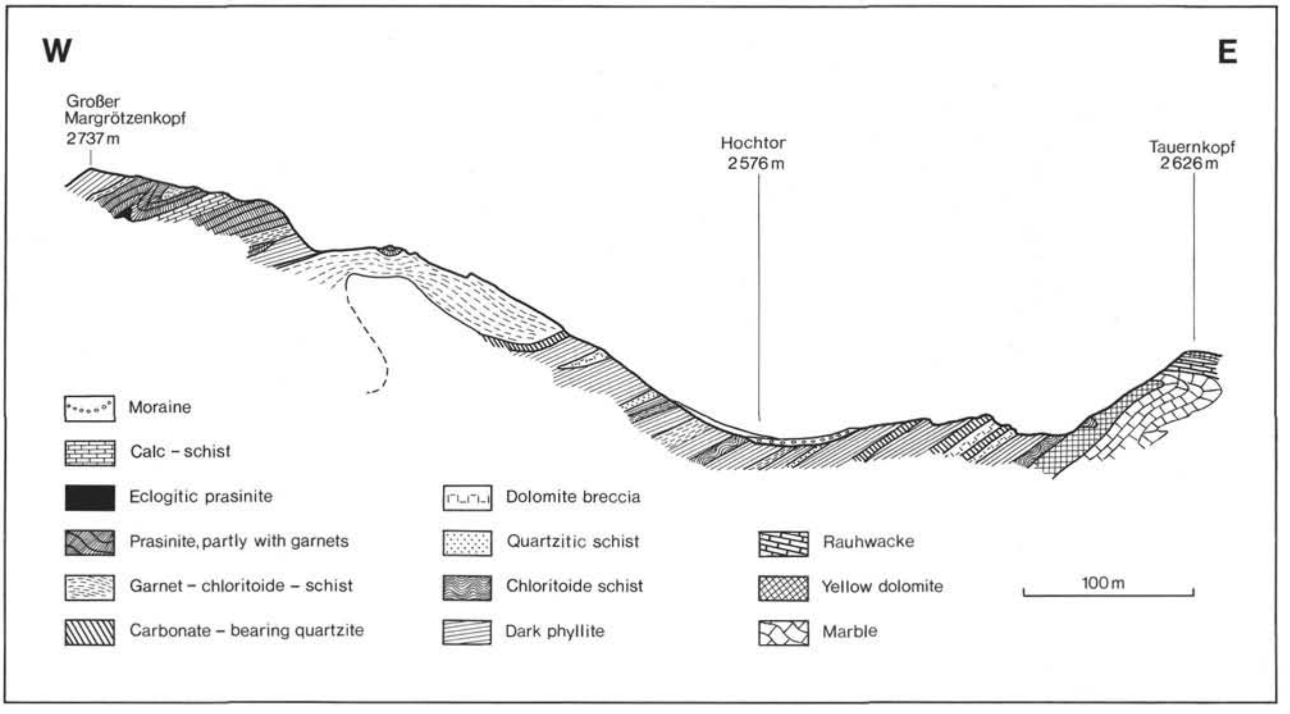

Fig. 18: Geological cross-section of the Brennkogel facies assemblage in the Hochtor area (after H. P. CORNELIUS and E. CLAR, 1939).

G e o l o g i c a l m a p and r e f e r e n c e s (see stop 3.4.)

R o u t e d e s c r i p t i o n: From the Hochtor Pass southwards the route descends into the Möll valley and at first crosses a suite of Brennkogel facies rocks (black phyllites and mica-schists, quartzites, serpentinites). Not only from the orographic but also from the structural point of view we are already on the southern side of the Tauern Window culmination. The summits on top of the opposite flanks of the Möll valley are formed by crystalline rocks of the Austro-Alpine Unit and mark the southern border of the Tauern Window.

In the Guttal we leave the main-road and take the side road to the Franz Josefs-Haus. Immediately after this road junction we enter the Upper Schieferhülle Unit and cross an assemblage of Glockner facies rocks such as calc-schists, serpentinites and prasinites.

occurrences of phyllites, and garnet-mica-schists as well as serpentinites are locally interbedded. The basic and ultrabasic rocks partly represent an ophiolitic suite, which is tectonically highly dismembered. There are only few localities where the original sequence of serpentinite-metagabbro-metabasalt can be recognized (e. g. east of Stubach valley). Usually the green metabasic rocks here are termed prasinites comprising metamorphic rocks mainly of basic origin, consisting of albite/oligoclase, epidote, actinolitic amphibole and epidote with various amounts of chlorite. These meta-basalts and leucocratic meta-gabbros of the Glockner facies exhibit a chemical composition of tholeiites (tab. 6) with normative hypersthene or sometimes even normative quartz. Analyses of trace elements Zu, Nb, Y, Ti (BICKLE & PEARCE, 1975; HÖCK and MILLER, 1980) confirm the assumption of ocean floor affinities for the meta-basalts of the Glockner facies assemblage.

A major body of prasinites crops out in the area around the Franz Josefs-Haus. They consist of albite, with additional oligoclase and amphiboles, which are mainly complex solid solutions between a tremolite and a tschermatitic end member with some contribution of a Na-amphibole end member like glaucophane or pargasite. The amphiboles are generally zoned with increasing Al and Fe towards the rims whereas in the zoned epidots only Al increases from the core to the rim while Fe^{3+} decreases. Clorite and sphene are always present.

We walk from the bus-parking-place northwestwards and take the path towards the Hoffmannshütte. This path begins through a small tunnel. At first we are crossing prasinites of the Freiwand, which occasionally contain light pseudomorphs with rhombohedral outlines. These consist of clinozoisite with some chlorite and are believed to be pseudomorphs after lawsonite indicating an early high pressure phase during the metamorphic evolution of the Tauern Window.

The trail continues through banded, micaceous marble alternating with zones of prasinites and small interlayers of carbonate-bearing garnet-mica-schists. Apart from calcite, quartz and dolomite the carbonaceous rocks consist of phengite, sometimes margarite, zoisite and chlorite. Pseudomorphs after lawsonite are also found as small dark dots in the calc-schists, similar to those from the quarry in the Bärenschlucht (stop 3.1.).

In the Gamsgrube "eclogitic prasinites" can be studied. Some omphacites and garnets are considered as relics of a previous eclogite which has been altered into prasinite during the Alpine metamorphism and support the above mentioned assumption of an early Alpine high pressure phase.

Calc-schists and prasinites are generally dipping SSE and are folded about N-S-axes. This can be observed near the Hoffmannshütte.

Along the whole path there is a magnificent view to the Pasterze (largest glacier in the Eastern Alps) and the Glockner mountain group. The Großglockner on the opposite side of the valley is mainly formed of prasinites.

Geological map

CORNELIUS, H. P. & CLAR, E. (1935): Geologische Karte des Großglocknergebietes. — 1 : 25.000, Geol. B.-A., Wien.

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Route description: The route continues down the Möll valley. In the section of the Möll valley between Heiligenblut and Döllach the Bündnerschiefer series are rather narrow upon a lamella of Zentralgneis in the valley floor and below the crystalline rocks of the Austro-Alpine Unit on top of the southwestern valley flanks. Immediately south of Döllach the route crosses the Matrei Schuppenzone which here is a few hundred meters thick. It represents a highly deformed and steeply southwards dipping zone comprising Penninic and Lower Austro-Alpine elements and marks the southern boundary of the Tauern Window. Then we enter the Austro-Alpine crystalline complex consisting here of quartz-rich mica-schists, various paragneisses, augen-gneisses, amphibolites and sporadic marbles. At Winklern we leave the Möll valley and take the road-branch towards Iselsberg which is a pass between the Möll valley and the Drau valley.

Stop 3.5. Iselsberg

Austro-Alpine Crystalline Complex, view of Lienzer Dolomiten mountains
Top. sheet 179 Lienz/180 Winklern

At the road-bend approximately 150 m west of the village of Iselsberg there are outcrops of two-mica paragneisses with oligoclase (inverse zoning), garnet and staurolite. In general the schistosity is steeply enclined striking west-east.

G. TROLL & al. (1976) support two phases of pre-Alpine metamorphism mainly based on studies of the eclogite-amphibolites occurring in the central part of the neighbouring Schober mountain group in the northwest from where some branches of the eclogite-amphibolites are reaching as far as the area of Iselsberg. The earlier metamorphic phase which at some place attained eclogite facies conditions is believed to be Caledonian.

The whole region between the Tauern Window to the north and the Periadriatic Lineament to the south underwent intensive Alpine compression. Sporadic occurrences (shales, quartz-conglomerates, fine-breccias, sandstones, quartzites) of questionable Palaeozoic resp. Permomesozoic age preserved in narrow synclines were chiefly found in the Kreuzeck mountain group neighbouring in the east.

Two diagonal fault systems intersect the Austro-Alpine Altkristallin in this region. Their pattern is depicted by the course of the main valleys. One ENE-WSW-striking fault is passing few kilometers east of our place over the Zwischenbergen Sattel. Another ESE-WNW-striking fault follows the Drau valley southeast of Lienz.

From a platform near the parking place after the road bend there is an impressive view of the Lienzer Dolomiten mountains in the south.

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Day 4

Western Drauzug, Southern Alps
Route: Lienz — Gailberg Sattel — Naßfeld — Nötsch — Windische Höhe Pass — Spittal/Drau

Introduction

The program of the fourth day is to demonstrate the geology of the southernmost part of Austria.

The Periadriatic Lineament is the most prominent structure in this region. It is associated with a mylonite zone of considerable width and makes a strong topographic feature following the east-west trending furrow of the Lesach valley and the Gail valley in the excursion area from where it can be traced for long distances in both directions. This fault system is believed to have played an important role in the structural evolution of the southern part of the Alps separating regions of different depositional and tectonic history during Palaeozoic and Mesozoic. Considerable dextral but also vertical displacements are supposed to have occurred along this structure during late Alpine times.

The Western Drauzug (Lienzer Dolomiten mountains, Gailtal Alps) to the north comprises an assemblage of crystalline, Palaeozoic and Mesozoic rocks. According to its position in a region of strong compression the beds are generally steeply inclined and supposed previous stratigraphic contacts are tectonized. The lithofacial features of the Permomesozoic suite are considered to be of an intermediate type between the North-Alpine and South-Alpine facies. Extensive Pb-Zn-mineralization of Carnian Beds (upper Wetterstein Limestone and lower Raibl Beds) has been worked extensively in the famous Bleiberg mine in the eastern part of the Gailtal Alps near Villach. The Carnic Alps as the northernmost part of the Southern Alps extend south of the Lesach and Gail valley.

Only a narrow marginal section of the Southern Alps is exposed in Austria comprising mainly Palaeozoic and less Mesozoic rocks. Variscan folding and thrusting and subsequent erosion separates two sedimentary cycles. The earlier cycle begins during the Ordovician and is terminated by the flyschoid Hochwipfel formation (Upper Carboniferous). The later cycle begins with the uppermost Carboniferous Auernig Beds and continues into the Mesozoic.

Route description: From Lienz we proceed down the broad glacial trough of the Drau valley. Between Oberdrauburg and Kötschach the route is crossing the Western Drauzug via Gailbergsattel. The road-sided outcrops on the northern side of the pass road exhibit strongly folded middle-Triassic limestones and dolomites steeply dipping north. Permoskythian conglomerates and sandstones crop out along the southern section of the pass road. After Kötschach the route continues eastwards downstream the Gail valley. Now and then outcrops of the Gailtal crystalline complex (micaschists, paragneisses, amphibolites) appear along the road. The south side of the valley is made of the Carnic Alps. Near Tröpolach we turn southwards and take the road to the Naßfeld Pass.

Stop 4.1. SE Tröpolach

South-Alpine Unit, Early Palaeozoic
Top. sheet 198 Weißbriach

Around the memorial of the construction of the Naßfeld pass road, appr. 1300 m southeast of Tröpolach, there are exposures of grey, banded Silurian-Devonian limestones steeply dipping north.

Weather permitting we can see the Permian/Triassic section of the Reppwand and the Gartnerkofel (fig. 19).

Route description: After passing Silurian to Lower Carboniferous Hochwipfel Formation the major part of the route continues in an extensive mountain slide area (Reppwand Slide).

Stop 4.2. Garnitzenberg (Naßfeld area, Carnic Alps) (A. FENNINGER) *)

South-Alpine Unit, Late Palaeozoic
Top. sheet 198 Weißbriach

General remarks

The Late Palaeozoic of the Carnic Alps shows its widest extent in the area around the Naßfeld and the Straninger Alm. The Carboniferous up to Westfalian

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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.

The Upper Carboniferous Auernig Group transgresses over the Carboniferous flysch (Hochwipfel Formation) characteristic elements of fauna and flora are dasycladaceans, rhodophyceans, fusulinids, small foraminifers, sphinctozoans, brachiopods, corals, conulariids, lamellibranchs, gastropods, bryozoans, trilobites, and echinoderms. Elements of terrestrial flora are abundant in single layers, predominantly in finer-clastic rocks. In accordance to the frequency and thickness of carbonates the Auering Group is divided into five formations (Heritsch et al., 1934) (fig. 21). Selli 1963 registered

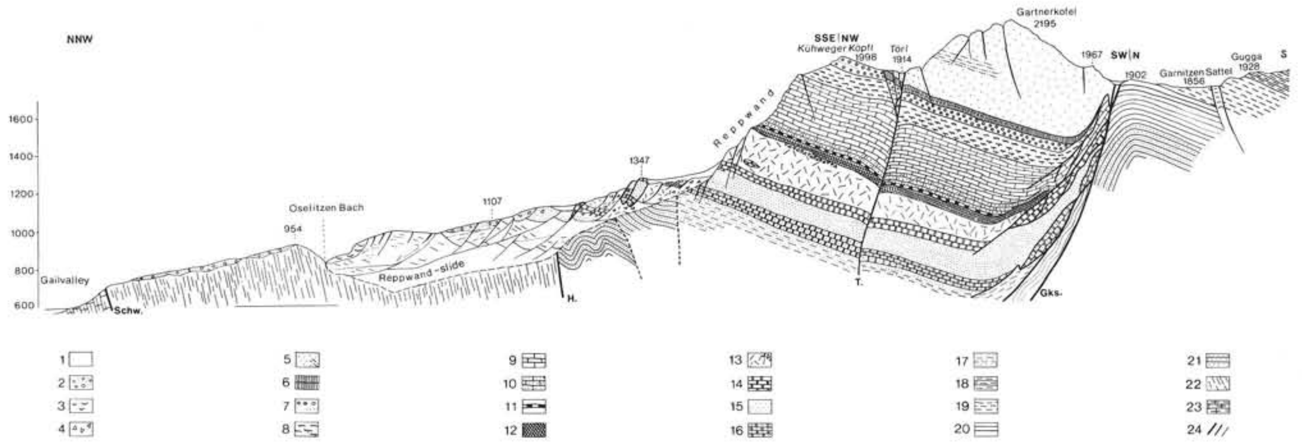

Fig. 19: Reppwand-Gartnerkofel section in the Carnic Alps (F. Kahler & S. Prey, 1963). 1 = Talus, Alluvium, Landslip debris; 2 = Moraine deposits; 3 = Landslides; 4 = Rock masses decomposed to blocks; 5 = Schlern Dolomite with calcareous layers; 6 = Muschelkalk with tuff band; 7 = Muschelkalk conglomerate with tuff band; 8 = Werfen Beds, locally in Plattendolomit facies; 9 = Bellerophon Dolomite; 10 = Slates, rauhwackes and dolomites; 11 = Bituminous dolomite; 12 = Gröden Beds; 13 = Trogkofel Limestone and Tarvisio Breccia; 14—16 = Rattendorf Beds; 14 = Upper Pseudoschwagerina Limestone; 15 = Grenzland Beds; 16 = Lower Pseudoschwagerina Limestone; 17—21 = Auernig Beds; 17 = Upper calc-poor group; 18 = Upper calc-rich group; 19 = Middle calc-poor group; 20 = Lower calc-rich group; 21 = Lower calc-poor group; 22 = Hochwipfel Beds; 23 = Early Palaeozoic banded limestone; 24 = Faults, joints; Schw = Schwarzwipfel Fault; H = Hochwipfel Fault; T = Törl Fault; Gks = Gartnerkofel-South-Side-Fault.

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 inner-shelf facies which gradually passes into a carbonate platform (Rattendorf Group, Trogkofel Limestone, Tressdorf Limestone). Synsedimentary tectonic activities at the Lower/Middle Permian boundary led to a destruction of this carbonate platform. Conglomerates and breccias were deposited in local depressions (Tarvis Breccia). The Alpine cycle starts in the Middle Permian with the clastic Gröden Formation which is in the Carnic Alps 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. 20).

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 these lithologic names and proposed formational designations based on local (topographic) names. The correlation is shown in the following table.

Heritsch et al. 1934	Selli 1963
Upper "kalkarme" Formation	Formazione del Carnizza
Upper "kalkreiche" Formation	Formazione del Auernig
Middle "kalkarme" Formation	Formazione del Corona
Lower "kalkreiche" Formation	Formazione del Pizzul
Lower "kalkarme" Formation	Formazione del Meledis

The Lower "kalkarme" Formation in the Naßfeld area is sparsely exposed. It is typically developed however in the area of the Straninger Alm (Waschbühel Section) and famous of the Waidegger Fauna (Gauri, 1965). 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 overlie 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 cylothems, 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. 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 of 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 appeareance of *Pseudoschwagerina alpina*. Thus the first unit of Asselian is the Lower Pseudoschwagerina Limestone. The evolution of the flora corresponds with the fusulinid stratigraphy.

The excursion route is only crossing one part of the Garnitzen Section (fig. 22), 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.

Description of the outcrops

a) Top-station of the Gartnerkofel chair-lift, Pt. 1902.

The limestones and marls, which belong to the upper parts of the Lower "kalkreiche" Formation, can be divided into three horizons: a basal pebbly, sometimes dolomitic limestone, a middle layer consisting of marls, and an upper crinoidal breccia. The fauna was identified 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 sphinctozoan 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.

The limestones and marls mentioned above are overlain by partly carbonatic sandstones and mica-rich

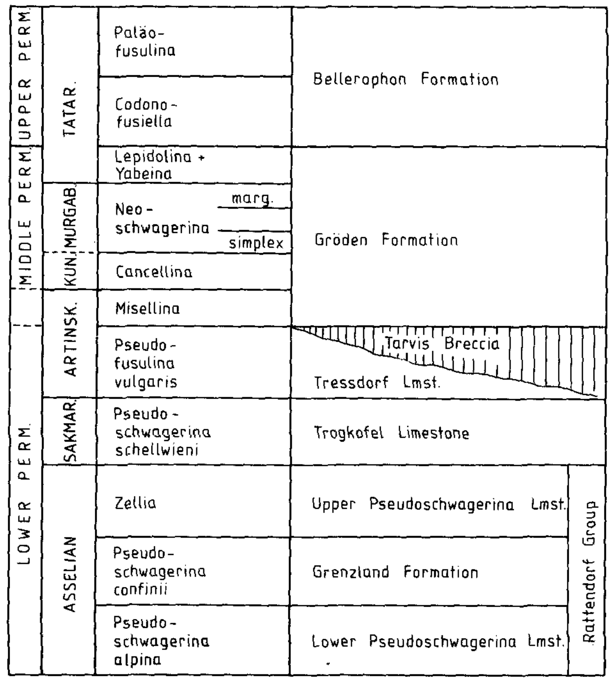

Fig. 20: Fusulinid stratigraphy of the Permian, Naßfeld Area (according to KAHLER, 1974; BUGGISCH et al., 1976).

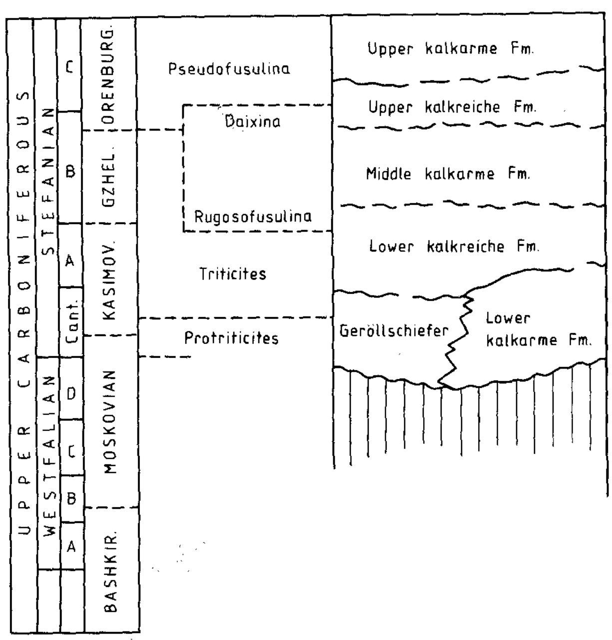

Fig. 21: Fusulinid stratigraphy of the Auernig Group (according to FRANCAVILLA & VAI, in press).

shales containing *Isogramma paotechowensis*. Moreover one can find:

Orbiculoidea, *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 reaches up to the Permian. GORTANI 1924 described *Orthothetes expansus* which seems to be a younger synonym of *Isogramma paotechowensis*.

Orthida indet., *Linoproductus* cf. *cora* (d'ORB), Rhynchonellida indet., *Phricodothyris* ? sp.

c) Flora, 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, Pecopteris unita, Pecopteris hemitelicides, Pecopteris (?) *obliquenervis, Pecopteris* sp.,

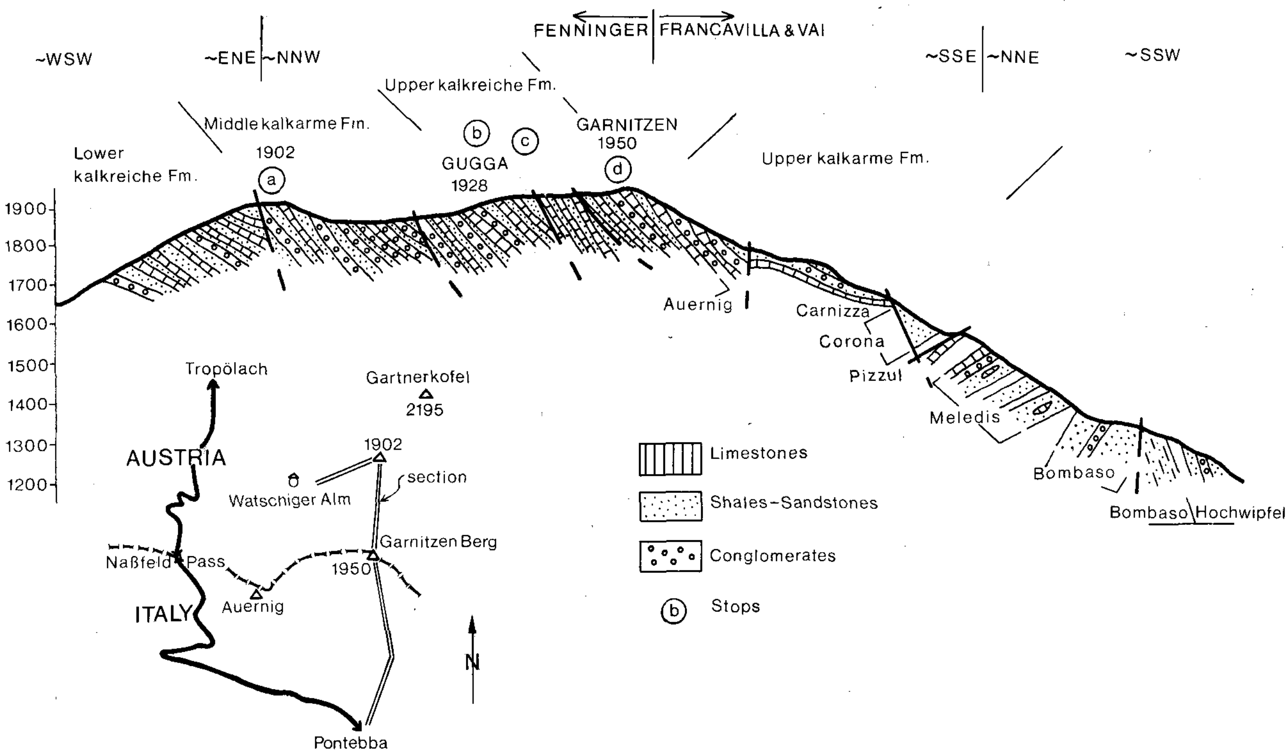

Fig. 22: The Garnitzen Section (simplified)

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.

b) Gugga, Upper "kalkreiche" Formation.

Beginning with the Upper "kalkreiche" Formation the conditions of exposure become 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:

Crossotheca sp., fructifications comparable *Acitheca, Odontopteris brardii, Alethopteris subelegans, Cordaites* cf. *borassifolius, Cordaites* sp., *Rhabdocarpus* sp., ? *Frigonocarpus* sp., *Annularia sphenophylloides, Sigillariophyllum* sp.

d) Garnitzenberg

Following the path to the Garnitzenberg we cross algae-rich marls (mainly with *Antracoporella spectabilis* and phylloid algae). Beside the algae one can find:

Enteletes lamarckii (FISCHER v. WALDH.), Strophomenida indet., *Urustenia* sp., *Protegulifera* ? 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.), *Neo-*

spirifer 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 we can see above mentioned marls bearing: *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.

Geological map

KAHLER, F. & PREY, S. (1959): Geologische Karte des Naßfeld-Gartnerkofel-Gebietes in den Karnischen Alpen. — Geol. B.-A., Wien.

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Route description: Returning to the Gail valley the route continues eastwards down the Gail

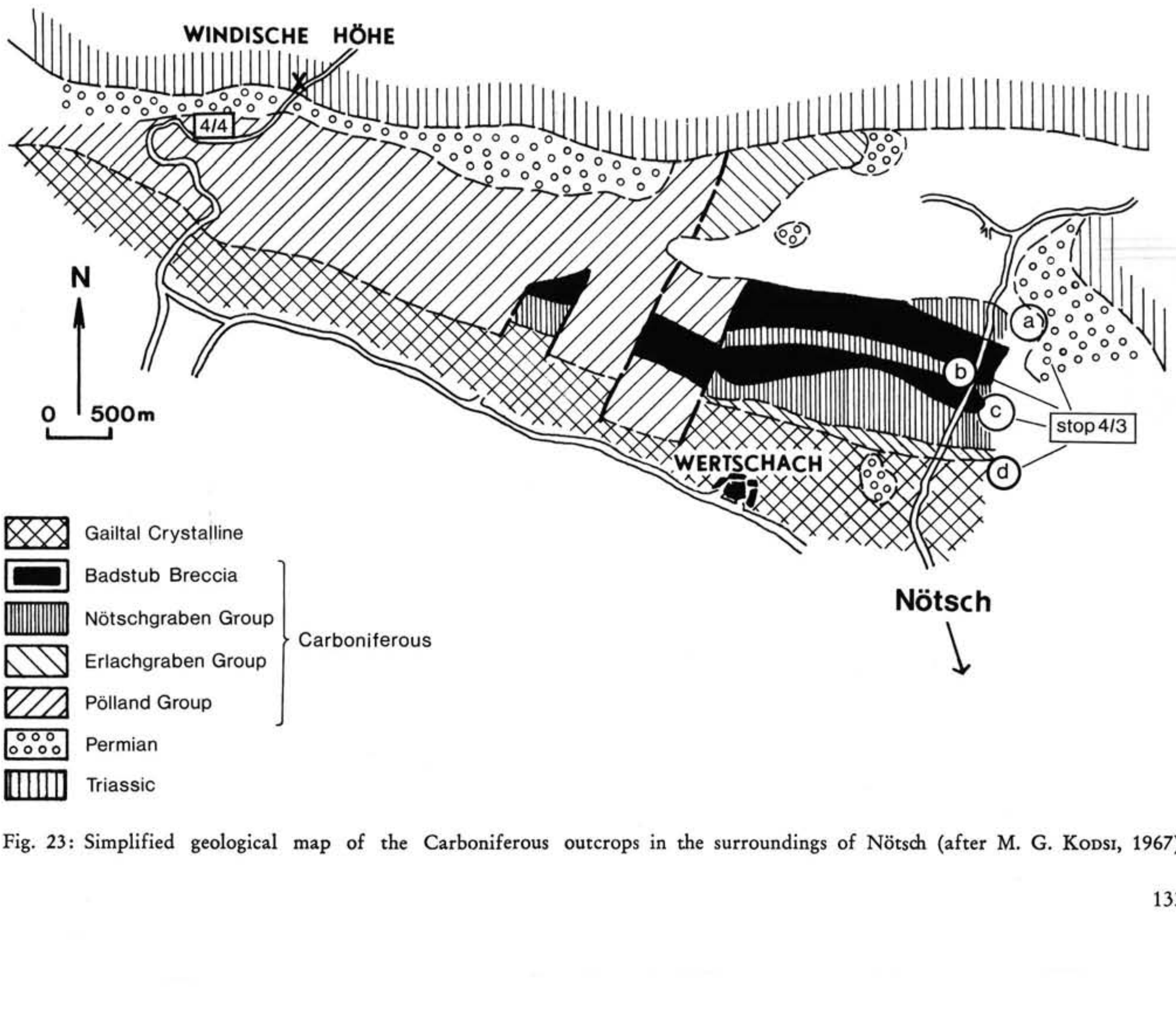

Fig. 23: Simplified geological map of the Carboniferous outcrops in the surroundings of Nötsch (after M. G. KODSI, 1967).

	Nötschgraben Group	Erlachgraben Group	Pölland Group
Lithology	Shales, siltstones, impure limestones, volcanics (tuffs, tuff-breccias), conglomerates, sandstones	dark micaceous sandstones, conglomerates, siltsones	conglomerates sandstones siltstones
Fauna and flora	Brachiopods, solitary corals, bryozoans, bivalves, trilobites cephalopods, Foraminifera, crinoids, algae	plant remains (*Archaeocalamites*, *Calamites*, *Gymnoneuropteris*, *Bowmanites*, *Pecopteris*)	plant remains (*Pecopteris*, *Alloiopteris*, *Calamites*, *Asterophyllites*)
Trace fossils	*Zoophycos*	*Zoophycos*	*Nereites*, *Lophoctenium*, *Phycosiphon*, *Dictyodora liebeana*
Environment	Shallow coastal	shallow water with strong terrigenuous influence	deep water (?)
Age	Viséan	Namurian	Westfalian A — Stefanian (?)

Tab. 7: Fossils and rock-types in the Carboniferous of Nötsch (after M. G. Kodsi & H. W. Flügel, 1970).

valley between the Gailtal Alps in the north and the Carnic Alps in the south. At the village of Nötsch it turns towards north into the Nötschgraben.

The Carboniferous of Nötsch

(H. P. Schönlaub) *)

(Introduction to the stops 4.3. and 4.4.)

North of the village Nötsch outcrops of Carboniferous age are exposed which belong to a tectonically isolated block the size of which can now be traced over an area of 8 × 2,5 km. Most of the Lower and Upper Carboniferous sediments and volcanics, however, are covered by glacial deposits. Tectonically, this sequence may be regarded as the original molasse-type cover of crystalline rocks north of the Gail valley; its link with the Permo-Mesozoic of the Drauzug has been a matter of discussion for even longer times (fig. 23).

Due to the abundance of fossils the Carboniferous outcrops have been known since 1807. Hence, various fossil-groups have been repeatedly studied, for example, brachiopods, trilobites and corals (see summary by H. P. Schönlaub 1979: 63). In addition, more recently an analysis of the lithofacies has been carried out which resulted in the recognition of three bio- and lithostratigraphically defined groups (see table 7):

The Nötschgraben Group is almost 500 m thick and consists of siltstones, shales, impure limestones and two volcanic horizons (= "Badstub-Breccia"). They are conformably overlain by shales, sandstones and conglomerates.

Fossils have been reported from several horizons below and above the volcanics. The fauna is dominated by brachiopods, but also corals, bivalves, bryozoans a. o. occur suggesting a younger Visean age for the major part of these rocks.

The Erlachgraben Group is a series of dark sandstones and shales with intercalations of conglomerates. According to rare plant remains its age might be Namurian. Typical exposures of the Erlachgraben-Group are tectonically separated from strata belonging to the above mentioned Nötschgraben Group. However, rock similarity and the flora at the locality Erlachgraben suggest that the uppermost Nötschgraben Group and the Erlachgraben Group are identical. Both groups can be characterized as a very shallow water environment with more or less strong terrigenous influence.

Rocks of the Pölland Group are exposed in the western part of the region. This group mainly comprises sandstones and conglomerates and to a minor extent siltstones. The only fossils in these rocks are very rare plant remains which indicate a Westfalian or early Stefanian age. According to trace fossils such as *Dictyodora liebeana*, the Pölland Group reflects a deep water environment and thus contrasts with the two older groups.

Stop 4.3. Nötschgraben

Austro-Alpine Unit, Carboniferous of Nötsch, Nötschgraben Group, Gailtal Crystalline
Top. sheet 200 Arnoldstein

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The excursion begins in the north and continues down the Nötschgraben (see fig. 24).

a) Roadcut Hermsberg

At this locality south-dipping shales and calcareous beds represent the lowermost part of the continuously exposed Nötschgraben Group. Close to this outcrop on the northern flank of the "Lärchgraben" another very fossiliferous exposure has been known for long which according to goniatites belongs to the Granosus Zone of Upper Visean. However, this locality is separated from the roadcut here by a prominent fault.

separates two breccia-bearing moderately bedded greenish rocks. The nature and genesis of these rocks have been debated for almost a century long.

Components of the dark green breccia are poorly sorted amphibolites, white and reddish marbles, quartzites, quartz, granite and red slates. The matrix of the breccia as well as the rock itself consists of microcrystalline plagioclase, quartz, hornblende and chlorite.

Most probably the Badstub Breccia is of volcanic origin assuming a submarine volcanic eruption during which crustal rocks and parts of the roof were incorporated into mostly basic material.

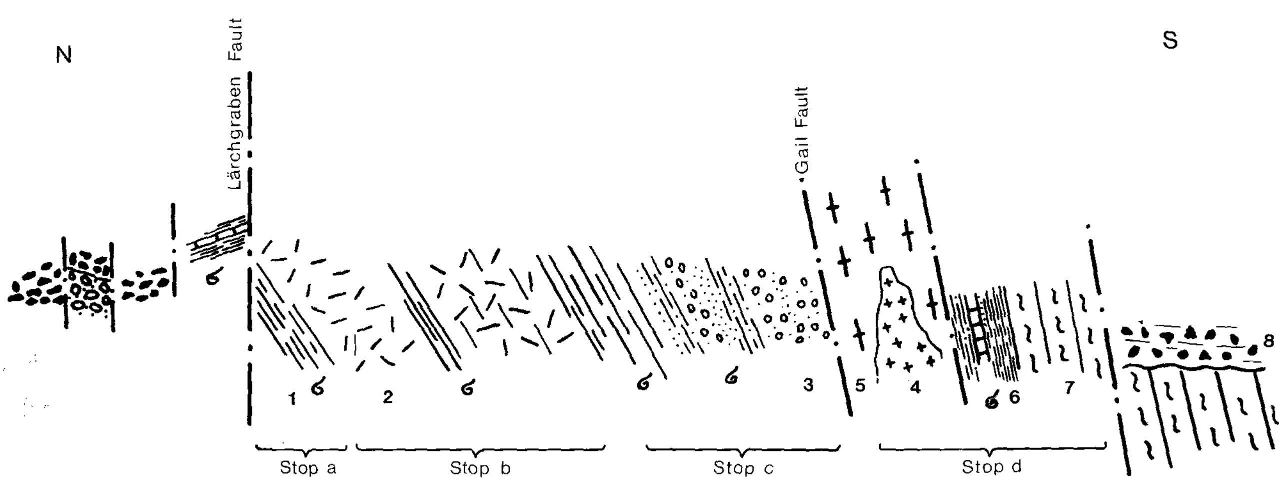

Fig. 24: Schematic section along the Nötschgraben (length of the section appr. 2,5 km). 1 = shale; 2 = Badstub Breccia; 3 = Conglomerates; 4 = Nötsch Granite; 5—7 = Gailtal Crystalline; 5 = Amphibolite; 6 = Graphitic slates with limestone interlayers; 7 = Quartz-phyllite; 8 = Permian.

The abundant and highly diversified fauna consists mainly of rugose corals, brachiopods, bivalves, forams and algae. M. G. Kodsi found that most of the productids are in life-position. The fauna clearly demonstrates a Visean age. Yet precise assignments within that stage cannot be made.

Allorisma sp., *Hexaphylla mirabilis* (Duncan), *Tetrataxis* sp., *Endithyrella* sp. ?, *Limipecten dissimilis* (Fleming), *Pernopecten phillipsi* (Goldf.), *Solemya* (J.) *privaeva* Phill., *Pinna* (P.) *flabelliformis* Martin, *Cypricardella rectangularis* (McCoy), *Cypricardella selysiana* (Koninck), *Edmondia sulcata* (Phill.), *Sanguinolites abdenensis* Etheridge, *Sanguinolites plicatus* (Port.), *Loxonema* sp., *Uralopora* sp., *Girvanella* sp., *Koninckopora* sp., *Osagia* sp., *Isogramma carinthiaca* Aigner, *Isogramma* cf. *germanica* Paeckelmann, *Isogramma paeckelmanni* Aigner & Heritsch, *Alitaria* sp., *Buxtonia* sp., *Gigantoproductus* sp., *Semiplanus* sp., *Brachythyris* sp.

b) Jakomini quarry, Badstub Breccia

On the north side of the quarry the 15 m thick fossiliferous "Zwischenschiefer" (brachiopods, solitary corals)

According to H. W. Flügel 1972 the coral fauna of the Zwischenschiefer belongs to the Dibunophyllum Zone (= Visé 3 b).

c) South of the bridge (Pt. 721) across the Nötschgraben.

At this stop the upper members of the Nötschgraben Group are exposed attaining a thickness of more than 100 m. They comprise dark grey micaceous shales, sandstones and more than 1 m thick beds of quartzconglomerates. Fossils are rare throughout this part and this make it difficult to find the exact boundary between Visean and Namurian strata.

Finally, the tectonic contact between the Carboniferous sediments and the cataclastic Hercynian (?) Nötsch granite with the surrounding banded amphibolites will be visited.

d) Pt. 719 at the bridge.

At this locality the contact between granites and amphibolites to the north and quartzphyllites of the Gailtal Crystalline to the south will be studied. Interestingly, in the quartzphyllites up to 30 m thick graphitic slates with intercalations of dolomitic limestones occur. The small outcrop near the bridge yielded conodonts (*Neopanderodus* sp., *Ozarkodina remscheidensis* ssp.) of Upper Silurian or Lower Devonian age (H. P. SCHÖNLAUB 1979).

Geological map

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Route description: We leave the Nötschgraben and take the road to the Windische Höhe Pass.

Stop 4.4. Windische Höhe Pass

Austro-Alpine Unit, Carboniferous of Nötsch, Pölland Group
Top. sheet 199 Hermagor

This sedimentologically interesting roadcut over a length of 500 m west of the Windische Höhe Pass exhibits typical strata of the Upper Carboniferous "Pölland Group". The section comprises conglomerates, sandstones, graywackes and siltstones with varying thicknesses. The conglomerates are composed of well rounded pebbles of quartz, mica-schists, phyllites, amphibolites, gneisses and quartzites as well as of sedimentary rocks. They may reach a size up to 20 cm. Frequently, graded bedding, erosional surfaces, flute casts and other sedimentary phenomena typical for proximal flysch deposits can be found as well as trace fossils, for example *Nereites* sp., *Lophoctenium* sp., *Phycosiphon* sp., *Dictyodora liebeana* (GEINITZ). Hence, the roadcut may represent part of a fluxoturbidite succession deposited along a slope of a flysch trough.

Plant remains, so far discovered at various horizons have been identified as *Pecopteris* sp. ?, *Neuropteris* sp. ?, *Alloiopteris* sp. ?, *Asterophyllites equisetiformis* (SCHLOTH.) and *Calamites* sp. According to REMY this flora reflects an early Westfalian to early Stefanian age.

The contact between the strata mentioned in the chapter above and red sandstones of Lower Permian age underlying the calcareous Triassic rocks is not exposed; the road is crossing this contact on top of the Windische Höhe.

References (see stop 4.3.).

Route description: The route traverses the Gailtal Alps, mainly Triassic limestones and dolomites, and descends into the Drau valley. As the Permomesozoic assemblage has the structure of a syncline we again meet its Permoskythian basis on the northern flanks of the Gailtal Alps. Before we arrive at the village of, Feistritz in the floor of the Drau valley we are crossing quartz-phyllites and mica-schists of the Austro-Alpine crystalline complex. Then we turn to northwest and continue upstream the broad Drau valley as far as Spittal/Drau. The valley follows a prominent fault line. The valley flanks made of Altkristallin are extensively covered by glacial deposits.

Day 5

Austro-Alpine crystalline complex, Permomesozoic of Central-Alpine Facies
Route: Spittal/Drau — Lieser valley — Innerkrems/Nock road — Katschberg tunnel — Radstadt Tauern Pass — Radstadt

Introduction

The day's program is to return to the northern side of the main ridge of the Eastern Alps. The route takes its course along the eastern frame of the Tauern Window.

The southern part of the route lies within the Austro-Alpine crystalline complex and its stratigraphically overlying Central-Alpine Permomesozoic assemblage of the Stangalm. The crystalline complex is chiefly made up of mica-schists and paragneisses with intercalations of marbles, amphibolites and granitic augengneiss (Bundschuh Orthogneiss). The meso- to katazonal metamorphic Liesergneiss series in the southwest is rich in pegmatites.

The northern section of the excursion route is passing an assemblage of Central-Alpine Permomesozoics of the Radstadt Tauern mountains, the Radstadt Quartz-Phyllites and associated minor proportions of diaphthoritic crystalline rocks. The structural position of this assemblage is generally regarded as Lower Austro-Alpine according to its position upon the Penninic system of the Tauern Window in the west and below the Austro-Alpine crystalline complex in the east. The occurrence of this Lower Austro-Alpine series in the Radstadt Tauern mountains is of considerable extension. However, its southern continuation (Katschbergzone) along the eastern end of the Tauern Window is very narrow and highly deformed and believed to be connected with the Matrei Schuppenzone.

The day's program is a good opportunity to demonstrate the principal features of the internal structure of the Austro-Alpine Unit and to discuss their interpretation. One model supports two superimposed thrust-sheets designed as Upper resp. Lower Austro-

Alpine Unit. According to this model the Upper Austro-Alpine Unit consists of the Austro-Alpine crystalline complex (Altkristallin) and its overlying Palaeozoic and Mesozoic cover. The Lower Austro-Alpine Unit comprising Palaeozoic quartz-phyllites, Permomesozoic carbonate rocks and minor proportions of crystalline rocks appears in some tectonic windows. According to A. TOLLMANN, however, (since 1960) the Austro-Alpine Unit represents a pile of three regional thrust-sheets, the Upper, Middle and Lower Austro-(or East-)-Alpine Units. He emphasizes the fact that the Austro-Alpine crystalline complex has its individual Permo-mesozoic cover of Central-Alpine facies type and allocates this assemblage to the Middle Austro-Alpine Unit. The term Upper Austro-Alpine according to TOLLMANN's opinion is restricted to the uppermost thrust-sheet comprising Palaeozoic rocks (f. e. Gurktal nappe, Grauwackenzone) and Permomesozoic series of North-Alpine facies type (f. e. Northern Calcareous Alps, Drauzug).

Route description: From Spittal/Drau we take the road upstream the Lieser valley mainly passing paragneisses and mica-schists of the Austro-Alpine Altkristallin. Around Gmünd, however, a certain section of the route lies in quartz-phyllites of the Katschbergzone. At the village of Kremsbrücke we turn to the east and follow the Kremsbach valley as far as Innerkrems where we take the Nockalm road.

Structural review of the Gurktal Alps

(J. PISTOTNIK) *)

(Introduction to stops 5.1. to 5.3.)

The Austro-Alpine complex of the Nock area consists of biotite-rich paragneisses, mica-schists (with garnet, staurolite, locally also kyanite) as well as intercalations of marbles and amphibolites. Lamellas and lenses of granitic orthogneisses occur at many places. Their contact against the country rock is tectonic. Structure and metamorphism of the Altkristallin were mainly caused by the Variscan orogeny. The (early) Alpine events (100 m.y.) are believed to be responsible for a low-grade metamorphism and phyllonitisation along major Alpine movement planes such as at the boundary to the underlying Lower Austro-Alpine quartz-phyllites of the Katschbergzone. The stratigraphic contact between the Altkristallin and its Permomesozoic sedimentary cover (Stangalm Mesozoic) is tectonized at many places. This Stangalm Mesozoic has also been affected by low-grade Alpine metamorphism.

The Upper Austro-Alpine Gurktal nappe comprising mainly Early Palaeozoic phyllites and greenschists rests with tectonic contact upon the Altkristallin and the Stangalm Mesozoic rocks. At the western margin of the Gurktal nappe not only an isolated occurrence of its crystalline basement (Pfannock Gneiss) is preserved but also a non-metamorphic post-Variscan transgression series (Pfannock Schuppe). It exhibits stratigraphic contact with both Pfannock Gneiss and Gurktal phyllites, but due to Alpine movements it is dipping eastwards under the Palaeozoic phyllites. This Pfannock Schuppe assemblage begins with plant-bearing Upper Carboniferous and is topped by Rhaetian strata. Its facies resembles the Mesozoic of the Northern Calcareous Alps as well as of the Drauzug.

Another occurrence of the post-Variscan transgression series is known from the eastern part of the Gurktal nappe (Krappfeld in eastern Carinthia) where it normally rests upon the Palaeozoic phyllites. Upon partly eroded Triassic an Upper Cretaceous-Early Tertiary sequence has been deposited.

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Stop 5.1. S Innerkrems, Gurktal Alps

Austro-Alpine crystalline complex, Bundschuh Orthogneiss

Top. sheet 183 Radenthein

Along a road-cut appr. 1 km south of Innerkrems the Bundschuh Orthogneiss is exposed. This medium-grained gneiss exhibits augen texture and consists of microcline, minor plagioclase (oligoclase), quartz, light mica (partly phengite), locally biotite and sporadic garnet. The augen of alkalifeldspar attain a max. size of about 3 cm. The origin of the very well developed parallel texture was connected with cataclasis. Later (presumably during Alpine times) recrystallisation of quartz, feldspar and mica took place. The radiometric whole rock determination of an orthogneiss sample from the Kremsbach valley proved ages of 371 ± 12 m.y. and 381 ± 30 m.y.

The Bundschuh Orthogneiss forms several major intercalations within the pararocks of the Nock area (Gurktal Alps). In general their position is parallel to the schistosity. Intrusive contacts are missing. Therefore the contact between the Bundschuh Orthogneiss and its country rock is regarded as tectonic. The age of the related movements is believed to be Variscan because of the unconformable transgressive contact of the overlying Stangalm Mesozoic.

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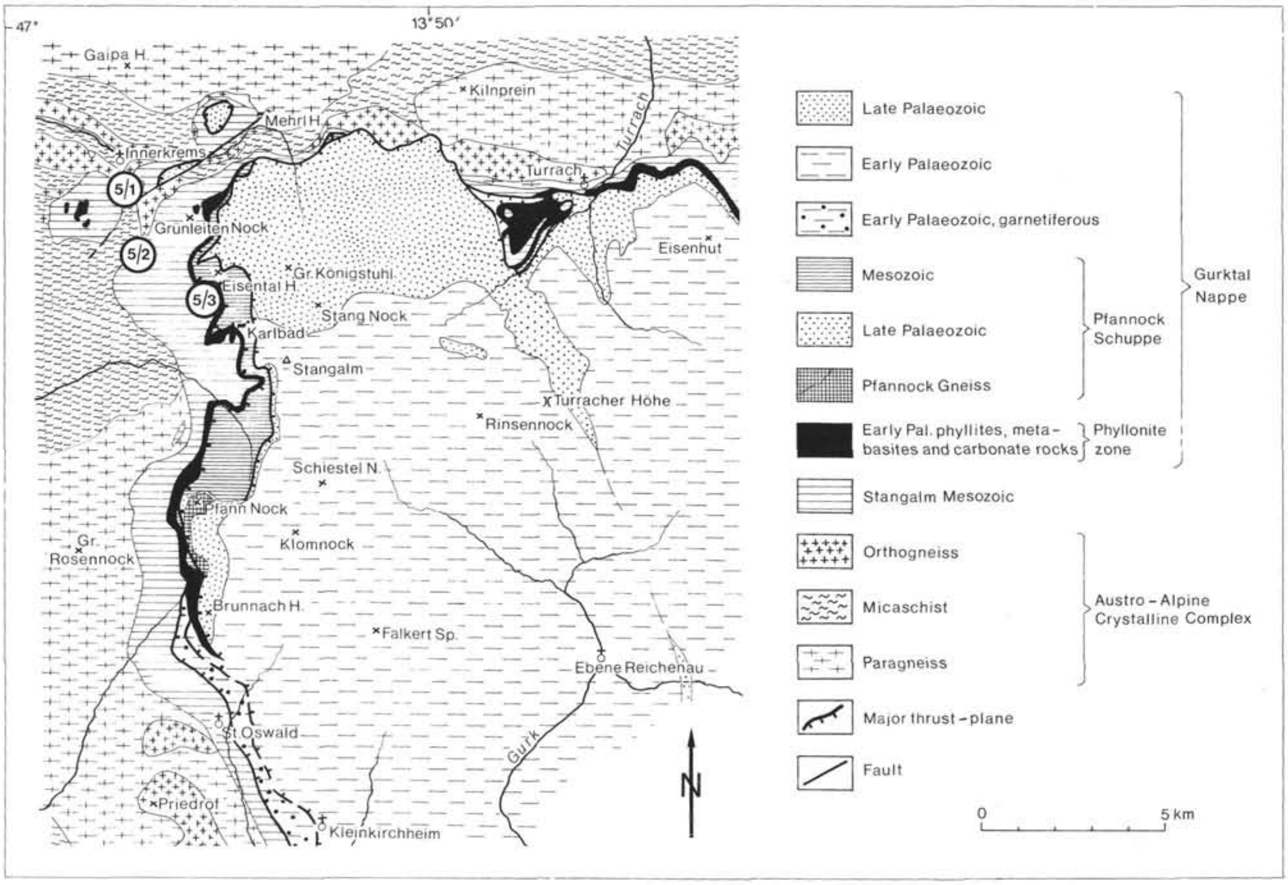

Fig. 25: Geological sketch-map of the western Gurktal Alps (J. Pistotnik).

Stop 5.2. Postmeisteralm, Gurktal Alps

Unconformity between the Austro-Alpine crystalline complex and the Stangalm Mesozoic
Top. sheet 183 Radenthein

Along the road-cut of the Nockalm road (around km 4) south of the bridge at the Postmeisteralm the unconformity between the Austro-Alpine crystalline complex and the Stangalm Mesozoic is exposed (figures 25 and 26).

The crystalline basement is represented by mica-schists, containing quartz, biotite, less muscovite, garnet, and staurolite. The feldspar content (plagioclase) is concentrated in parallel layers. Sometimes on the s-planes tourmaline can be recognized. Pre-Alpine tectonic movements resulted in strong folding about E-W-axes. The crystalline rocks underwent Alpine retrograde metamorphism which caused chloritization and micatization of staurolite, garnet, and biotite.

The Permomesozoic assemblage of the Stangalm Mesozoic rests with unconformable contact upon these deformed mica-schists. The Stangalm Mesozoic underwent progressive Alpine low-grade metamorphism.

The succession begins with well-bedded quartzites with conglomeratic layers and cross-bedding. At some places a streaky arrangement of biotites can be observed on the schistosity planes and probably indicates original ripples. The heavy mineral pattern of the quartzites and their basement are corresponding. These quartzites are typical for the Central-Alpine Permo-skythian. The quartzite turns into an alternation of quartzites, sericite schists, and carbonate layers (uppermost Skythian, Alpine Röt).

They are overlain by dark-grey, partly banded, thin-bedded dolomites, layer-wise crinoid-bearing, with transitions into dolomite phyllites. These beds are stratigraphically correlated with well-established lower Anisian strata.

The succeeding section of banded and cherty limestones is not exposed along this road-cut but evident in the talus.

The overlying Wetterstein Dolomite attains a maximum thickness of about 400 m. This pale, fine-crystalline, locally (mainly in the higher sections) banded dolomite is believed to have been formed under lagoonal conditions. Locally a laminated texture is preserved.

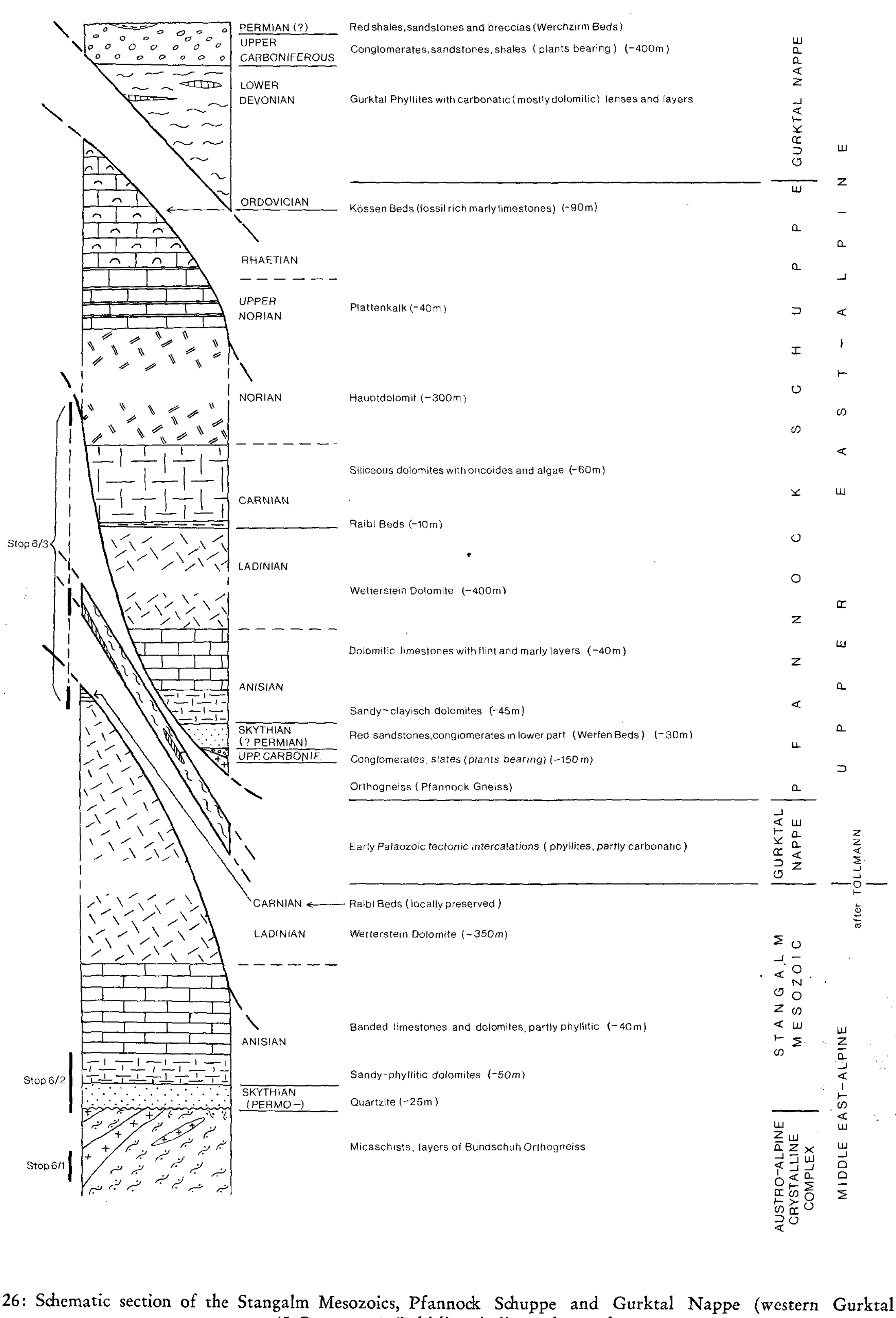

Fig. 26: Schematic section of the Stangalm Mesozoics, Pfannock Schuppe and Gurktal Nappe (western Gurktal Alps) (J. PISTOTNIK). Bold lines indicate thrust planes.

The stratigraphic position of the dolomite is considered to be (? Upper Anisian to) Ladinian.

References (see stop 5.1.).

Route description: The route between stop 5.2. and 5.3. along the Nockalm road is crossing a thick succession of the pale Wetterstein Dolomite.

Stop 5.3. Eisental Alm, Gurktal Alps

Stangalm Mesozoic (Middle Austro-Alpine), Gurktal Nappe (Upper Austro-Alpine)
Top. sheet 183 Radenthein

The subject of this stop can be studied along a 400 m long section of the Nockalm road (around km 8) in the valley head of the Eisental southwest of the Eisental Höhe (Pt. 2180 m; see figures 25 and 26).

The section begins in the uppermost part of the Wetterstein Dolomite representing here the (Middle Austro-Alpine) Stangalm Mesozoic.

It is separated from the overlying lithologies of the Upper Austro-Alpine Gurktal Nappe by a thrust-plane with low-angle eastward dip. Alpine Movements caused the complex internal structure of the Gurktal Nappe (tectonic repetitions and inversions) which is especially evident here at the western margin of the Gurktal Nappe.

The bottom part of the Gurktal Nappe is represented here by a narrow zone of Early Palaeozoic rocks comprising dark-grey, partly graphitic quartz-phyllites, a thin lamella of middlegrey dolomite (by weathering its surface becomes light-coloured), and tuffitic greenschists (as talus fragments only in the road bend). The formation of biotites from the quartz-phyllites is dated early Alpine (appr. 100 m.y.). This zone is considered to have acted as a lubricant for the gliding of the Gurktal Nappe.

This horizon is succeeded by the Pfannock Schuppe which generally consists of a gneiss-lamella and its Upper Carboniferous to Rhaetian cover. In the excursion area, however, around the summit with the parking place this unit is only represented by dark-grey, hardly bedded, siliceous Norian Hauptdolomit and (not exposed in this road section but present in the talus) dark Rhaetian limestones and shales rich in fossils (lamellibranchs, corals, crinoids). The absence of the older parts of the Pfannock Schuppe is explained by tectonic amputation during Alpine thrust movements.

From the parking place at the summit in about 2050 m there is a nice panoramic view towards south. The eastward dipping Altkristallin occupies the area in the southwest. The carbonate rocks of the overlying Stangalm Mesozoic form prominent topographic features in the south. The Gurktal Nappe extends in the east.

References (see stop 5.1.).

Route description: We return to the Lieser valley and continue northwards. After passing the Katschberg tunnel the route enters the region of the Lungau. As far as Mauterndorf the route lies mainly within the pararocks of the Altkristallin. Then we come into the Lower Austro-Alpine Unit of the Radstadt Tauern mountains.

The area of the Lower Austro-Alpine Unit of the Radstadt Tauern mountains is famous for its well-exposed alpinotype structure. A. Tollmann who did a great deal of deciphering the stratigraphy and tectonics in this area recognized several subsidiary nappes (see also fig. 27):

Top	Middle Austro-Alpine Crystalline Complex		
	Quartz-Phyllite Nappe (inverted succession)		Lower Austro-Alpine Unit
	Kesselspitz Nappe Pleisling Nappe Lantschfeld Nappe	Pleisling facies	
	Hochfeind Nappe Speiereck Nappe	Hochfeind facies	
Bottom	Penninic Zone		

The internal structure of the different nappes frequently exhibits recumbent, northward overturned folds. Besides the predominating east-west direction of fold-axes also westwards-facing cross-folds are developed. The major part of the lithologies is formed by the Radstadt Permomesozoic succession of Central-Alpine facies type. Two different sub-facies can be distinguished: the Hochfeind facies with abundant breccias in the Jurassic section and the Pleisling facies with a thick carbonatic Triassic section of variable lithology. The early Palaeozoic quartz-phyllites attain their greatest thickness in the highest sub-unit in the north and are almost lacking in the southerly deeper sub-units. The so-called Tweng crystalline rocks are believed to represent the basement and are mainly preserved at the base of the Lantschfeld Nappe. From studies on these rocks F. Becke (1909) introduced the term "Diaphthoresis". The whole succession has been affected by low-grade Alpine metamorphism and strong internal deformation. 180 km east of the Radstadt Tauern mountains the Lower Austro-Alpine Unit reappears in the Semmering area with similar lithologies.

Greenishgrey to white and rather massive quartzites, practically indentic to the Permoskythian Lantschfeld quartzite, are exposed in a new road-cut northwest of Mauterndorf near the restaurant Hammerkeller. By A. Tollmann (pers. comm.) however, these quartzites are considered to be of Jurassic age.

Brecciated Wetterstein dolomite which directly underlies the previous quartzites appears in the quarry Fingerlos after some 200 m. Azurite, malachite, fahlore and sphalerite mineralization (pers. comm. by G. Nieder-

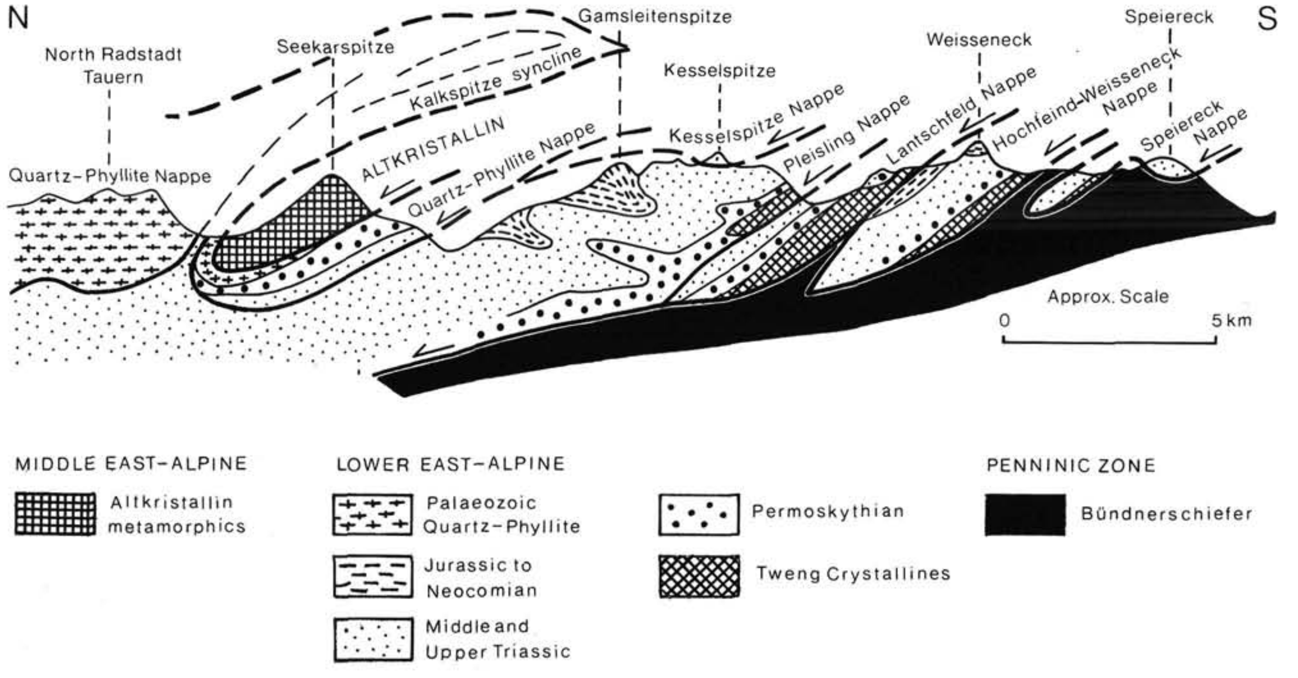

Fig. 27: Generalized cross-section through the Radstadt Tauern mountains (after TOLLMANN, 1964; OXBURGH, 1968).

MAYR, Mus. Nat. Hist., Vienna) along fissures as well as quartz veins can be recognized.

Near Tweng we are passing the Tweng crystalline rocks. At the Twenger Talpaß, a narrow passage of the Taurach valley, the route leaves the Lantschfeld Nappe and enters the overlying Pleisling Nappe. Lantschfeld quartzite and Wetterstein dolomite are well exposed near the Hohe Brücke. The steep rockwall of the Rauchwand north of the Twenger Talpaß is of Norian Hauptdolomit.

Stop 5.4. Hotel Schaidberg

Lower Austro-Alpine Unit, Radstadt Permomesozoic
Top. sheet 156 Muhr

There are road-sided exposures of pale, banded Wetterstein dolomite of Ladinian age and dark, pyritous slates of the Carnian with rare fragments of coal. Note the isoclinal folding. This point appr. 1,5 km southeast of the Radstadt Tauern Pass is considered to represent the core of the recumbent fold of the Schwarze Wand which is one of the principal aims of the next stop.

R e f e r e n c e (see stop 5.5.)

Stop 5.5. Zehnerkar Spitze (2381 m)

Lower Austro-Alpine Unit, Radstadt Permomesozoic, Pleisling Nappe, Panoramic View
Top. sheet 156 Muhr

The accomplishment of this excursion stop depends on excellent weather conditions. From the top station of the cable car (bottom station 1 km west of Obertauern) we ascend by foot to the Zehnerkar Spitze 200 m height difference, half an hour climbing). Along the path there are exposures of white dolomite (Hauptdolomit, Norian), black phyllites, schistose marbles, pyritous calc-phyllites of the Pleisling Nappe. Note the intense small-scale folding.

From the top of the Zehnerkar Spitze there is an excellent panoramic view: dominating is the recumbent fold of Upper Triassic carbonate rocks and shales in the Schwarze Wand in the east (fig. 28); the top of the Kesselspitze displays Anisian to Ladinian carbonates of the Kesselspitze Nappe upon folded series of the Pleisling Nappe (fig. 28); to the southwest and west we look into the Penninic Zone of the Tauern Window; to the north across the Radstadt Tauern mountains and the Grauwackenzone view of the Northern Calcareous Alps (Dachstein, Tennengebirge, etc.).

R e f e r e n c e

TOLLMANN, A. (1977): Geologie von Österreich. Bd. 1: Die Zentralalpen. — 766 pp., Wien (Deuticke).

R o u t e d e s c r i p t i o n: The road descends along the Taurach valley northwards. Because of the general northward dip we are moving from deeper to higher structural units. The first section of the route remains within the Pleisling Nappe. The narrow part of the Taurach valley after the Gnadenalm traverses middle-Trias-

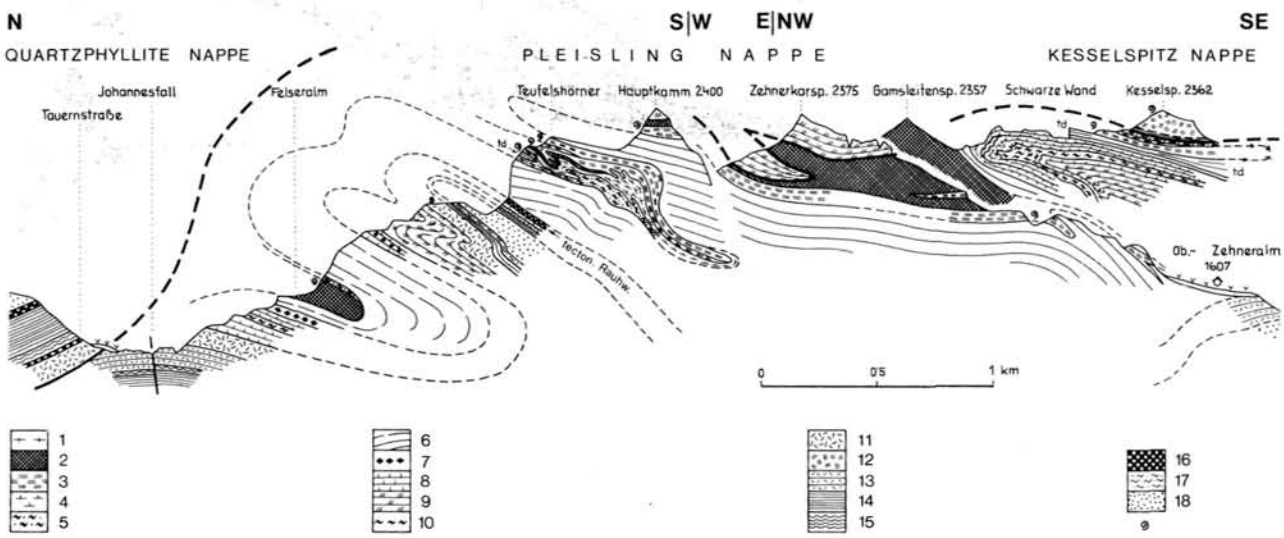

Fig. 28: Collective section across the Pleisling mountain group to depict the structural style of the Lower Austro-Alpine Unit of the Radstadt Tauern mountains (after A. TOLLMANN, 1977). 1 = Middle Jurassic slates and crinoidal limestones; 2 = Pyritous slates (Lias); 3 = Limestone (Lias); 4 = Limestone (Upper Rhaetian); 5 = Kössen Beds (Rhaetian); 6 = Hauptdolomit, Norian); 7 = Breccia (Carnian); 8 = Dolomites (Raibl Beds, Carnian); 9 = Arlberg Dolomite (Cordevolian); 10 = Pyritous slates (Carnian); 11 = Wetterstein Dolomite (Ladinian); 12 = Trochitendolomit (Upper Anisian); 13 = Dark dolomite (Anisian); 14 = Banded limestones (Anisian); 15 = Pyritous slates (Anisian); 16 = Rauhwacke; 17 = Slates (upper Skythian); 18 = Lantschfeld Quartzite (Skythian).

sic limestones and dolomites. The flanks of the lower part of the Taurach valley (from around Untertauern northwards) are made of the overlying Quartz-Phyllite Nappe. At two places the Pleisling Nappe appears in the valley floor.

The last ridge at the eastern side just before we arrive at Radstadt in the Enns valley is formed by Triassic rocks of the northward dipping Mandling Wedge. It is considered to be a tectonically isolated part of the Northern Calcareous Alps. It joins the Northern Calcareous Alps several kilometers in the east. Radstadt itself is situated in the Grauwackenzone.

Day 6

Northern Calcareous Alps, Werfen Fm., Gosau Beds, Dachsteinkalk Fm., Hallstatt Fm., Oberalm Fm.
Route: Radstadt — Annaberg — Paß Gschütt — Gosau — Abtenau — Paß Lueg — Hallein — St. Leonhard — Salzburg.

Introduction

The excursion route of the 6th day leads into one of the most complex areas of the Northern Calcareous Alps. The main Calc-Alpine formations of Triassic, Jurassic and Cretaceous age are demonstrated. In addition the complexity of facies patterns and tectonic structures is shown.

The Northern Calcareous Alps have been sedimented upon the Palaeozoic sediments of the Grauwackenzone. However, the sedimentary contact is generally lost by tectonic movements.

Most of the sedimentary cycles must have been laid down under shallow water conditions. Reef building corals indicate tropical climate from the Triassic to the Upper Jurassic. Temperate warm climate must have been dominating in the Cretaceous proved by the evidence of corals and rich floras.

The sedimentary cycles of the Northern Calcareous Alps began in the Lower Skythian in an extensive shelf region under shallow water and arid climate conditions. One of the turnovers was the beginning of the carbonate sedimentation in the Upper Skythian (stop 6.1.). It was prevailing from the Upper Skythian until the Lower Cretaceous with only one general interruption in the Carnian.

In Middle Triassic times a facies pattern became established with carbonate platforms, basins with shaly sedimentation and intermediate areas of cherty limestone and volcanic influence. A specific Hallstatt facies with low sedimentation rates and ammonite rich successions of limestones, dolomites and marls developed within a network of branched channels and small basins. In Carnian time the platform area was greatly influenced by detritic sedimentation from crystalline source areas. Reefs, lagoons and basins were buried under shales, sandstones and dark shaly limestones.

The facies pattern after the Carnian was similar as before and endured until Rhaetian times (fig. 30).

The main types of carbonate facies in the Upper Triassic of the Northern Calcareous Alps are the Hauptdolomit facies in the north and west and the Dachsteinkalk facies in the south and east. Both have been sedimented in a large platform area; the Hauptdolomit in a shallow water hypersalinar lagoonal environment, the Dachsteinkalk also in a lagoonal system, interrupted by channels and small basins of the differentiated Hallstatt facies (fig. 30). Reefs marked the southern margin of the Dachsteinkalk lagoonal system (fig. 31).

The platform area is thought to have been subsiding over a long period since Carnian times up to the Rhaetian. Therefore the platform sediments measure thicknesses up to 1.500 m. On the other side the Hallstatt facies is characterized by a low rate of sedimentation according to its relative uplift during the general subsidence of the surrounding area. Numerous synsedimentarily filled fissures in the Hallstatt facies, especially in marginal positions bear rich ammonite faunas (Carnian, Norian).

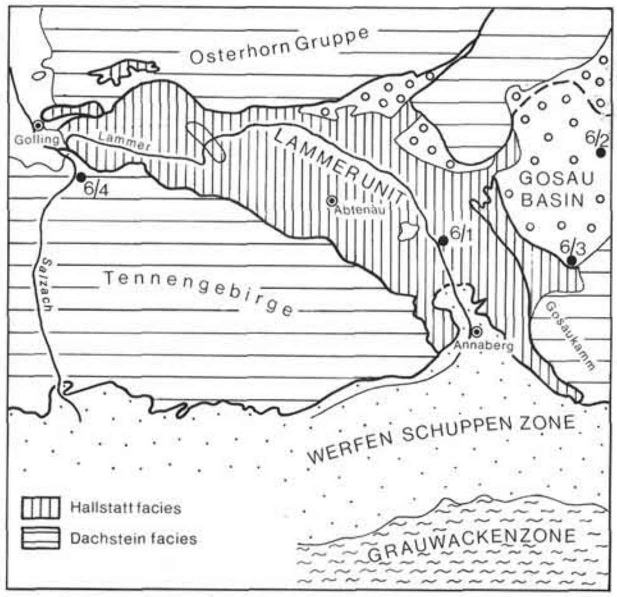

Fig. 29: Facies distribution in the Triassic of the Lammer region, Salzburg (modified after TOLLMANN, 1969).

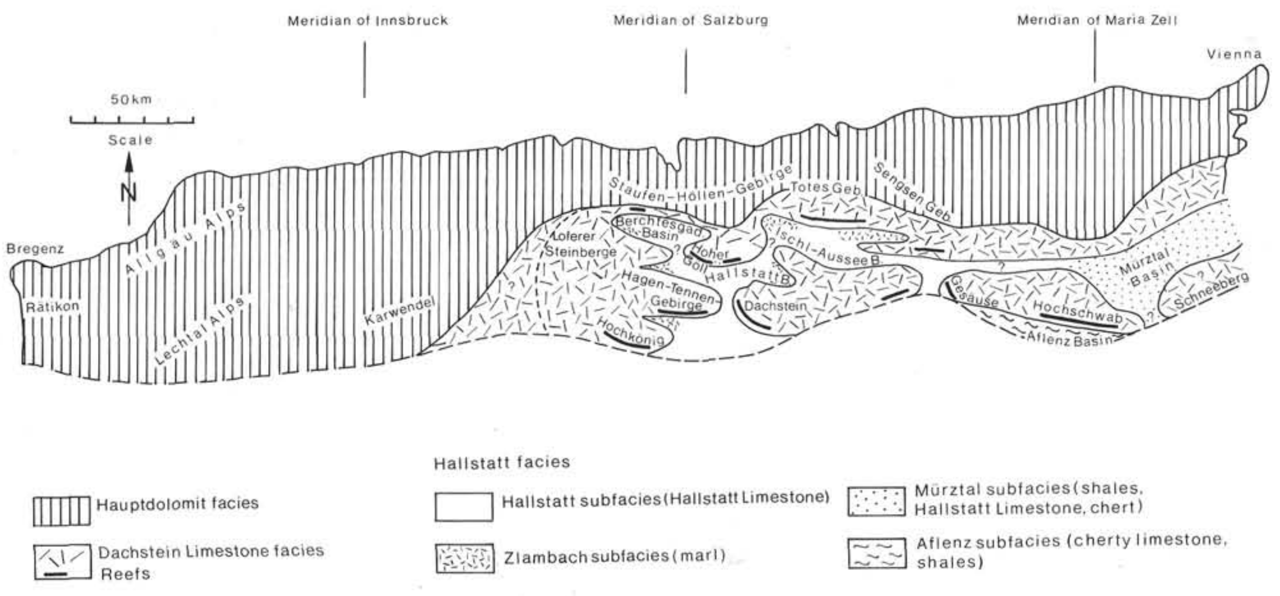

Fig. 30: Facies distribution in the Upper Triassic of the Northern Calcareous Alps (after ZANKL, 1967).

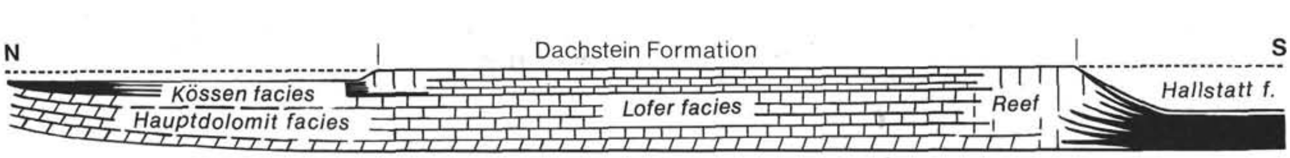

Fig. 31: Diagrammatic restoration of Late Triassic facies in the Northern Calcareous Alps, Salzburg region (after A. G. FISCHER, 1964).

The paleogeographic situation changed again in the Lower Jurassic. Red limestones appeared, partly the ammonite rich nodular Adnet Limestone, partly the transgressive and fissure filling Hierlatz Limestone built by skeletal elements of crinoids. The relief was sharply accentuated. Within deep basins enormous masses of Allgäu Formation were sedimented. These basins kept stably until the Lower Cretaceous. Folding, tension fracturing and the sliding of large masses (stops 6.5., 6.6) since Lower Jurassic times announced the big Cretaceous/Tertiary orogeny.

Route description: The excursion moves on from the Grauwackenzone around Radstadt through the Werfen Schuppenzone. Near the Highway junction Eben greenschist intercalations are visible within the phyllites of the Grauwackenzone. The lower Werfen formation usually consists of sandy shales and quartzites, red or greenish in colour. The landscape is mostly covered with meadows and is used for cattle breeding. Practically no exposures.

Stop 6.1. Lammer gorge near Annaberg (Salzburg)

Northern Calcareous Alps, Top of Werfen Formation (Upper Skythian)
Top. sheet 95 St. Wolfgang

The examined sequence (exposure extends from km 16,7 until km 17,3 of the road) is located in the tectonically isolated Lammer Unit (fig. 29). A section of well exposed Werfen formation shows characteristics of subtidal sedimentation. The Middle and Upper Triassic sediments of the Lammer Unit are developed in Hallstatt facies, which appears to be distinctly different from the surrounding platform carbonates of the Dachstein facies. The morphologic depression of the Lammer Unit is randomly narrowed by the massive blocks of the Osterhorn Gruppe, the Tennengebirge, the Dachstein and the Gamsfeld.

The Upper Werfen Formation of the Lammer gorge begins with red clays and sandy shales (fig. 32). The following 12 m are characterized by grey/green colours, high content of silica detritus and beginning intercalation of sandy limestones. After that, the rock colour changes again. 60 m of red claystones bear a rare fauna of bivalves (*Anodontophora* sp., *Gervillia* sp.). Also a fragment of *Tirolites* was found. The top of the Werfen formation is built by red oolites and porous yellow dolomite. The strata 10 m below the top bear a rich fauna of small gastropods.

The Upper Skythian age is documented by *Meandrospira iulia* (PREMOLI-SILVIA) and *Tirolites* sp. The rich crinoid fauna is described by H. MOSTLER & R. ROSSNER (1977). The overlying basal Gutenstein Limestone is also of Upper Skythian age (for the related conodont fauna see MOSTLER & ROSSNER, 1977, p. 15).

The Lammer gorge sequence gives the opportunity, to study the breakdown of the sand/silt sedimentation of the extensive shelf area of the Upper Skythian and the buildup of the carbonate sedimentation cycle, which dominated the Triassic and the Jurassic of the Austro-Alpine system. The type of subtidal sedimentation of clastic Werfen formation is found along the south-eastern extension of the Alpine belt until Turkey. According to the paleogeographic conception of H. MOSTLER & R. ROSSNER a broad arid alluvial plain, the area of the Buntsandstein formation, is believed to have extended north and west of the Werfen Formation beyond a narrow Watt facies.

Following the conception of LEUCHS (1927), TRAUTH (1937), ZANKL (1962), HÖCK & SCHLAGER (1967), TOLLMANN (1976) and MOSTLER & ROSSNER (1977) the Lammer Unit is situated relatively autochthonous between two blocks of thick upper Triassic platforms, the Dachsteinkalk facies of the Tennengebirge in the south and the Dachsteinkalk area of the Osterhorn Gruppe in the north. The latter grades northwards into Hauptdolomit facies.

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Route description: After passing the depression area between the Dachstein and the Tennengebirge the excursion route follows downstream the Lammer until Bad Abtenau (salt and sulphur spring). The wide depression of the Lammer valley is caused by soft rocks in Hallstatt facies. At Rußbach we enter the Gosau Basin, famous for its fossiliferous sequences.

The Pleistocene Gosau glacier took its way over the Paß Gschütt through the Lammer valley and joined the Salzach glacier at Golling.

Stop 6.2. Zwieselberg forest road, Gosau

(H. A. KOLLMANN) *)

Gosau Beds
Top. sheet 95 St. Wolfgang

General remarks: Rock sequences of considerable thickness have been deposited in local subsiding areas within the Eastern Alps during the Upper Cretaceous and the lowermost Tertiary. Although the term "Gosauschichten" is generally applied for these sequences they have not to be considered as a lithostratigraphic but as a tectonic unit. The Gosau sedimentary cycle began with the world wide sea

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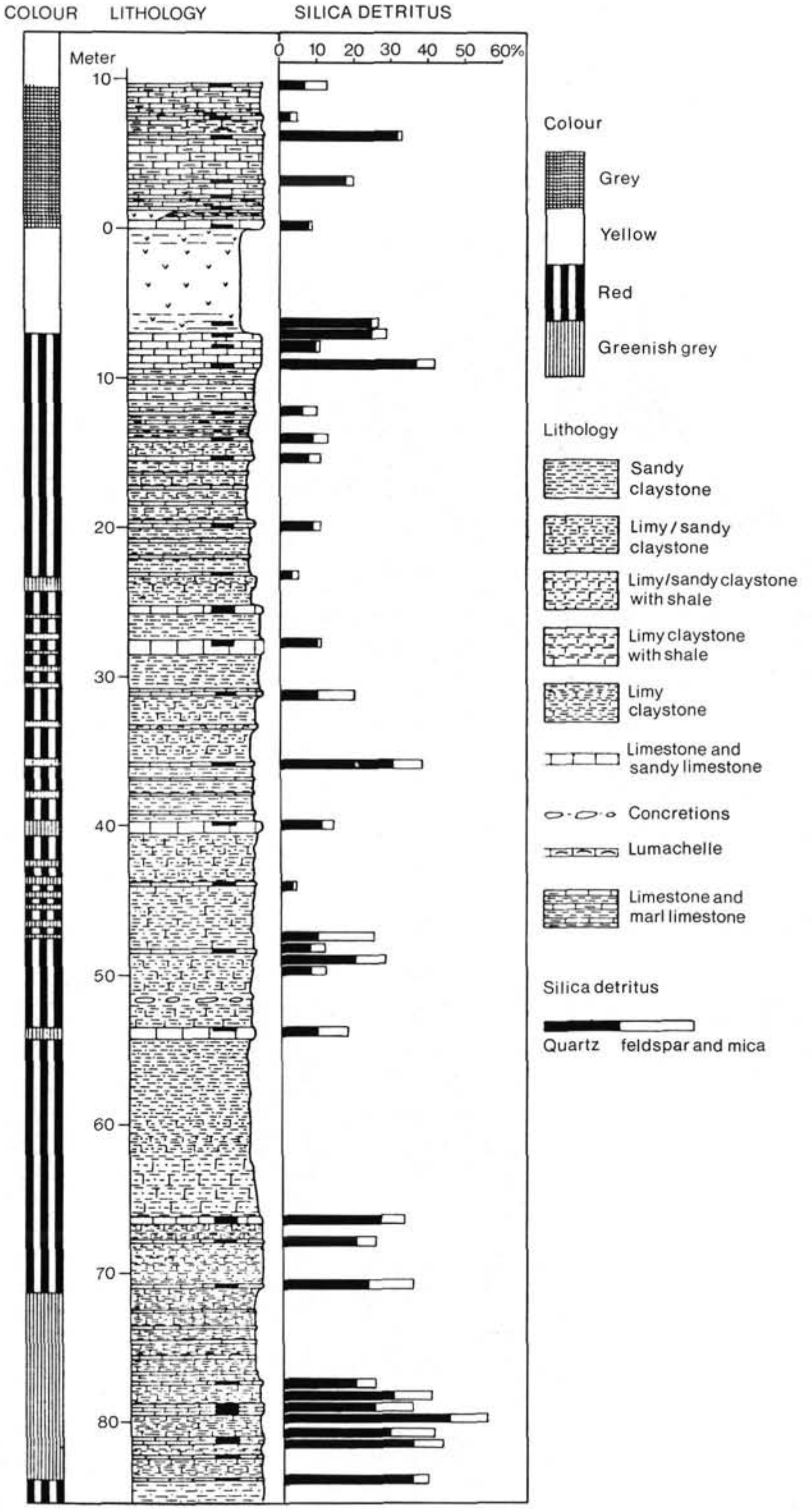

Fig. 32: Lithostratigraphic sequence of the Upper Werfen formation in the Lammer gorge (after MOSTLER & ROSSNER, 1977).

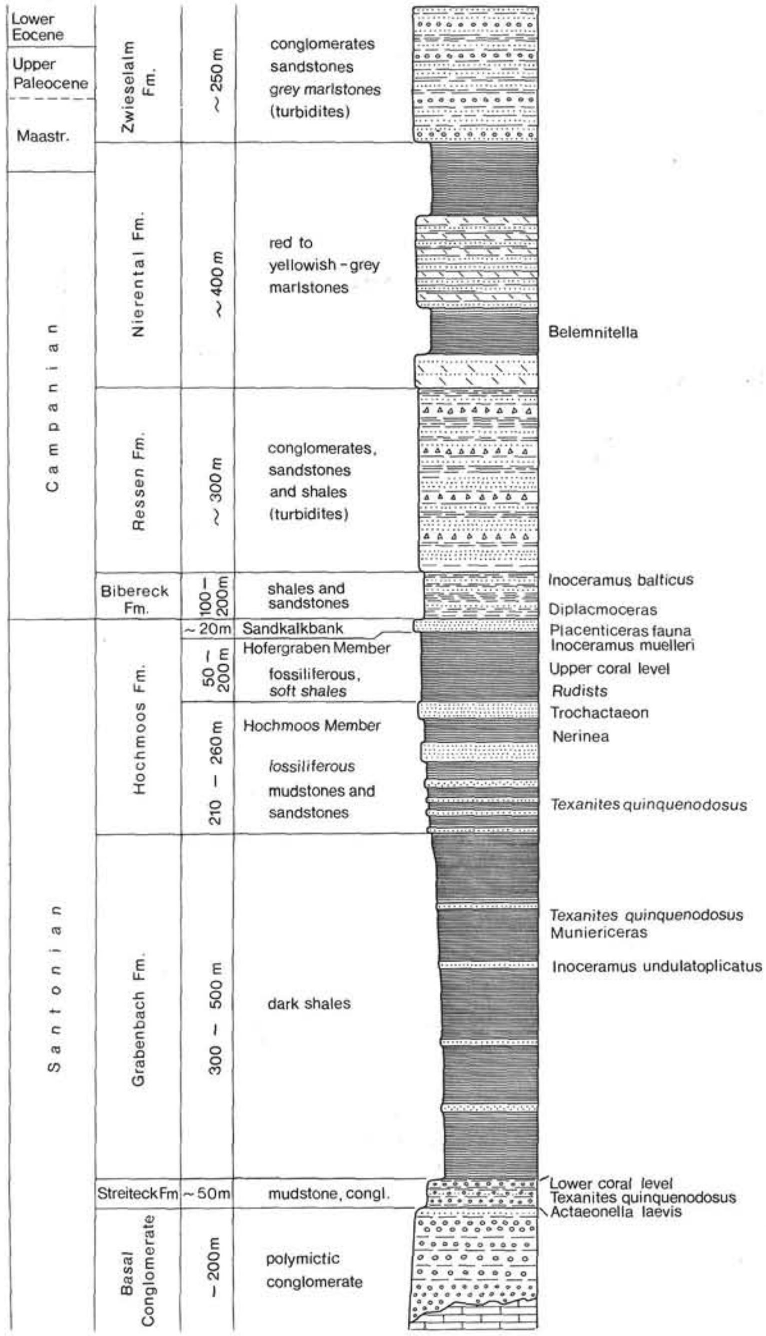

Fig. 33: Generalized stratigraphy of the Gosau Beds in the area of Gosau and Abtenau (after WEIGEL, WEISS, WILLE-JANOSCHEK, SUMMESBERGER and KOLLMANN).

level rise at the beginning of the Coniacian. But the geologic history of the individual basins varies according to a heterochronous beginning of the subsidence and different subsidence rates.

In the Gosau area, the thickness of the Gosauschichten is approximately 2300 meters. The subdivision into "Schichten" (in the sense of formations, the work on their definition by means of type sections is in progress) given in fig. 33 is based on WEIGEL (1937), WEISS (1977), SUMMESBERGER (1979) and own investigations. In the Santonian the environment has been generally shallow marine. All the highly diverse mollusc and coral assemblages described in monographs from Gosau are of this age. The calcarenite which is visited by the excursion party is the highest bed in the Santonian and the youngest one with a diverse megafauna in the sequence.

With the beginning of the Campanian the water depth increased. The megafaunas are poor in this upper part of the section but planctonic foraminifera are abundant (WILLE-JANOSCHEK, 1966). The Ressen Schichten are flysch sediments. The Nierentaler Schichten which are widely distributed in the Northern Calcareous Alps are gray to red marlstones and have been deposited under eupelagic conditions (HESSE & BUTT, 1976). The Zwieselalm-Schichten extend into the Lower Tertiary. Within the clastic components pebbles of phyllites, quartz and laminated algae are abundant.

Description of the locality: The gray calcarenite which has been called "Sandkalkbank" by WEIGEL (1937) is consistent throughout the basin with only minor lateral changes. After G. NIEDERMAYR (personal communication) the calcarenite consists of minor quartz and dolomite besides of calcite. The diverse megafauna is dominated by pelecypods and corals. Gastropods, ammonites, nautilids and bryozoans are less abundant.

The environment of the deposition has been shallow marine but low energetic. This is shown by the nearly complete lack of heavy minerals and by the preservation of the fauna. All pelecypods which have lived infaunal or semi-infaunal (*Astarte, Trigonia, Cucullaeids, Pinna* and others) are preserved bivalved. The valves of the heavy shelled epifaunal inoceramids are displaced but generally not transported.

Among the gastropods the occurrence of pleurotomariids is noteworthy. In the Upper Cretaceous of the Eastern Alps they have been recorded only from this locality and are indicative for a boreal influence in the otherwise Tethyan faunas.

An ammonite fauna with 23 taxa which is the largest known from a single locality in the Eastern Alps has been collected here and was described by H. SUMMESBERGER (1979). Most abundant are Placenticeratidae. *Hauericeras gardeni* (BAILY), *Gaudryceras mite* (v. HAUER), *Stantonoceras depressum* (HYATT) are indicative for an Upper Santonian age. WEISS (1977) has recorded *Globotruncana elevata elevata* (BROTZEN) from the base of the overlying Bibereck Schichten which therefore are of Campanian age.

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Route description: On the way from the village of Gosau to the Gosau lake a giant landslide with scarp is visible on the right side. It is of post-Pleistocene age and possibly caused by glacial oversteepening and subsequent deglaciation of the Gosau valley.

Stop 6.3. Gosau Lake

Panoramic view
Top. sheet 95 St. Wolfgang

Stop 6.3. is situated upon an end moraine of the Gschnitz stade. The dammed lake is located at the Reißgang fault with a large lateral displacement. The flanks of the valley are oversteepened by glacial erosion.

Depending on weather conditions this point gives an excellent view upon one of the largest reef complexes within the Northern Calcareous Alps — the Gosaukamm. Looking southwards, the Hoher Dachstein is visible (3.004 m) with its distinctly layered carbonate masses. It is built up by Lofer Cyclothems (fig. 34) of the lagoonal environment of the Dachstein Formation. Megalodontidae (fig. 36) are the prevailing fossil group. Southwest and west of the standpoint the Gosaukamm reef extends, now separated from the lagoonal system. Main reef building groups are spongues, corals. Additionally large snails and as messengers from the neighbouring Hallstatt facies Ammonites and *Heterastridium* are scarcely to be found. In the northwestern edge of the Gosaukamm reef sediments are linking with Zlambach marls (Hallstatt facies). A very rich fauna of corals has been described by FRECH (1890) from that point.

The top station of the cable car is closely neighboured to the type area of the Zwieselalm Beds (Maastricht—Eocene). The coarse clastic sediment series of the Zwieselalm Beds are closing the Alpine cycles of the Gosau

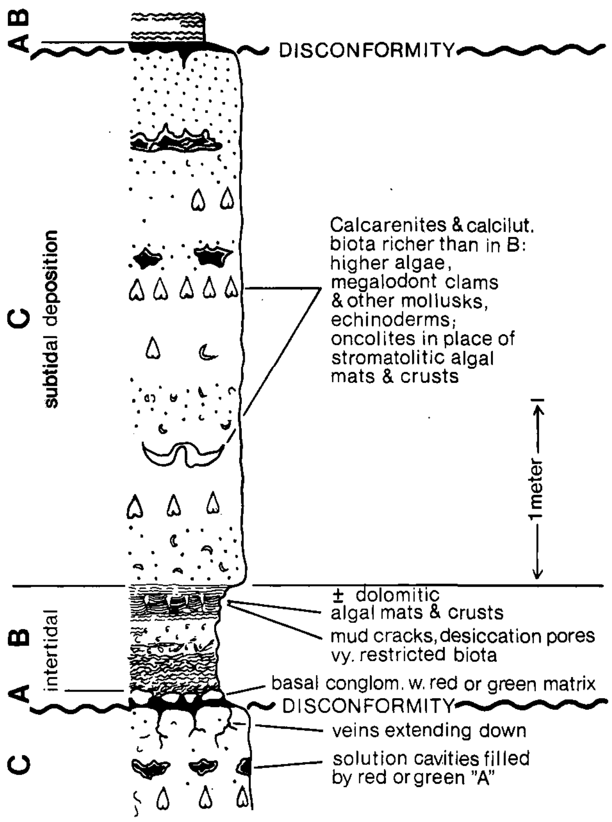

Fig. 34: Diagrammatic representation of the Lofer cyclothem: A — basal, argillaccous member, representing reworked residue of weathered material (red or green) commonly confined to cavities in underlying limestone. B — intertidal member of *loferites* with algal mats and abundant desiccation features. C — subtidal *megalodont limestone* member, with cavities produced by desiccation and solution during succeding drop in sea level (after A. G. FISCHER, 1964).

Beds (stop 6.2.). The underlying fine clastic Nierental Beds are visible in the north. The Nierental Beds represent a timespan (Campanian—Maastrichtian) of corresponding sedimentary conditions in the widespread Gosau basins.

The original position of the Hallstatt facies has been passionately discussed since a long period. Most of the prominent authors of our century considered the Hallstatt facies occurrences as individual nappes of divergent origin. The writer, however, follows the opinion of ZANKL (1962) who revitalized the old channel idea of MOJSISOVICS (1903). In fact, overthrusting during the Alpine movements plays a certain role, especially between the massiv blocks of carbonate masses and the flexible Hallstatt series, but does not exceed local importance in the middle section of the Northern Calcareous Alps. Whereas, the idea of the synsedimentary sliding of considerable masses is getting more and more accepted (SCHÄFFER 1976; PLÖCHINGER 1974, Stop 6.5.).

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TOLLMANN, A. (1976): Der Bau der Nördlichen Kalkalpen. — 449 pp., Wien (Deuticke).

Route description: The route returns over the Paß Gschütt to Abtenau and continues as far as the Salzach valley.

Stop 6.4. Paß Lueg

Dachstein Formation, Lofer Cycle, member C
Top. sheet 94 Hallein

The Paß Lueg is situated at the northern end of a narrow passage of the Salzach valley between the Tennengebirge and the Hagengebirge, both built by Upper Triassic platform carbonates. Polished rocks on both sides of the road give evidence of remarkable glacial activity.

The bivale family Megalodontidae characterizes the benthos of the Lofer facies of the Dachstein limestone. It is generally accepted since A. G. FISCHER (1964), that the well-bedded Lofer facies of the Dachstein formation is a lagoonal sediment with more or less regular cyclothems. Prior investigations of SANDER (1963) and SCHWARZACHER (1948) brought similar results. FISCHER pointed out, that the sedimentation depth oszillated around the water level.

ZAPFE (1957) suggested, that occurrences of *Conchodus infraliasicus* STOPP. appear in live position. *Conchodus infraliasicus*, the Dachstein-bivalve, is well known in Austria and has the popular name "Kuhtritte" (cow-prints). In relation to the large size of the animals (fig. 36), the shell is relatively thin.

The exposed megalodont rich member C of a typical Lofer cycle (fig. 34) is interpreted to be of subtidal origin. In a normal cycle follows member A. A is the basal unit consisting of argillaceous limestone or shale as a matrix of reworked material, sometimes only filling cavities sometimes intruding into sheet cracks and mud cracks. It is distinctly coloured and interpreted as a modified soil from supratidal phases.

Member B consists of laminated intertidal beds — the Loferites. The mm-lamination is caused by algal mats in tidal emerging areas. This is testified by shrinking structurs and mud cracks. It is thought, that the environment is similar to modern tidal flats.

Megalodonts were excellently adapted for living in the mud. They are usually found in live position because of their inability to dig out after being buried under sediment.

Unit C can be several metres thick. Member B usually

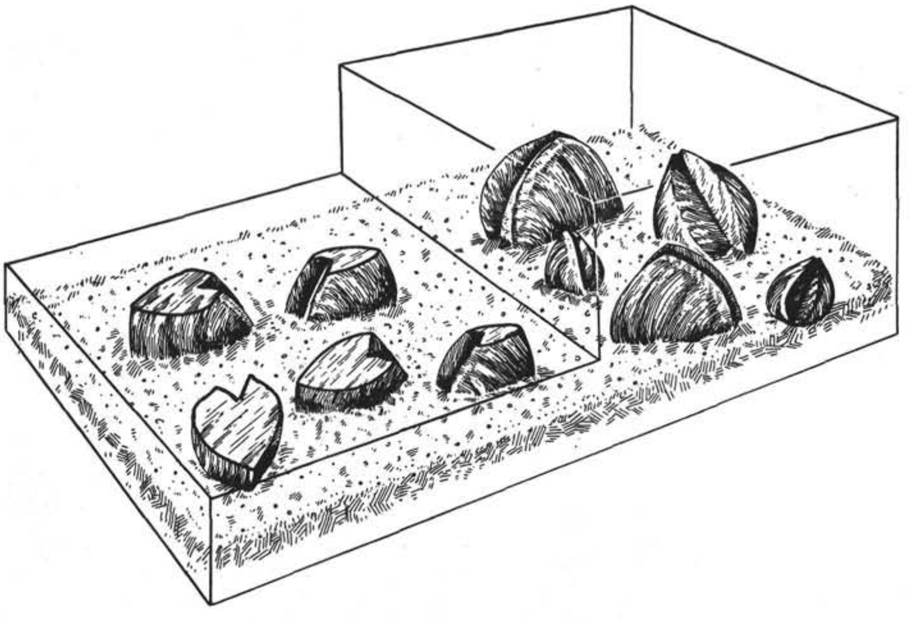

Fig. 35: Diagrammatic restoration of the live position of *Conchodus infraliasicus* (STOPPANI) (after ZAPFE, 1957).

does not measure more than 50 cm. Member A is of less importance. After FISCHER the Dachstein formation comprises about 300 cycles, each representing a timespan of 20.000 to 100.000 years. For the whole formation of 1.000 to 1.500 m thickness a timespan of 15 million years is calculated. To explain the mechanism of the Lofer cycles FISCHER assumed a periodical fluctuation of the sea level superimposing the general subsidence. After ZANKL (1971) it is necessary to assume a third criterion to give a full explanation: current activity should be an additional factor for mass distribution and regular bedding, additional to general subsidence and low amplitude eustatic sea level changing.

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ZAPFE, H. (1957): Dachsteinkalk und Dachsteinmuscheln. — Natur und Volk **87**, 87—94, Frankfurt.

Route description: Near the highway junction Golling exists a quarry on Torrener Nagelfluh. This Pleistocene conglomerate fills the glacially deepened Salzach valley until 338 m depth. This fact was the surprising result of the drill hole Vigaun of the ÖMV-AG (KRAMER & KRÖLL, 1977).

Thin-bedded limestones with chert nodules are to be seen on both sides of the highway from Golling to Hallein. These Oberalmer Beds (Upper Jurassic) will be visited and discussed at stop 6.6. Near Hallein the small village of Adnet is situated. It is famous for the Adnet Limestone of Lower Jurassic age, quarried since Roman times. It is a nodular thin-bedded swell sediment, ammonite rich and indicating subsolution and low rate sedimentation.

Stop 6.5. Dürrnberg near Hallein

(B. PLÖCHINGER) *)

Hallstatt Unit, Hallstatt Zone of Hallein—Berchtesgaden, Hallstatt Limestone (Norian)
Top. sheet 94 Hallein

The area around the top station of the cable car gives opportunity to study the lithologic character of the red Norian Hallstatt Limestone which is unbedded near the top station. Several sections of cephalopods are visible at the glacially overworked rock faces.

A nodular facies of bedded Hallstatt Limestone is well exposed in the old quarry behind the church or in the walls of the church itself. Faulting in the rock walls and cracks in the structure of the church are evidently caused by movements of the underlying saliferous beds

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Fig. 36: *Conchodus infraliasicus* (STOPPANI) — the Dachstein bivalve. Horizontal section through a colony in live position. Diameters from 12 to 18 cm. Original from the Paß Lueg in the Museum of Natural History, Vienna.

(Haselgebirge) which were mined in this area since prehistoric times (800 a. D.).

From the platform of the Dürrnberg church square there is a total view of the whole Hallstatt Zone of Hallein and its frame. The frame belongs to the Staufen-Höllengebirge Nappe (Tirolian Nappe System). A first impression may already be gained during the cable car ride. Note the prehistoric excavation area of the La Tene period.

The Hallstatt Zone of the Hallein—Berchtesgaden area is divided (fig. 37, 38) into two tectonic slices. Stop 6.5. is located within the higher southeasterly unit, which contains the greater part of the saltbearing Haselgebirge.

The question of the emplacement of the Hallstatt Unit in general has been subject of controversies. On the one hand there is a renewed tendency to consider the Hallstatt zones as having originated in the area which they occupy today, as did Mojsisovics with his idea of the Hallstatt channels; on the other hand, since it was proposed by O. Ampferer (1936), the assumption of a long distance transport of the Hallstatt Unit of the Hallein-Berchtesgaden area towards the north gained wide recognition. Moreover, as both, the series of Hallstatt outliers at the basis of the Berchtesgaden nappe (Higher Juvavicum) as well as the outliers of the Roßfeld area overlie Neocomian series one tended to consider the wide Hallstatt Unit of the Hallein-Berchtesgaden area as having been thrust in post-Neocomian times.

Recent studies of the author led to the conclusion, that the whole Hallstatt Unit of Hallein (Haselgebirge, Triassic and Liassic) has been buried by the deposition of the Tithonian Oberalm Beds which now surround the Hallstatt Unit with steep to overturned strata at the surface. However, the Hallstatt Unit itself is resting upon Oberalm Beds which was proved by drillings in the salt mine. These facts as well as experiences obtained from outliers east of Golling support the assumption of intra-Tithonian sliding events of enormous dimensions. It seems possible that the entire mass of the Hallstatt zone of the Hallein-Berchtesgaden area, some 10 km long, slid into sediments of the Tithonian Oberalm Beds.

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Geological map

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Stop 6.6. St. Leonhard

(B. Plöchinger)

Oberalm Fm., Schrambach Fm., Roßfeld Fm.
Top. sheet 93 Berchtesgaden

The subject of this stop is to study a section of the Tithonian-Neocomian formations of the Staufen-Höllen-

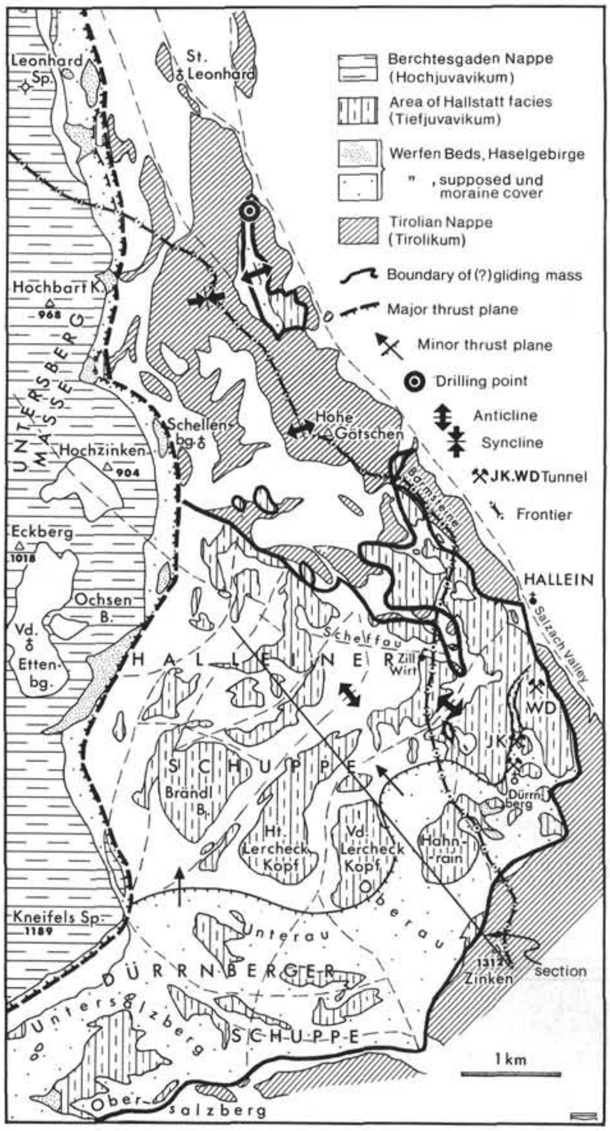

Fig. 37: Structural sketch-map of the Hallein area (B. Plöchinger).

gebirge Nappe in the quarry of the Gebrüder Leube Portlandzement factory (fig. 39). A 60 m thick series of the Oberalm Formation (Tithonian-Berriasian), a 120—130 m thick series of the Schrambach Formation (Valanginian) and the Roßfeld Formation (Upper Valanginian-Hauterivian) is exposed.

Within the Oberalm Formation one may observe a NNW-SSE-striking anticline (Schneiderwald-Anticline), in the center of which a 1 km long body of Haselgebirge is to be found. The Oberalm Formation of the anticline shows cyclothems containing allodapic sediments (Tonflatschen breccia, Barmstein Limestone), which are characterized by their content of components of upper Permian Haselgebirge and of Malmian shallow-

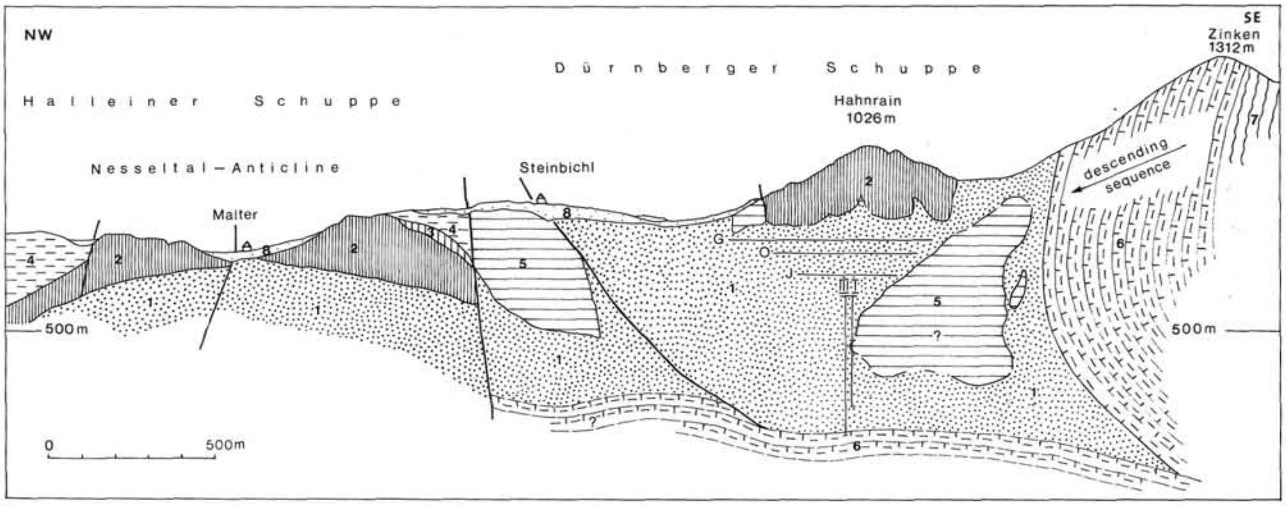

Fig. 38: Section across the Halleiner Schuppe and Dürnberger Schuppe (B. PLÖCHINGER). Location see fig. 37. 1 = Haselgebirge (salt-bearing evaporites); 2 = Anisian dolomite; 3 = Zill (Steinalm) limestone; 4 = Lercheck limestone; 5 = Upper Triassic limestone; 6 = Oberalm Beds; 7 = Schrambach Beds; 8 = Moraines; I, III = Drillings below the Hahnrain.

water limestones and can be considered as mud-current breccia, fluxoturbidites and turbidites.

While Cyclothem 1 begins with the large Haselgebirge body, each of the other cyclothems begins with a middle to coarse-grained breccia, rich in clay of the Haselgebirge and named Tonflatschenbrekzie. In Cyclothem 2 this breccia is 3—4 m thick and in cyclothem 3 only 2,5 m (fig. 39). This shows a rhythmic decrease of the transport of allodapic material towards more pelagic sediments of the clayey Oberalm Limestone, which itself belongs to the coccolith-tintinnid-radiolarian facies.

Spherical chert components of the Oberalm Limestones often contain in their center upper Permian Haselgebirge. This is explained by the rise in salinity of seawater due to the salt content of turbiditically-introduced Haselgebirge. It may have caused a decrease of the solubility of silicium and the precipitation of the already dissolved silicium.

A deep drilling project of the Österreichische Salinen

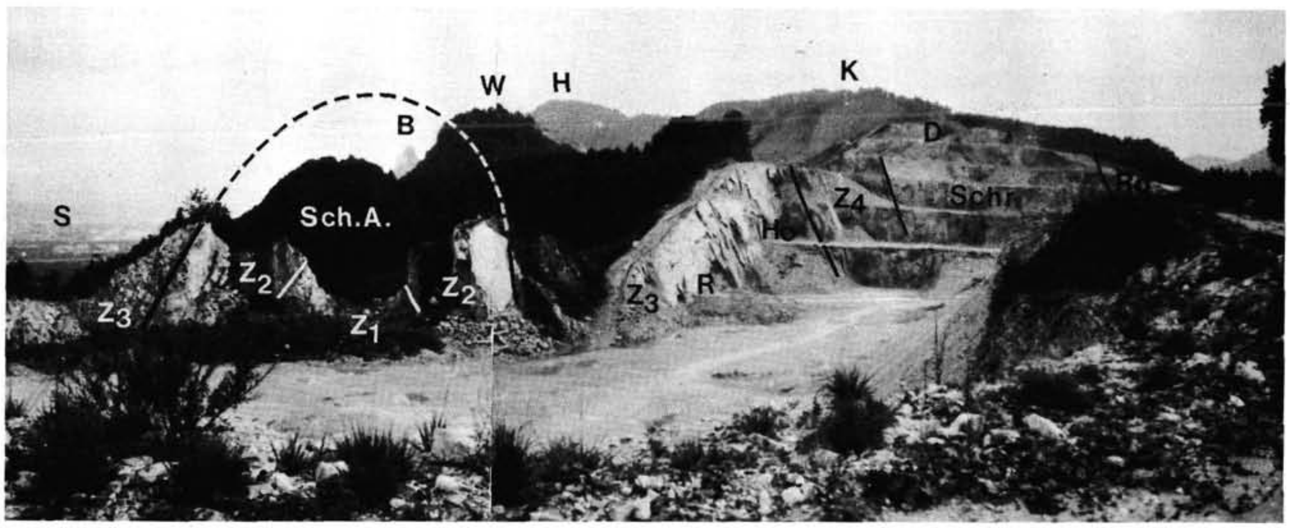

Fig. 39: The quarry of the cement factory Gartenau/St. Leonhard. Floor in 575 m. B = Barmsteine; D = Denninghöhe; H = Hohe Götschen; Ho = Chert globes with Haselgebirge core; K = Köppelschneid; R = Bedding plane with ripple marks; Ro = Roßfeld Beds (Neocomian); S = Salzach valley; Sch. A. = Schneiderwald Anticline; Schr = Schrambach Marls (Neocomian); W = Wulzlkopf; Z_1—Z_4 = Cyclothems of the Oberalm Beds (Tithonian).

(Austrian Salt Works) proved the assumption that the Haselgebirge body, which lies after a transversal movement at the center of the Schneiderwald Anticline, glided synsedimentarily into its present position during the Malmian (fig. 40); it was transported, together with a Triassic-Liassic intercalation, as a sedimentary clippe of Hallstatt facies type, into the sediments of the Oberalm Formation. Thus, the gliding of the Hallstatt outliers into the sediments began in the Tithonian, as is now also known from the area east of Golling. This process ended after the sedimentation of the upper Roßfeld Formation and of the lower Aptian Grabenwald Formation. The components of the allodapic sediments in the Oberalm Formation of our locality indicate that the gliding process began with an undersea updoming, caused by salt diapirism.

The Schrambach Formation (Lower Valanginian) occurring in the quarry (with ammonites of the genera *Olcostephanus, Berriasella, Neolissoceras* and with *Lamellaptychus,* foraminifers, radiolaria and nannoflora) consists of light gray, limy marls and marly limestones. In their highest parts they contain a four meter thick

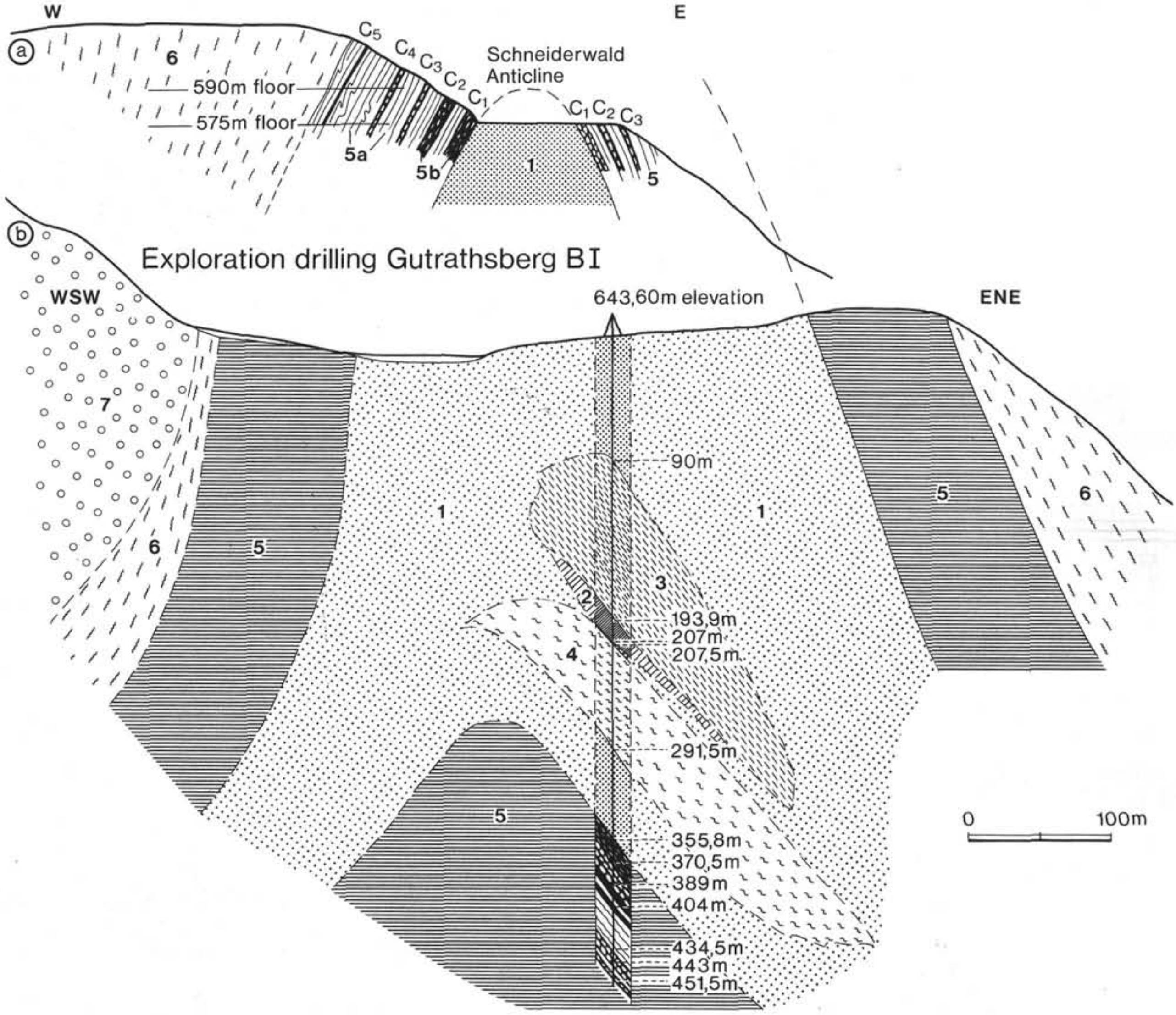

Fig. 40: Sections across the Schneiderwald Anticline in the quarry of the cement factory Gartenau/St. Leonhard (a) and the site of the exploration well Gutrathsberg (b) (B. Plöchinger). 1 = Haselgebirge clay; 2 = Halobia Beds (Carnian); 3 = Dolomite (Upper Triassic); 4 = Mottled Marls (Lias); 5 = Oberalm Beds (Tithonian-Berriasian); 5 a = Argillaceous Oberalm Beds; 5 b = Allodapic intercalations (Barmstein Limestone, breccias with abundant Haselgebirge clay); 6 = Schrambach Beds (Valanginian); 7 = Roßfeld Beds (Neocomian).

horizon of packed, bedded marly limestone, the limestone-clay proportion of which corresponds to that of portland cement. Above the relatively thin layer of the reddish, marly limestones of the Anzenbach Formation, there begins, marked by a rise in sand content, the only thin developed unit of gray, sandy marls of the Lower Roßfeld Formation, which are of upper Valanginian and Lower Hauterivian age. The sandstone member of the Lower Roßfeld Formation is missing here; the marls of the Lower Roßfeld Formation are immediately below the conglomerate (olisthostrome-rich upper Roßfeld Formation of the Hauterivian).

Geological map

Prey, S. (1969): Geologische Karte der Umgebung der Stadt Salzburg, 1 : 50.000. — Geol. B.-A., Wien.

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Plöchinger, B. (1977): Die Untersuchungsbohrung Gutrathsberg B I südlich St. Leonhard im Salzachtal (Salzburg). — Verh. Geol. B.-A. **1977**, H. 2, 3—11, Wien.

Route description: On the way northward we pass a small ridge of Gosau sandstone with the castle Glanegg on top. It is the type area for several Coniacian ammonites described by Redtenbacher (1873). The city of Salzburg itself is situated at the river side of the Salzach between the "Nagelfluh" mountains of the Mönchsberg (Hohensalzburg castle) and the Kapuzinerberg.

Day 7

Salzburg (half day individual program), Molasse Zone
Route: Salzburg — Kremsmünster

Route description: We are leaving Salzburg eastwards on the Autobahn (highway). The first section of the route lies within the Flysch Zone. The topography shows strong glacial influence (moraine ramparts, glacial tongue basins). Near the junction Thalgau a large sand pit is visible with gravel and sand of glacial origin. Near the northern end of the Attersee we enter the Molasse Zone which is generally covered with glacial drift from the Alpine rivers.

The scenic Salzkammergut lakes are situated in the position of the Pleistocene tongue basins behind the end moraine walls of Würmian age. A small tectonic window of the Helvetic Zone (Gschliefgraben) situated between the Grünberg near Gmunden and the high walls of the Traunstein should be mentioned. It appears within Flysch series and contains sediments from the Jurassic (Gryphea Beds) to Eocene age (Nummulite sandstone). Abundant ammonites, echinoderms, spongues characterize the Upper Cretaceous sediments of the Gschliefgraben window.

The oil pumps near Kremsmünster are producing from the Molasse basin.

Stop 7.1. Kremsmünster

Molasse Zone (Palaeogene—Neogene), Pleistocene, Abbey of Kremsmünster
Top. sheet 50 Bad Hall

The famous Abbey of Kremsmünster was founded in 777 p. D. by Tassilo, Duke of Bavaria, the unlucky antagonist of Charles the Great. Besides the abundance of various cultural treasures the abbey is famous for a unique astronomic observatory from the 17th century. It contains a museum which has been restored on the occasion of the 1.200 years jubilee of the monastery. The Cabinet for Geology and Paleontology was renewed by one of the authors (Summesberger) together with H. A. Kollmann (Museum of Natural History, Vienna). The collection is of more than local importance and is a cultural monument itself. The main stock of objects dates from the 17th century too.

Room no. 4 contains a newly arranged exhibition on the paleogeographic situation of the Molasse basin in Upper Austria. The following comments are closely related to this subject.

The Upper Austrian Molasse Zone, a Geological Review

(O. Malzer) *)

The Molasse Zone of Upper Austria (fig. 41) is part of the Paratethys that accompanies as a Tertiary foreland basin the Carpatho-Alpine ranges along their northern edge from Romania in the east, through Czechoslovakia, Austria and Germany into Switzerland. It can be characterized as an asymmetric trough (fig. 42), filled during the Paleogene and Neogene with largely marine detritic sediments of predominantly Alpine origin and overthrust in the south by the northernmost Alpine units. Wedged between autochthonous Molasse and the Alpine nappes is a sheet of imbricated Molasse and older rocks, which have been sheared off by the nappe-movement further south. This unit is known as the Subalpine Molasse.

In Lower Austria, where the Alpine nappes almost meet the south-eastern spur of the Bohemian Massif, the Molasse basin is rather shallow and narrow. It

*) Dr. Otto Malzer, Rohöl-Aufsuchungs Ges.m.b.H., Schwarzenbergplatz 16, A-1015 Wien.

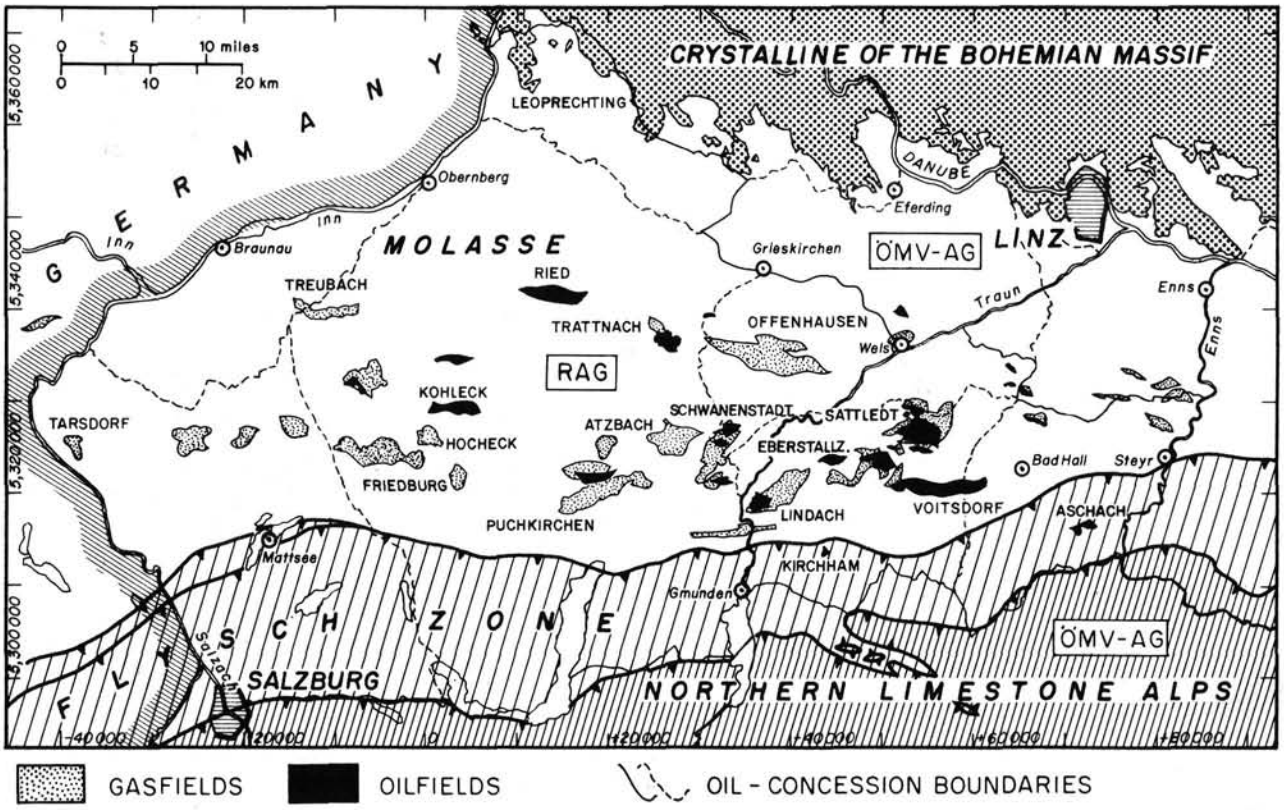

Fig. 41: Generalized Geological Map of the Molasse Zone in Western Austria (Upper Austria and Salzburg) showing its outline and tectonic frame and the distribution of gas and oil fields within the basin.

widens and deepens westwards throughout Upper Austria into Germany, where it attains its maximum width of 140 km. Width in Upper Austria is between 25 and 50 km — the overthrust part not included. The depth increases from zero at the northern rim to 2000 m at the mountain front near the river Enns and over 4000 m at the Austro-German border north of the city of Salzburg.

The substrate of the Molasse basin in Austria is the Bohemian Massif with granites and high grade metamorphics of Paleozoic age. It has a rather subdued relief and is overlain by an incomplete Mesozoic sediment cover. Very small relics of Permo-Triassic continental deposits have also been found. Widespread clastics, usually assigned to the Upper Carboniferous, are probably of Middle and Upper Jurassic age. From then on, the southern part of the Bohemian Massif has been submerged twice, as is testified by up to 400 m of Jurassic sediments, mainly limestones and dolomites in Franconian facies, and up to 1000 m of Upper Cretaceous. The latter sequence consists entirely of clastics, deposited in shallow marine environment. In late Creta-

GEOLOGICAL CROSS SECTION THROUGH THE MIDDLE PART OF THE MOLASSE ZONE OF UPPER AUSTRIA

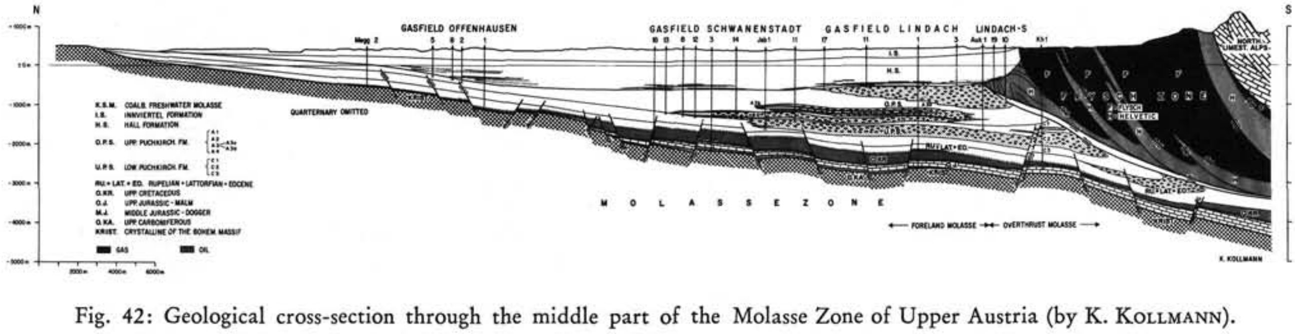

Fig. 42: Geological cross-section through the middle part of the Molasse Zone of Upper Austria (by K. KOLLMANN).

ceous, regional NNW-SSE faulting has dissected the Mesozoic platform into large tilted blocks. Finally the whole area has fallen dry again and was exposed to intensive erosion during Middle Campanian to Middle Eocene.

beginning of the Molasse era. Up to 120 m of shale, sandstone, and algal limestone were initially deposited under fluviolimnic, paralic, and shallow marine conditions, followed by the thin Fishbearing Shale — an excellent source rock for oil —, marly limestones, and

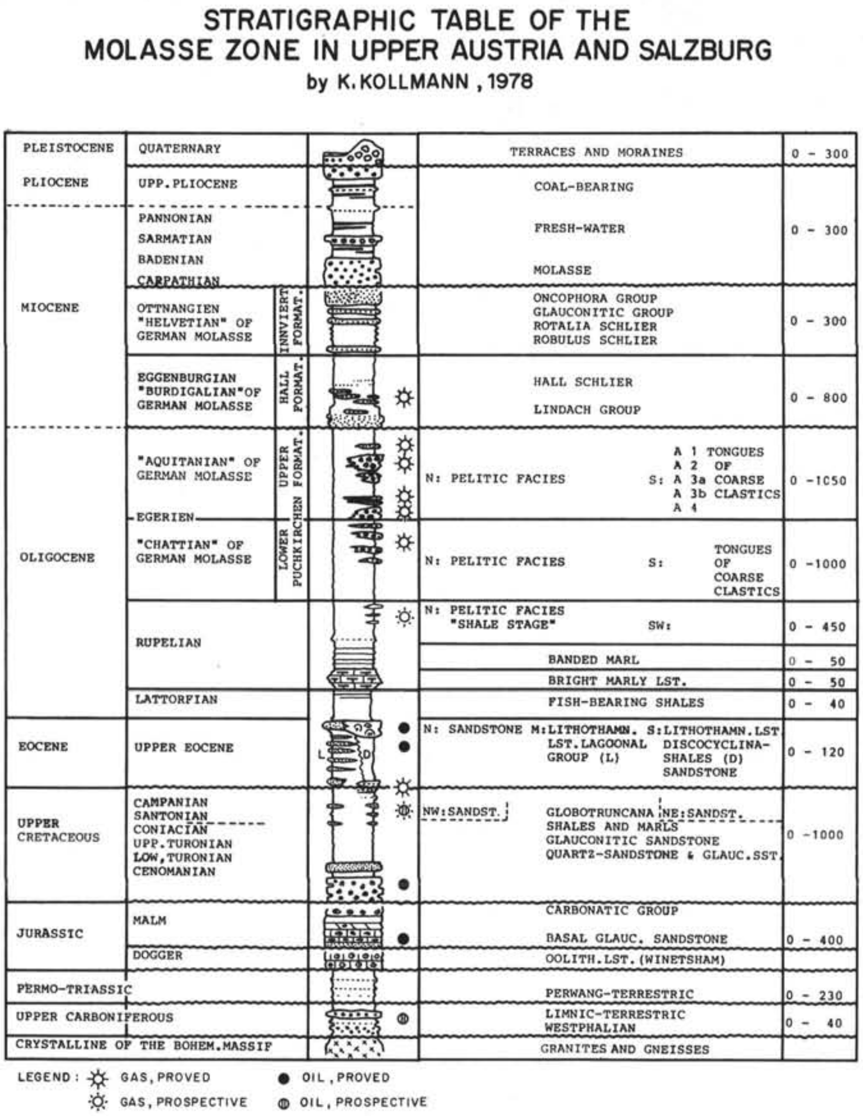

Fig. 43: Stratigraphic table and column of the Molasse Zone in Upper Austria and Salzburg (by K. KOLLMANN).

Jurassic and Upper Cretaceous contain clastic reservoir rocks, which are oil- and gas productive in a number of small fields, generally associated with the younger Eocene. No obvious Mesozoic source rocks have yet been identified.

In the Upper Eocene, renewed subsidence and slow marine transgression, starting form the Helvetic sea in the SW and advancing NE, properly mark the

marls. Source area of these early Molasse sediments is the Bohemian Massif. In the Middle Oligocene, however, the new basin began to tilt strongly towards the south and at the same time started to be filled with sediment derived from the Alps in the south. This unilateral subsidence was accompanied by E-W tensional faulting, which has created the majority of the oil traps at the base of the Tertiary, and which died out towards the end of the Oligocene. There is also most likely a connection between tilt of the basin and oil migration.

The Alpine debris, now discharged into the foreland basin, was fine grained at first. In late Rupelian and throughout the Egerien, however, up to 1500 m of gravels and sands accumulated on deep-sea fans in a relatively narrow belt parallel to the Alpine front. Fan deposition migrated north as Flyschzone and Helvetic Zone were mobilized and glided into their fore deep. These fans, deposited in perhaps 1000 m of water, interfinger northwards with the shales of the basin. They contain the bulk of the younger Molasse gas, which is of biogenic origin, in predominantly stratigraphic traps and flat compaction structures.

At the end of the Oligocene, the Alpine front stabilized and at the same time the supply of coarse material greatly diminished. What remained of the Molasse basin — the width was reduced to no more than 35 km — was filled mainly with pelites during the Miocene. Minor sand deposits are found along the flat northern and the steeper new southern coastline and over shoals in central parts of the basin. These sands also contain significant amounts of gas.

Eventually, subsidence appears to have ceased and during deposition of the Innviertel Formation the sea began to retreat for the last time from the Upper Austrian foreland basin. The Molasse sequence ends with limno-fluvial gravels containing some poor lignite seams of the Lower Pliocene.

The youngest sediments in the area are moraines and periglacial gravels of the Pleistocene, which mainly form the surface relief.

Since 1955 almost 100 exploration wells have been drilled in the Molasse zone of Upper Austria and Salzburg by two oil companies — RAG (50% Mobil, 50% Shell) and ÖMV-AG (Austrian National oil company) — and some 30 small oil- and gas fields have been discovered and developed. Daily production averages approximately 900 tons of oil and 2 million m^3 of gas. Exploration is gradually moving into the more complex areas like the overthrust Molasse in the south.

From the top of the observatory one can study the Pleistocene topography. The region of Kremsmünster became one of the classical areas for Pleistocene geology because of the well developed terrace landscape. The main glaciations of the Pleistocene age are represented by moraines and accompanying terraces (fig. 44). The Abbey itself is founded in gravels of Riss age.

Reference

KOHL, H. (1970): Das Quartärprofil von Kremsmünster. — Geogr. Jber. aus Österreich **33**, 82—88, Wien.

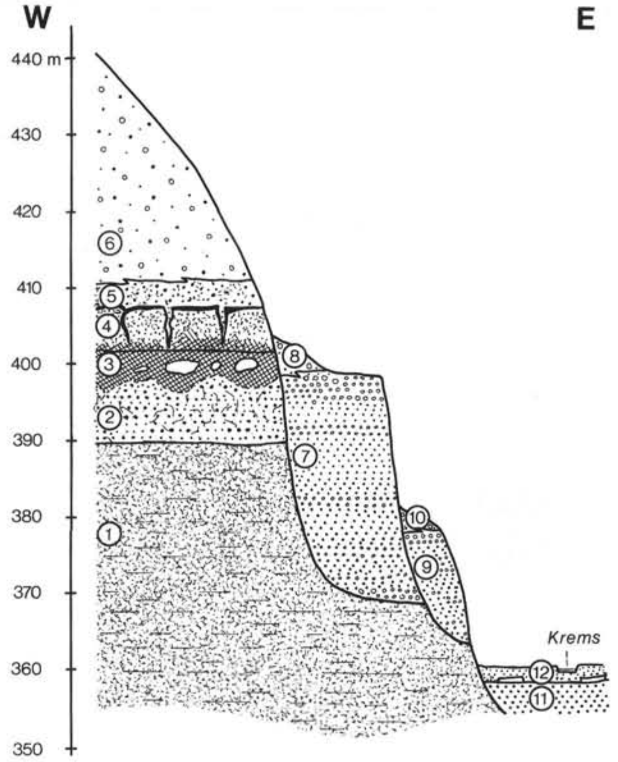

Fig. 44: Section through the western side of the Krems valley, 3 km south of Kremsmünster (after KOHL, 1977). 1. Mid-Miocene clay (Robulus Schlier); 2. Günz glacial advance gravel; 3. Günz moraine; 4. White Carbonaceous conglomerate (Weiße Nagelfluh); 5. Mindel Glacial advance gravel (Mindel), (Graue Nagelfluh); 6. Mindel moraine; 7. Gravel terrace (Riss); 8. Riss moraine (end moraine); 9. Gravel of late Riss time; 10. Late Riss moraine; **11.** Würm periglacial gravel (Würm); 12. Holocene gravel and loam. Subfossil oak trees at the base.

Day 8

Gresten Klippenzone, Northern Calcareous Alps, Window of Brettl, Molasse Zone

Route: Kremsmünster — Großraming — Großreifling — Lunz — Brettl — Zelking.

Introduction

The program of this day is to give some important complementary information about the previously studied major tectonic units of the northern part of the Eastern Alps and to repeat the general structural situation at the northern front of the Eastern Alps.

R o u t e d e s c r i p t i o n: We are leaving Kremsmünster eastward as far as Steyr where we turn southwards following upstream the river Enns. Fluvius anisius was the Roman name of this river from which the term for the Anisian stage is derived. Immediately south of Steyr the route is crossing the Flysch Zone. Near Ternberg we enter the Northern Calcareous Alps. At Großraming the route leaves the Enns valley for the visit of the LEOPOLD VON BUCH memorial. The small road through the Pechgraben at first passes a sequence of Jurassic and Cretaceous rocks at the northern front of the Calcareous Alps, then a narrow section of Flysch Zone and arrives in the Gresten Klippenzone which appears below the Flysch Zone.

Stop 8.1. LEOPOLD v. BUCH Memorial

(W. SCHNABEL) *)

Granite of the LEOPOLD v. BUCH memorial, Gresten Klippenzone
Top. sheet 69 Großraming

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

LEOPOLD VON BUCH (1774—1853), one of the great predecessors of European geology, was very much envolved into the historic controversy about the origin of rocks in general and of granites in particular. As a student of ABRAHAM GOTTLOB WERNER he initially supported the neptunistic theory. Later on he changed his mind and became one of the opinion leaders of the plutonists. His conceptions were critically respected by J. W. GOETHE in his famous papers "Die Natur" and "Der Granit". Numerous fossils named after L. v. BUCH keep his name in dignified mind.

According to P. FAUPL (1972) the major constituents of this coarse-grained granite to granitegneiss are quartz, plagioclase (An-content appr. 23%), pink alkalifeldspar (microcline), biotite, and chlorite. Epidote, sericite, apatite, titanite, zircon and magnetite are the accessories. A parallel fabric is very well developed. The granite underwent diaphthoritic metamorphism (partial

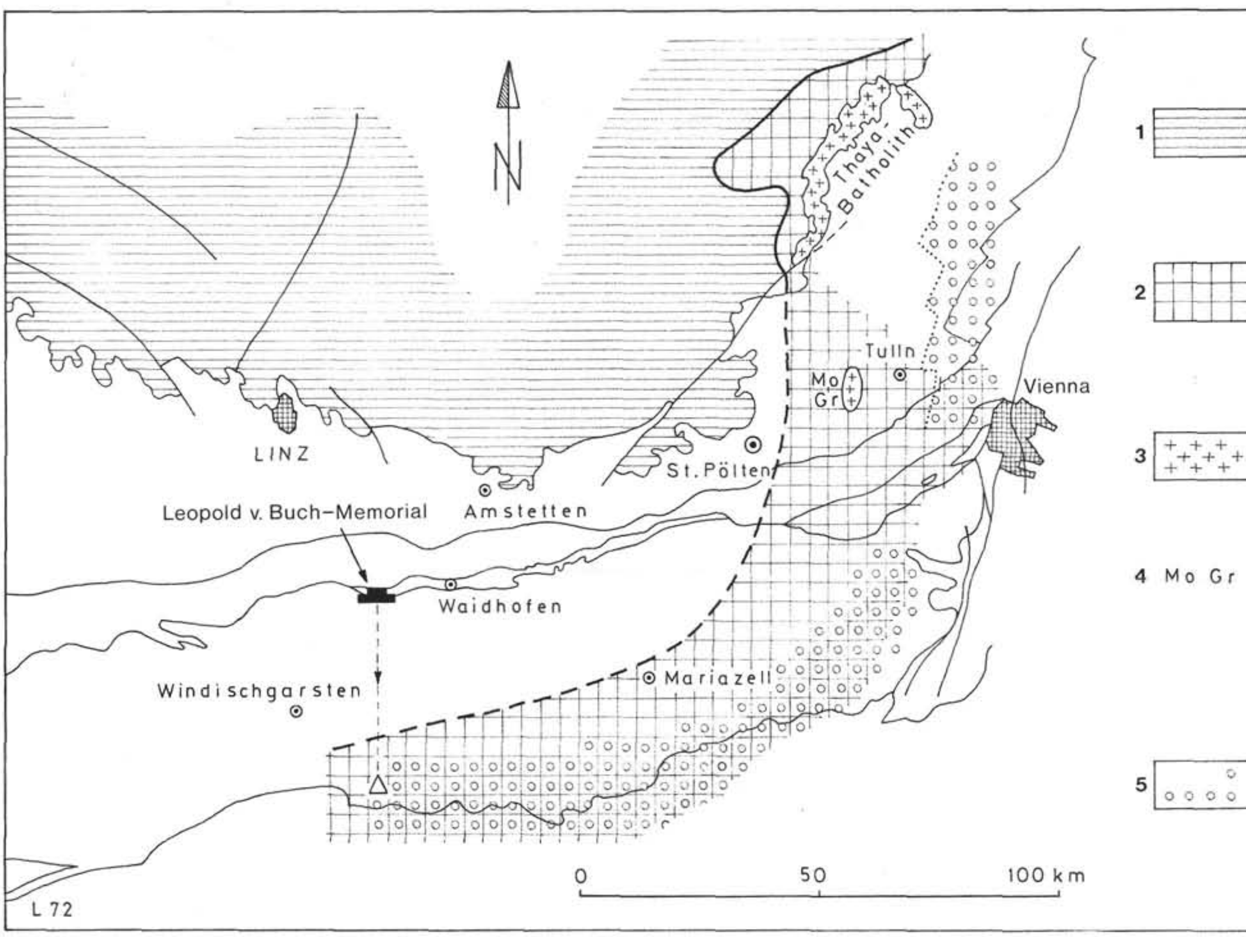

Fig. 45: Interpretation of the paleogeographic relationship between the crystalline baserock of the Gresten Klippenzone and the Moravian Zone of the Bohemian Massif (after FAUPL, 1973). 1 = Crystalline basement of the Moldanubian Zone; 2 = Crystalline basement of the Moravian Zone; 3 = Moravian granites and granodiorites; 4 = granodioritic massif of Moosbierbaum under the Molasse; 5 = Facies area of the Mesozoic of the klippen cores and the autochthonous Mesozoic upon the Bohemian Massif under the Molasse Zone.

alteration of biotite into chlorite as well as of plagioclase into microlites of epidote and sericite; evidence of pumpellyite, recognized by G. FRASL 1978). There is a single amphibolite layer which shows also retrograde alteration.

The granite resembles some rock types of the Thaya Batholith of the Moravian Zone. This is the background of the paleogeographic interpretation of P. FAUPL (1972) illustrated in fig. 45. The granite of the L. v. BUCH memorial is located in the Gresten Klippenzone which is correlated with Ultrahelvetic series in the western part of the Eastern Alps. The granite is now interpreted as a slice of the pre-Liassic crystalline base of the sedimentary Gresten Formation. Reworked material is found in the basal conglomerates of the Gresten Formation (Lias) and in Eocene conglomerates of the Buntmergelserie. The Buntmergelserie is a series of red

kom) von Ober- und Niederösterreich. — Jb. Geol. B.-A. 118, 1—74, Wien.

LÖGTERS, H. (1937): Zur Geologie der Weyrer Bögen, insbesondere der Umgebung des Leopold von Buch-Denkmals. — Jb. Oberösterr. Musealverein 87, 369—437, Linz.

Route description: Returning to Großraming the route continues upstream the Enns valley crossing the Weyrer Bögen structure where the internal structures of frontal parts of an eastern section of the Northern Calcareous Alps are gradually turning from their longitudinal east-west trending into a transverse north-south direction with evidence of westward thrusting. The subsidiary nappes known from the calc-Alpine front, f. e. the Ternberg and Reichraming nappes in the west and the Frankenfels and Lunz nappes in the east, were recognized to correspond in both, structural position and facies (P. STEINER, 1965).

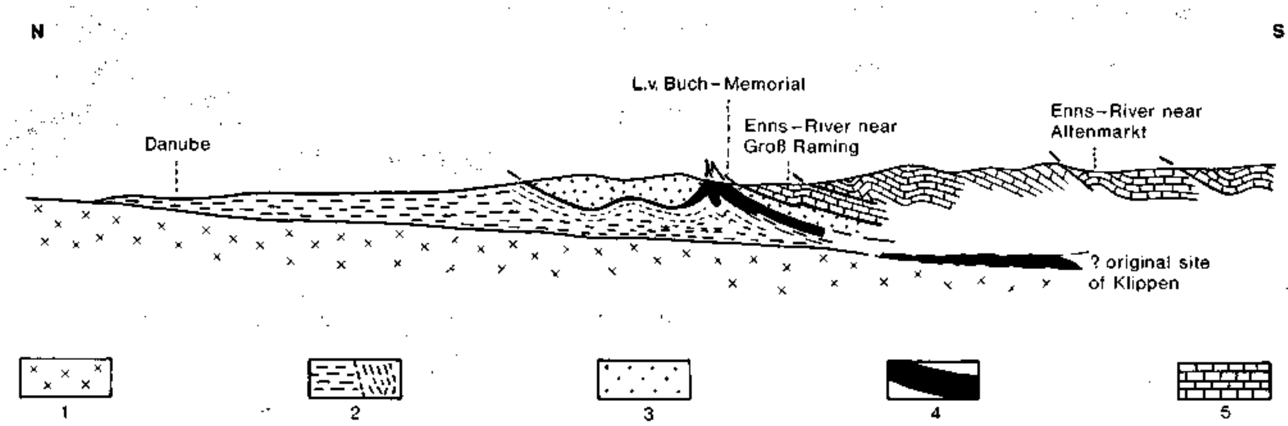

Fig. 46: Section through the northern part of the Eastern Alps in the meridian of the Leopold von Buch Memorial (W. SCHNABEL). 1 = Crystalline rocks of the Bohemian Massif; 2 = Molasse Zone; unfolded, folded; 3 = Flyschzone, 4 = Gresten Klippenzone; 5 = Northern Calcareous Alps.

and greenish carbonaceous marls with rich faunas of planctonic foraminifera. It is the original sedimentary cover of the Gresten Klippenzone.

The tectonic position of the Gresten Klippenzone is now interpreted to be par-autochthonous. Its original position is believed to have been at least 40 km in the south (fig. 46). The main thrust movements are of late-Alpine age (Oligocene—Eggenburgian) with a crucial point in the Egerian. The whole klippen belt is tectonically extremely stressed and considered as a tectonic carpet of the Rhenodanubian Flysch. It now appears in a chain of small windows at the southern margin of the Flyschzone.

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FAUPL, P. (1973): Der Granit des Leopold von Buch-Denkmales (Vorbericht). — Anz. Österr. Akad. Wiss., math.-naturwiss. Kl. 109, 158—164, Wien.

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Near Küpfern the overturned front of the Lunz Nappe (mainly of Wetterstein Fm.) is visible at the opposite side (SW) of the Enns valley.

Stop 8.2. Großreifling, Styria

Reifling Formation, Anisian/Ladinian Stage
Top. sheet 100 Hieflau

The locality Großreifling situated at the junction of the rivers Salza and Enns is known as the type locality of the lithostratotype for the Anisian/Ladinian Reifling Formation, as well as of the stratotype for the Anisian stage of the Triassic.

The Reifling Formation is a widespread representative of the facies intermediate between the mid Triassic reef/lagoonal facies (Wetterstein Formation) and the shaly basin facies (Partnach Formation). The dark grey Lower Reifling Formation is a nodular limestone with shaly coatings between the strata. The microfacies con-

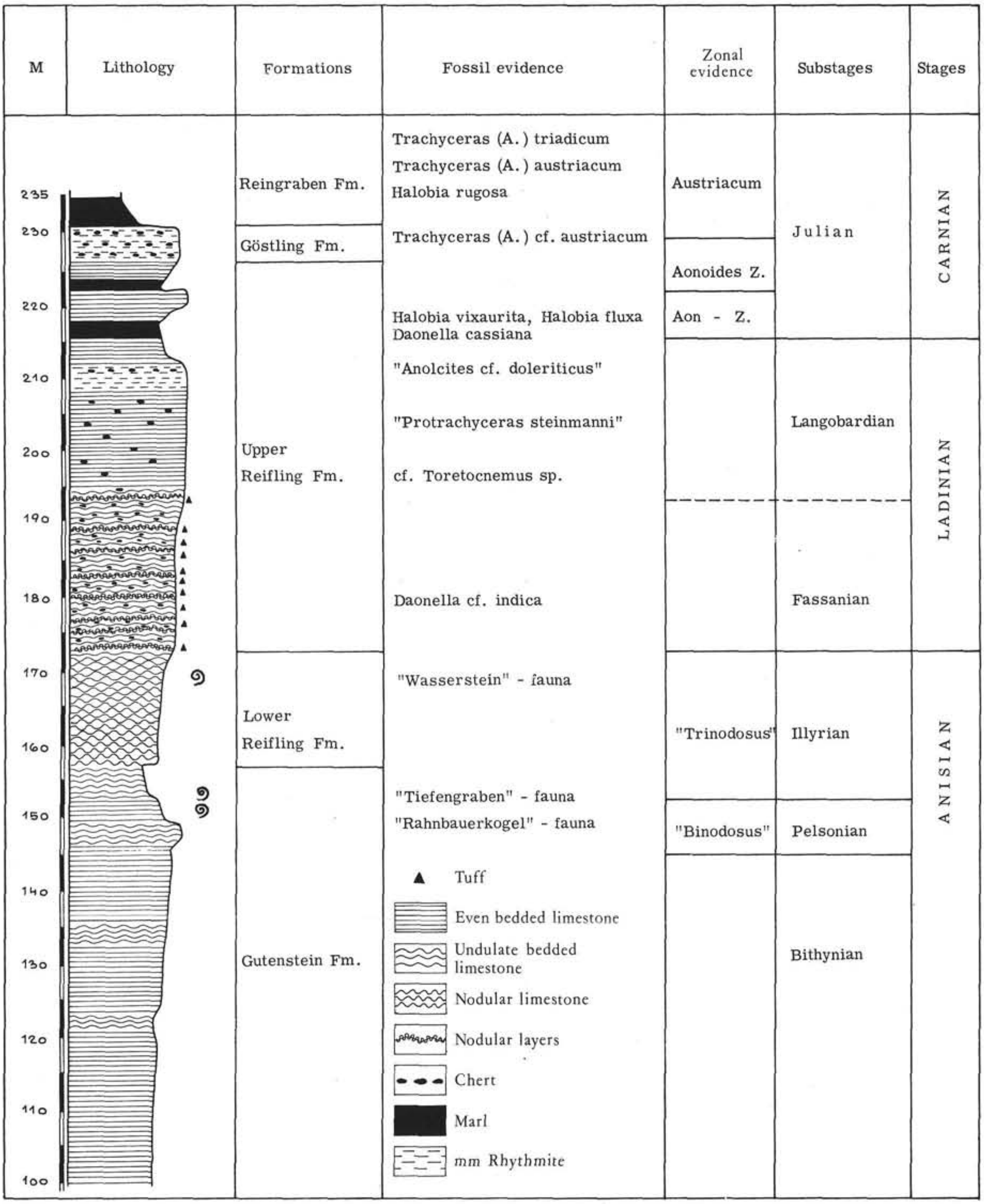

Fig. 47: Lithostratigraphic and biostratigraphic sequence of Großreifling (after SUMMESBERGER & WAGNER 1972; modified after KRYSTYN 1978, ASSERETO 1973).

sists of spiculae and radiolarians. The cephalopod fauna (Wasserstein Fauna) indicates Upper Anisian age. The Upper Reifling Formation is a well-bedded limestone with irregular stylolithic bedding planes. Additional characteristics are the interbedded tuffs, chert layers and chert nodules. Abundant *Daonella* and *Halobia* and the ammonite genus *Protrachyceras* prove Ladinian age. Marl intercalations (now under water level of the reservoir) indicate facial overlap to the Partnach Formation (SUMMESBERGER & WAGNER, 1972, Taf. 2).

A stratigraphic sequence of four ammonite bearing horizons (fig. 47) predestinates Großreifling to be one of the best sections for international correlation of the Anisian. It was originally proposed by MOJSISOVICS, WAAGEN & DIENER (1895) as type section of their Anisian stage. In those days only two ammonite bearing horizons have been known. Meanwhile four ammonite assemblages of Anisian age have been discovered: the Rahnbauerkogel Fauna and the Tiefengraben Fauna, both belonging to the Binodosus Zone; the Wasserstein Fauna and the Gamsstein Fauna, belonging to the Trinodosus Zone. The historic definition of the Anisian stage included the Tiefengraben Fauna and the Gamsstein Fauna. The last revisions of the stage by ASSERETO (1971, 1973) brought clear definitions. ASSERETO (1973) added also two new stages according to the alpine practice to include the Gutenstein Formation into the prior Hydaspian which is not a valid name (SPATH, 1934).

The generally accepted new scheme (Symposium Vienna, 1973) should help (tab. 8) to avoid further

Anisian Stage	Upper	Illyrian
		Pelsonian
	Lower	Bithynian
		Aegean

Tab. 8: ASSERETO's proposal for subdivision of the Anisian stage, generally accepted at the symposium 1973 in Vienna.

confusion. Further improvement is expected from a revision of the faunas. The principal faunal content is listed beneath.

Gamsstein Fauna: predominantly *Ptychites*, also *Bulogites*.

Wasserstein Fauna: *Paraceratites trinodosus* (MOJS.), *Piarorhynchia trinodosi* (BITTNER), *Mentzelia mentzeli* (DUNK.).

Tiefengraben Fauna: 18 genera, predominantly *Paraceratites, Balatonites, Norites, Acrochordiceras, Discoptychites, Ptychites; Nautilus.*

Rahnbauerkogel Fauna: 90% *Balatonites*, suggested to be closely related to *Balatonites balatonicus* (MOJS.) (ASSERETO, 1971).

The faunas of the Rahnbauerkogel and the Tiefengraben are originally described by ARTHABER's famous monographs (1896).

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ASSERETO, R. (1973): Aegean and Bithynian: proposal for two new Anisian substages. — The stratigraphy of the Alpine-Mediterranean Triassic, Symposium Vienna, 1973. — Österr. Akad. Wiss., Schriftenreihe erdwiss. Komm. **2**, 23—39, Vienna.

ARTHABER, G. v. (1896): Die Cephalopodenfauna der Reiflinger Kalke. I., II. — Beitr. Paläont. Geol. Österr. Ung. **10**, Wien.

SUMMESBERGER, H. & WAGNER, L. (1972): Der Stratotyp des Anis (Trias). — Ann. Naturhistor. Museum Wien **76**, 515—538, Wien.

Route description: The valley of the Salza is characterized by the steep banks of Pleistocene conglomerate terraces. Near Palfau the Gamsstein is visible on the left side of the route. It is mainly built up by Wetterstein Formation.

In the area of Lunz and Gaming Triassic coal occurrences gave rise for a considerable early industrialisation. Iron ore brought from the neighboured Erzberg was dressed and manufactured here. One ruin of a so-called *Eisenhammer* is still existing and visible near the road. Since that time (early 19th century) Austria is still exporting excellent scythes. The coal mines are abandoned now. The coal was produced from the Carnian *Lunz Formation*, which is composed of sandstones and shales. The associated shales bore a rich flora and an excellent fauna of fish and ammonites.

Stop 8.3. Brettl Window

(W. SCHNABEL)

Flyschzone below Northern Calcareous Alps.
Top. sheet 71 Ybbsitz.

Once the discovery of tectonic windows in the Eastern Alps and the geological consequences caused a revolution in the structural interpretation. But they are still fundamental facts regarding the structure of the Eastern Alps in general as well as of the Northern Calcareous Alps in particular.

In the depression of the small village Brettl (near Scheibbs, Lower Austria) sediments of the Rhenodanubian Flysch appear within the area of the Northern

Calcareous Alps 2 km south of the northern front. The window extends 3 km in east/west and 1,3 km in north/south direction. Despite the bad exposures a series from mid-Cretaceous to Campanian is evident.

Zementmergel series (Coniacian—Campanian): thin-bedded calcarenites and limy marls with abundant ichnofossils.

Reiselsberg Sandstone (Cenomanian—Turonian): typical Flysch sandstone rich in ichnofossils; marl intercalations.

Gaultflysch (Aptian—Albian): dark calcarenites, glauconitic sandstones, rhythmitic marl intercalations.

Coloured shales (Middle to Upper Cretaceous).

Additional series were identified as the pre-mid-Cretaceous base of the Flysch series.

Aptychus Limestone and spotted marlstone (Tithonian—Neocomian): Folded, steeply dipping series of coloured limestones to marlstones, some calcarenitic intercalations.

Radiolarian chert (? Upper Jurassic): thin-bedded red and green.

Picrite: isolated blocks.

The frame of the window is built by formations of the northernmost subsidiary nappe of the Northern Calcareous Alps in that region, the Frankenfels nappe, ranging from the Norian (Hauptdolomite) to the Neocomian (Schrambach Formation).

The structural situation of the Brettl window is illustrated in fig. 48.

R e f e r e n c e s

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R o u t e   d e s c r i p t i o n: The route continues eastwards and follows downstream the Erlauf valley. We are passing the tectonic window of Urmannsau which appears approximately 2 km SE of the village of Kienberg. This window within the Northern Calcareous Alps exposes sediments of the Frankenfels nappe below the surrounding Lunz nappe. It became perfectly documented by a drill hole of the ÖMV AG (KRÖLL & WESSELY, 1967). The drilling results give an overwhelming evidence of nappe structures in the Eastern Alps. Underneath 1990 m sediment series of the Frankenfels nappe lie 107 m of Flysch. 828 m of Gresten Klippenzone and Buntmergelserie are following below, interfingered by tectonic slices of the Subalpine Molasse. At last 80 m of autochthonous Molasse sediments were penetrated. The crystalline base of the Bohemian Massif was met in a depth of 3015 m.

Near Neubruck the route leaves the Northern Calcareous Alps. Around Scheibbs we are crossing the Gresten Klippenzone and the eastern part of the window of Rogatsboden in which Molasse sediments appear below Flyschzone and Gresten Klippenzone (fig. 48).

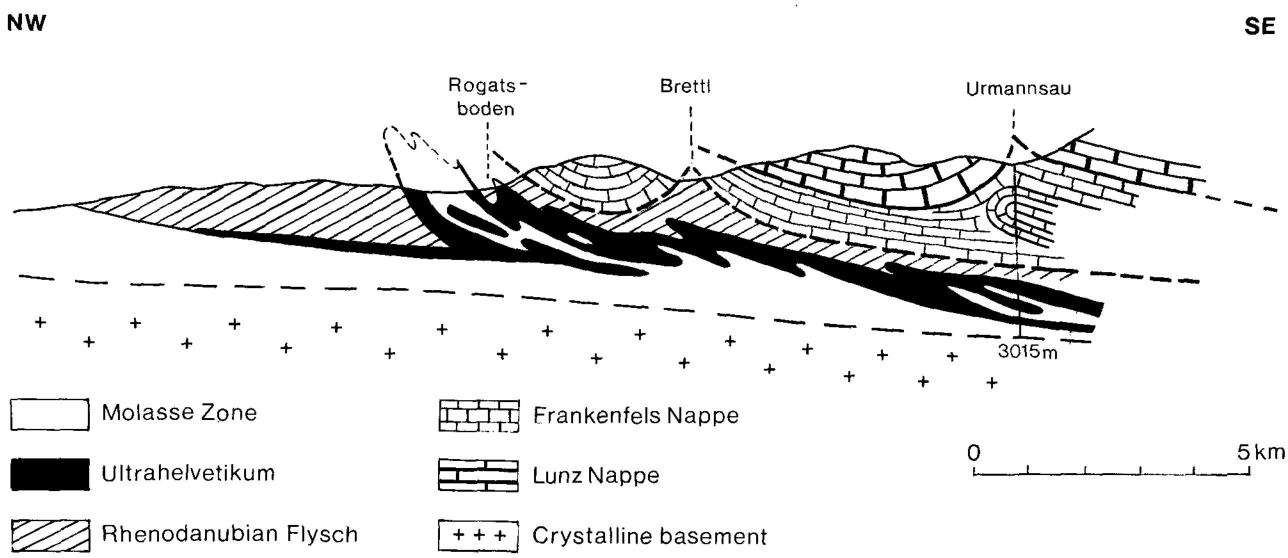

Fig. 48: Schematic section across the northern foothills of the Eastern Alps in western Lower Austria (W. SCHNABEL).

At Purgstall after crossing the Flyschzone, the route enters the Molasse Zone which is rather narrow in this region.

In the area around Wieselburg and north of it there are already several exposures of the crystalline basement represented here exclusively by granulites.

Stop 8.4. Zelking near Melk, Lower Austria

(A. Rögl & R. Roetzel) *)

Molasse Zone, Melk Sands, Pielach Clays
Top. sheet 54 Melk

Along the southern border of the Bohemian Massif in Lower Austria the Molasse sedimentation begins in the Oligocene and continues to the Early Miocene (Ottnangian). To the south the Molasse sediments are dipping down under the Alpine nappes. Eocene to Oligocene Molasse beds are imbricated into the nappes as proved by the deep well Urmannsau-1 about 14 km south of the Alpine front. In the visited area between Ybbs and Melk the Melk Formation consists of quartz sands (Melk Sands), dark gray to black clays and silts (Pielach Clays), and small interbedded coal seams. The depositional environment comprises limnic-fluviatile to paralic and marine. Basinwards dark gray marine clays and sands with mollucs faunas are dominant.

The sedimentation starts here in the Middle Oligocene (Rupelian) with limnic and paralic dark clays interbedded in the Melk Sands as dated by palynology and mollusc faunas. This facies continues in the Late Oligocene. The Early Miocene (Eggenburgian) is eroded (fig. 49), but it can be traced in Ottnangian boulder beds containing sandstones with typical mollusc faunas. The Ottnangian Schlier facies (gray silty clays with sand lenses) corresponds to that of Upper Austria, ending with a widespread sedimentation of regressive Oncophora Beds. Afterwards only the early Badenian marine transgression reached the area west of Krems.

The sand pit of the Quarzwerke Dr. Hansmann is situated at the southwest side of the village of Zelking. The washed clean sands are used for glass production and in foundries; the less valuable byproducts are for construction purposes.

The surrounding landscape south of the Danube shows the features of a deeply eroded relief of the Bohemian Massif filled by the near-shore facies of the Melk Formation. The Diendorf fault east of Zelking extends NE-SW along the Hiesberg mountain (558 m) and limits the area of quarrying as well as a minor fault south of the quarry.

In the quarry area upon cataclastic and strongly weathered, red granulite fluviatile sand and dark gray limnic and paralic clays were deposited. These clays are dipping to the south, rapidly increasing in thickness showing that block faulting was active during sedimentation. The palynologic determination by P. Hochuli (Zürich) shows frequently *Pityosporites*, *Tricolporopollenites margaritatus* (R. Pot.) and thermophilous elements with *Engelhardtioidites* and *Triatriopollenites* cf. *plicatus* (R. Pot.). Dominant arctotertiary elements are *Polyporopollenites undulosus* (Wolff). Stratigraphic important are *Aglaoreidia cyclops* Erdtm., *Periporopollenites stigmosus* (R. Pot.), and *Gramnidites subtiliglobosus* (Trevisan) giving an age of Palaeogene zone 20 b. The megaflora contained a larger number of *Comptonia* leaves. Moulds of the bivalve *Polymesoda* occur in the upper part of the clay.

Poorly sorted pale sands are following, and above that a second layer of gray clay contains leave prints of *Daphnogene*. Dark gray silty clays with plant debris and coal particles at the uplifted granulite wall of the quarry are probably corresponding to this higher clay level. These clays are very similar to the Cyrena Beds of Upper Bavaria, containing *Polymesoda convexa* (Brong.) (= *Cyrena semistriata*) and *Tympanotonus margaritaceus* (Brocchi). The palynologic investigation shows a microflora of Neogene zone I with dominant arctotertiary and intermediate elements as *Abiespollenites*, *Piceapollis*, *Zonalapollenites* and *Pityosporites*. The overlying quartz sands are light gray with horizons of trace fossils (*Heteromastus*?) indicating a beach environment. From the north a fluviatile channel is cutting through the beach sands and clays. It is filled with crossbedded coarse sands, gravels, and clay pebbles originating from the higher clay horizon.

The uppermost parts of the sands are fine grained, yellowish gray, with strong bioturbation and ophiomorph burrowings deposited at the lower fore shore.

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Day 9

Foreland Basement, Flyschzone, Vienna Basin

Route description: Starting from Melk downstream the river Danube we enter the Wachau. This is a section of the Danube valley of about 30 km of length and famous for its charming scenery. The river is bor-

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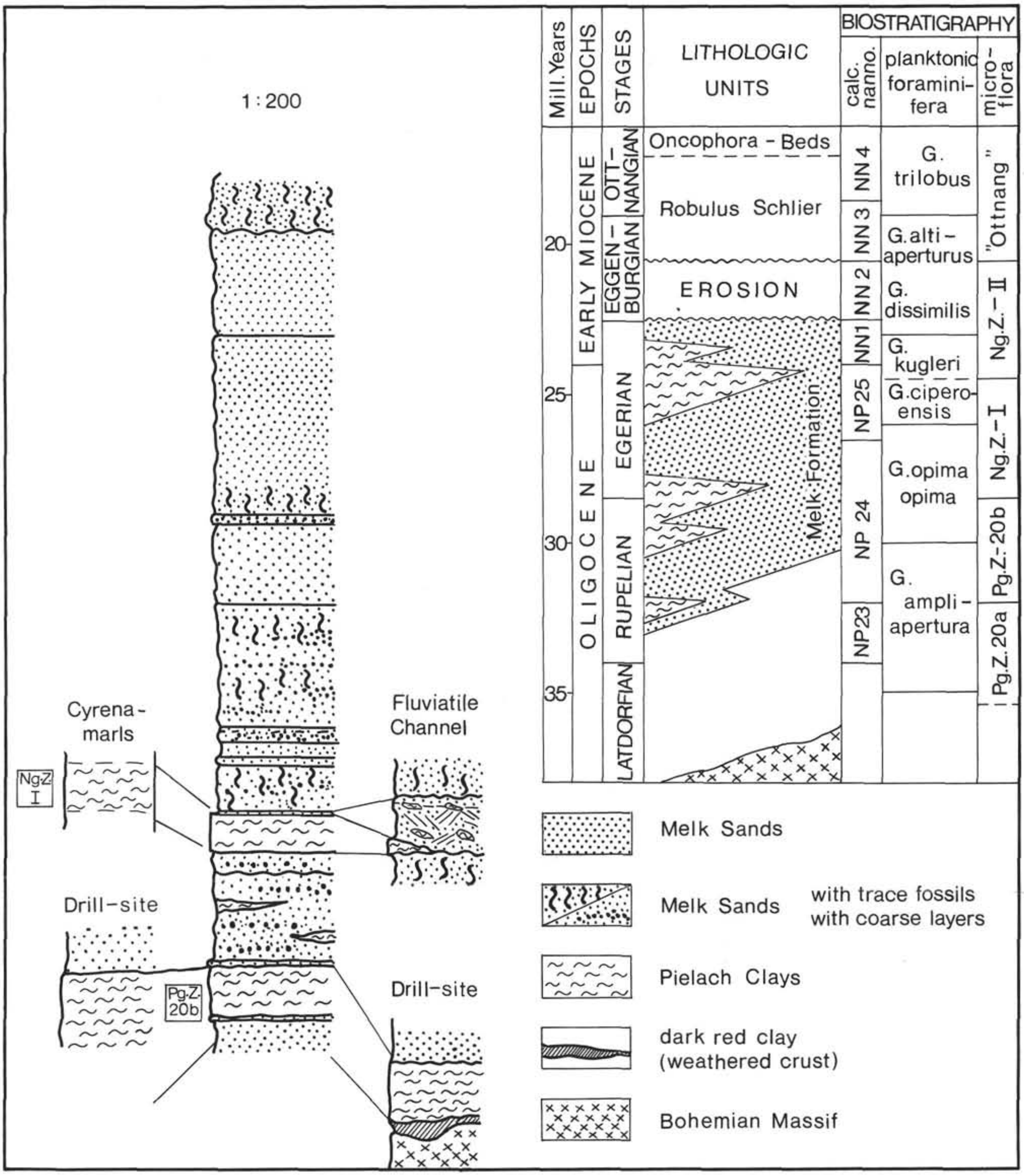

Fig. 49: Composite section (after R. ROETZEL) and stratigraphic correlation table of the region Melk—Krems (after RÖGL & al., 1979).

dered by wine-yards and orchards around small villages with a number of buildings that give evidence of old settlement. The wooded slopes behind are protruded by many cliffs and sporadic ruins of castles.

The valley was cut epigenetically during Pleistocene into the crystalline basement, a variegated sequence of orthogneisses and ± migmatitic paragneisses intercalated by marbles, amphibolites and quartzites, representing the southeastermost part of the Bohemian Massif. The history of incision is formed by a number of terraces in connection with loess accumulations.

The first part of the valley-section between Melk and Aggsbach follows the prominent Diendorf wrench-fault. At Aggsbach the Gföhl Gneiss crosses the Danube. This rock unit we will meet again at the next stop.

The downstream part of the Wachau between Spitz and Krems follows an old valley furrow that initially reached back from Spitz towards west over Mühldorf, Raxendorf to the middle-course of the Weitental. After W. Fuchs (1977) this furrow was formed pre-Chattian (pre-upper-Oligocene).

Stop 9.1. Dürnstein

Bohemian Massif, Moldanubian Zone, Gföhl Gneiss
Top. sheet 37 Mautern

The village of Dürnstein is situated upon a rock terrace. The bedrocks are exposed along the river bank promenade. They consist of a homogeneous fine grained orthogneiss of granitic composition called Gföhl Gneiss. Main constituents in volume percent are: alkali feldspar 35—45%, oligoclase (24% An) 10—20%, quartz 35—45% and biotite 2—5%. Prevailing of alkali feldspar (microline microperthite) in relation to oligoclase and the almost constant presence of garnet, sillimanite and kyanite as accessories are typical features of the Gföhl Gneiss. The well rounded zirkons of the Gföhl Gneiss are medium elongated (1,78—2,27; G. Niedermayr, 1967). The migmatite-like fabric of Gföhl Gneiss here is intersected by a medium-steeply-west-dipping transversal schistosity connected with microfolding. The older schistosity appears to have been almost horizontal or gently dipping towards east. Some dm-thick, ± sharply bounded aplite veins dipping medium steeply against east cut across the Gföhl Gneiss. Inclusions of dm- to m-size of schistose, biotite and garnet bearing amphibolites can be observed. But frequently this basic pieces are already removed remaining empty caves.

The Gföhl Gneiss continues from Dürnstein towards north and south and is a prominent rock type of this region. It shows many structural and petrological relations to granulites. Recently published radiometric Rb/Sr-whole rock ages of 440—470 m. y. (A. Arnold & H. G. Scharbert, 1973) for granulites of this region might be valid for the Gföhl Gneiss too.

The Gföhl Gneiss belongs to a zone of metamorphites which underwent a multiphase, pre-Variscan to Variscan influence of tectonic deformation and metamorphism. The intensity of the latter attained amphibolite facies in the major part of the region. Only in the easternmost part (Moravian Zone) a comparatively small zone of greenschist facies is developed. The last regional heating occurred in connection with the Variscan intrusion of the Moldanubian pluton. Numerous cooling ages of 330—300 m. y. indicate uplift and erosion during the Upper Carboniferous. Afterwards the consolidated block of the Bohemian Massif had been affected only by faulting. Along some prominent NE-striking sinistral wrench-faults displacements up to an extent of 25 km occurred in post-lower-Permian time (because of shearing of lower-Permian sediments by the Diendorf Wrench-fault near Zöbing).

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Fuchs, G. & Matura, A. (1976): Zur Geologie des Kristallins der südlichen Böhmischen Masse. — Jb. Geol. B.-A. **119**, 1—43, Wien.

Route description: At Krems the route turns southwards. Note the big quarry at Meidling im Tal exposing vertical east-west striking granulites and pyrope bearing ultrabasic rocks. Afterwards we enter the hilly landscape of the Molasse Zone again. Except the summits made of Tertiary rocks of the Molasse Zone the area is extensively covered by clastic Pleistocene and Holocene deposits in which several terraces can be distinguished. At St. Pölten the route follows the Traisen river upstream towards south. Before we arrive at the town of Wilhelmsburg we enter the Flyschzone.

Stop 9.2. Rotheau Quarry

(W. Schnabel)

Flyschzone, Maastrichtian
Top. sheet 57 St. Pölten

The Rotheau quarry near the main road from St. Pölten to Traisen shows about 70 m of normal and typical Flysch series. Turbidite sediments of the inner and outer fan region (cycles A—E, Bouma, 1962) are to be studied. Numerous sedimentary phenomena of a typical flysch are found as sole marks, flute casts. Ichnofossils were used for long times as indicators for the facies. Assemblages of arenaceous foraminifera and nannofossils characterize the poor fauna and flora.

Section Rotheau:

Top	3rd member: 10 m thin-bedded marls and thick-bedded sandstones in characteristic cycles.
	2nd member: 40 m medium to large size cycles. Dominating thick sandstone beds.
Bottom	1st member: Rhythmic succession of 40 m calcarenites, marly limestone. Abundant fucoid trace fossils.

The stratigraphic classification is based on combined technics. Nannofossils suggest Campanian age for member 3. On the other side the lithologic correlation with "Altlengbach" formation and the appearance of arenaceous primitive foraminifera suggest the idea of reworked Campanian sediments in Maastrichtian time. The content of heavy minerals agrees with that of the Altlengbach Formation.

No structural subdivision is so far known from the Flysch Nappe in this region. However, a few kilometers

		Salzburg, Upper Austria, western Lower Austria	Eastern Lower Austria (Wienerwald)		
		Flysch Nappe	Greifenstein Nappe	Kahlenberg Nappe	Laab Nappe
Palaeogene	L.+M.-Eocene		**Greifensteiner Schichten** 500 m, massive siliceous flysch facies separated by 3 shale intercalations		1000 m Laaber Schichten: **Agsbachschichten** thin-bedded flysch **Hoisschichten** siliceous flysch with massive sst.
Palaeogene	Paleocene	**Paleozän-Flysch** —500 m, thin- and medium-bedded *turbidite facies with siliceous* sandstones (partly glauconite-bearing) and shales	**Altlengbacher Schichten** to compare with the Paleozän-Flysch and the Mürbsandsteinführende Oberkreide	**Sieveringer Schichten** 200—300 m, lithology similar to Altlengbacher Schichten but different heavy minerals and flute directions	—40 m thinbedded dark shales
Cretaceous, Upper	Maastrichtian	**Mürbsandsteinführende Oberkreide** („Friable Sandstone Series") —2000 m, varied flysch facies (siliceous, calcareous, thick- and thin-bedded) **9.2.**			few meters thinbedded grey shales and dark quartzite
Cretaceous, Upper	Campanian Santonian	**Oberste Bunte Schiefer** —50 m, thin-bedded variegates shales **Zementmergelserie** 200—500 m, calcareous flysch facies with marls, marly shales, calc-sandstone beds. Lower part: thinbedded calcareous flysch		**Kahlenberger Schichten** some 100 m, similar to Zementmergelserie but sandstone intercalations at the top	**Kaumberger Schichten** —500 m thinbedded variegated shales and siltstone
Cretaceous, Upper	Coniacian Turonian	**Obere Bunte Schiefer** 50 m, thinbedded flysch with variegated shales and siltstone beds			
Cretaceous, Upper	Cenomanian	**Reiselsberger Sandstein** 30—100 m, siliceous flysch facies with thicker individual sandstone beds		**Reiselsberger Sandstein** some 100 m with variegated shales — pikrite	
Cretaceous, Lower	Albian Aptian	**Untere Bunte Schiefer** 10—50 m, thinbedded variegated shales **Gault-Flysch** —150 m, thin- and middlebedded clay/siltstone shales, glauconite bearing sandstones and quartzites	**Wolfpassinger Schichten** dark shales and bedded limestone	**Gault-Flysch** —200 m	
Cretaceous, Lower	Barremian Hauterivian	**Neokom-Flysch** —100 m, beds of grey, detritic limestone, breccias, shales and siltstones		**Klippen von St.-Veit**: **Aptychenschichten**	

Tab. 9: Schematic stratigraphy of the Flyschzone in Eastern Austria (W. SCHNABEL).

eastwards the structure of the Flyschzone is getting more complicated and, besides the Klippenzones, three subsidiary nappes can be distinguished (tab. 9).

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Route description: The route follows upstream the river Traisen. At the junction with the river Gölsen it bends westwards and follows the latter. After passing the Gerichtsberg the valley of the Triesting will be reached. The route continues westwards until Altenmarkt. Both valleys follow in general the morphologically marked thrust plane of the Austro Alpine Units above the Flysch Zone. At Altenmarkt the Triesting bends southeastwards and crosses the eastern spur of the Northern Calcareous Alps. The excursion route, however, turns north and follows the Schwechat valley which runs parallel to the Triesting. Near Sattelbach we cross the Schwechat Window in which the Lunz Nappe appears below the Ötscher Nappe.

We follow the romantic Helenental valley, which is flanked by two ruins of the 11th century. Near the city of Baden the street passes the Viennese Water conduit, an ingenious construction of the 19th century. It guarantees a good deal of the Viennese water supply from the resources in the Wetterstein formation of Schneeberg, Rax and Schneealpe in the south of the Northern Calcareous Alps. The water conduit was suggested by E. SUESS, the greatest Austrian geoscientist. The building stone was partly quarried at the place of the next excursion stop.

Stop 9.3. Baden, Rauchstallbrunngraben

Vienna Basin, Neogene, Badenian M_4
Top. sheet 76 Wiener Neustadt

The beautiful city of Baden, with a considerable number of buildings of the early 19th century (Biedermeier), is situated at the eastern tectonic margin of the Alps. Eastwards neighboured is the large subsidence area of the Vienna Basin.

The Vienna Basin is famous for its unique richness in fossils, as a type locality of hundreds of fossils, embracing stratotypes of the Neogene and lithostratotypes of the Neogene series. On the one side it is fa-

Mill. Yrs.	Epochs	Central Paratethys Stages	Zonation Vienna Basin	Nanno-plankton-Zones	Mediterranean Planktonic Foraminifera	Mediterranean Stages
	Middle Miocene	Sarmatian				Serravallian
				NN 8	*Globorotalia mayeri*	
13		Badenian	Bulimina-Bolivina and Rotalia Zones	NN 7		
14			Zone with Arenaceous Foraminifera	NN 6		
15			Lagenidae Zone	NN 5	*Globorotalia peripheroronda*	Langhian
16					*Praeorbulina glomerosa*	
	Early Miocene	Karpatian		NN 4	*Globigerinoides trilobus*	Burdigalian

Tab. 10: Correlation table of the Neogene of the Central Paratethys with the international scheme (F. RÖGL).

mous for classical studies in micropaleontology and invertebrate paleontology and early research on stratigraphy, on the other a central field for actual studies in stratigraphy, paleogeography of the paratethys and also for continuous research on micropaleontology and invertebrate paleontology. The results of the oil and gas exploration of the ÖMV-AG are of fundamental importance for the understanding of the geology of the Vienna Basin.

The subsidence of the basin began in Karpatian times. Steep fault systems with high subsidence rates are responsible for the abrupt end of the Eastern Alps. Hot sulphur springs at the Thermenlinie gave rise for medical use since Roman times.

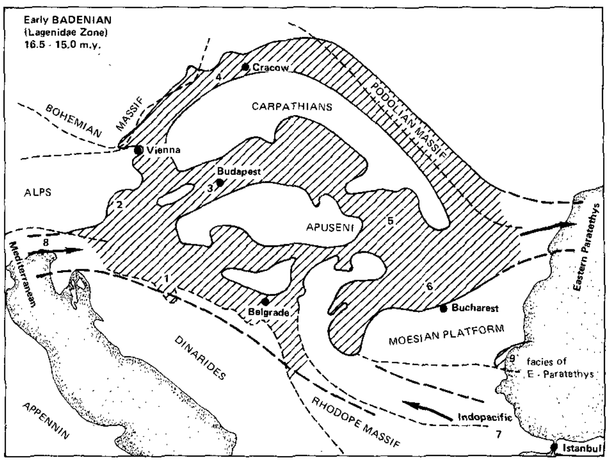

Fig. 50: The paleogeographic position of the Vienna Basin in the central Paratethys (Badenian; after RÖGL, STEININGER & MÜLLER, 1978.)

Baden is also known for the occurrence of the stratotype of the Badenian stage, the Baden Series and the Badener Tegel, a member of the Baden Series. Type locality is a little brick pit south of Baden (not in our program) with rich faunas of foraminifera and mollusks.

The visited quarry Rauchstallbrunngraben west of Baden displays the nearshore/deltaic facies of the Baden Series. Well-bedded coarse conglomerates consist mainly of flysch and carbonate components indicating a source area in the west. Clypeasters in live position indicate normal salinity. The demonstrated biodetritic layer is famous as type locality of several bryozoans described by REUSS 1874. *Heterostegina granulatotesta* PAPP & KÜPPER and *Heterostegina costata costata* d'ORB testify the classification into the Upper Lagenid Zone.

The paleogeographic position of the Vienna basin in the central paratethys during the Badenian is illustrated in fig. 50.

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In 1979 the ÖMV-AG drilled a hole near Berndorf approximately 7 km south of Baden. The drilling site is situated in the southern units of the Northern Calcareous Alps. The most surprising result was the enormous thickness of the Northern Calcareous Alps as their base was arrived in 5.640 m below the surface. They are underlain by Flysch sediments until 5.910 m and by Molasse sediments of Egerian age (*Miogypsina* sp.) The Molasse series rest with transgressive contact upon crystalline rocks of the Bohemian Massif, met at 5.945 m. There was no autochthonous Mesozoic cover on the crystalline basement. Bottom depth was reached at 6028 m (G. WACHTEL, ÖMV-AG, lecture Sept. 27, 1979). According to these new data the minimum distance of overthrust of the Northern Calcareous Alps upon their foreland is proved to be more than 40 km.

Stop 9.4. Laxenburg

(G. WESSELY and A. KRÖLL) *)

Vienna Basin, drilling site of the ÖMV-AG, Neogene basin filling, pre-Neogene basement
Top. sheet 59 Wien

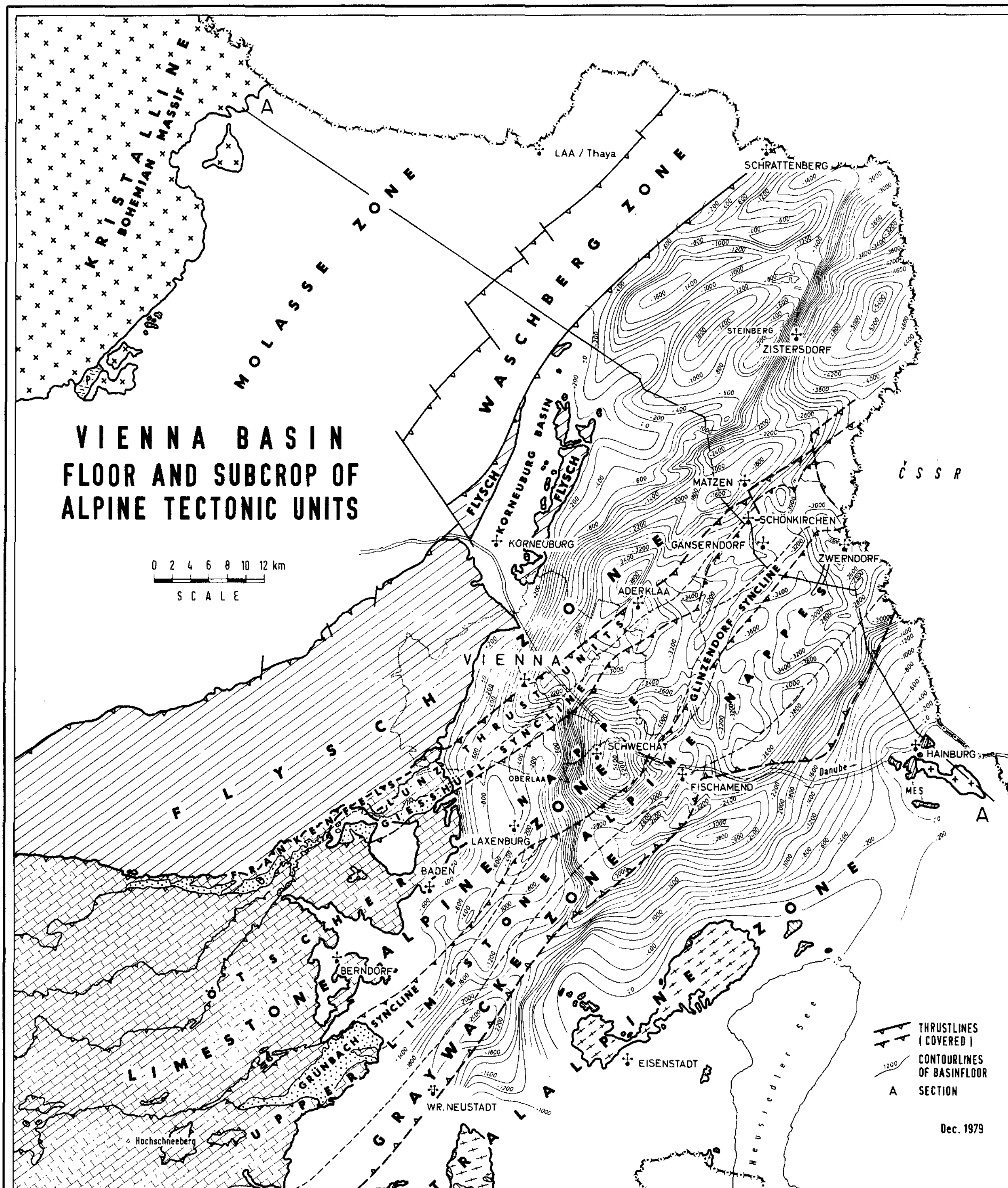
Subject of the last stop is the Vienna Basin and its basin floor as known from numerous wells drilled for oil and gas (figures 51 and 52).

The Vienna Basin is an area of young subsidence within the Alpine-Carpathian orogenic belt. Its longitudinal extension and the strike of its main faults follow the direction of an old structural system within the basement formed by the Bohemian Massif. This system was reactivated episodically also after the superposition of the Alpine-Carpathian nappes. The faults are caused by tension, the fault planes are dipping about 55°.

The basin is filled with marls, clays, sands and sandstones and in several areas with conglomerates and limestones. During the deposition of the older members (marine to brachyhaline sediments of Eggenburgian and Ottnangian age) subsidence was low and the shape of the early basin was different from the later one. In Karpathian time the sediments in the northern part of the basin were marine, in the southern part deltaic influence

*) Dr. GODFRID WESSELY and Dr. ARTHUR KRÖLL, ÖMV AG Vienna.

Fig. 51 (opposite side): Vienna Basin, floor and subcrop of Alpine tectonic units (A. KRÖLL and G. WESSELY).


VIENNA BASIN
FLOOR AND SUBCROP OF
ALPINE TECTONIC UNITS
0 2 4 6 8 10 12 km
SCALE
KRISTALLINE
BOHEMIAN MASSIF
MOLASSE ZONE
WASCHBERG ZONE
FLYSCH
KORNEUBURG BASIN
FLYSCH
LIMESTONE ALPINE ZONE
UPPER LIMESTONE ZONE
GRAYWACKE ZONE
CENTRAL ALPINE ZONE
GLINZENDORF SYNCLINE
GRÜNBACH SYNCLINE
MESOZOIC
LAA / Thaya
SCHRATTENBERG
STEINBERG
ZISTERSDORF
MATZEN
SCHÖNKIRCHEN
GÄNSERNDORF
ZWERNDORF
KORNEUBURG
ADERKLAA
VIENNA
SCHWECHAT
OBERLAA
FISCHAMEND
HAINBURG
Danube
LAXENBURG
BADEN
BERNDORF
EISENSTADT
WR. NEUSTADT
Hochschneeberg
GLOGGNITZ
Neusiedler See
ČSSR
HUNGARY
THRUSTLINES
(COVERED)
CONTOURLINES
OF BASINFLOOR
A SECTION
Dec. 1979
gez.: O. DVORAK

caused freshwater facies. Here the top is formed by the fluviatile conglomerate of Aderklaa. The largest subsidence in many parts of the basin, which led to its final shape, occurred in the Badenian with its marine sedimentation, as well as in Sarmatian and Pannonian time with its brackish to limnic-fluviatile development.

Differential subsidence created depressions and high zones. The most important highs in the Austrian part of the basin are the Steinberg-, Oberlaa-, Matzen-, Aderklaa- and Zwerndorf-highs because of their oil and gastraps in Neogene sandstones as well as in the basin floor (except Oberlaa). Huge depressions are those east of Steinberg near Zistersdorf and east of Oberlaa. The first one is separated from the Steinberg high in the west by the east-dipping Steinberg fault with a vertical displacement of more than 5000 m. The other depression east of Oberlaa is limited in the west from the Oberlaa high by the east-dipping Leopoldsdorf fault with a vertical displacement of more than 4000 m. Both faults as well as most other faults are growth faults with enormous thicknesses on the downthrown side.

Underneath the Neogene filling of the Vienna Basin ordered from north to south the Flysch Zone, the Limestone Zone, the Graywacke Zone and the Centralalpine Zone are striking across the Vienna Basin, well to be correlated with equivalent Alpine and Carpathian units which are exposed on the surface.

In the Flysch nappes a stratigraphic range from uppermost lower Cretaceous to Eocene was encountered.

The Limestone Zone, consisting mainly of Mesozoic limestones and dolomites as well as of subordinate marls, shales, sandstones and evaporites, is subdivided into two subsidiary nappes: the strongly folded and sliced frontal nappe (Frankenfels-Lunz system), discordantly superposed by the "Syncline of Gießhübl", which was filled by Upper Cretaceous and Paleocene sediments; these are overthrust by the system of the Ötscher nappe. The boundary to the overthrust uppermost limestone nappes is marked by a belt of Upper Cretaceous mostly in nonmarine facies ("Syncline of Glinzendorf").

The Graywacke Zone contains Palaeozoic shales and quartzwackes. Wells in the Centralalpine Zone encountered Triassic carbonates and continental "Keuper" in the Upper Triassic.

The sequence of tectonical movements is indicated by transgressions from Upper Cretaceous till Paleocene (Syncline of Gießhübl) over a sliced and folded system of nappes. Paleocene or post-Paleocene thrusting pushed the system of the Ötscher nappe upon the Syncline of Gießhübl. Connected with this movement are probable steep thrust faults which dislocate the Paleocene of this syncline. The Limestone Zone as a whole was moved upon the Flyschzone in late Paleogene. Later on the thrust plane in the northern frontal part of the Limestone Zone was steepened and overturned.

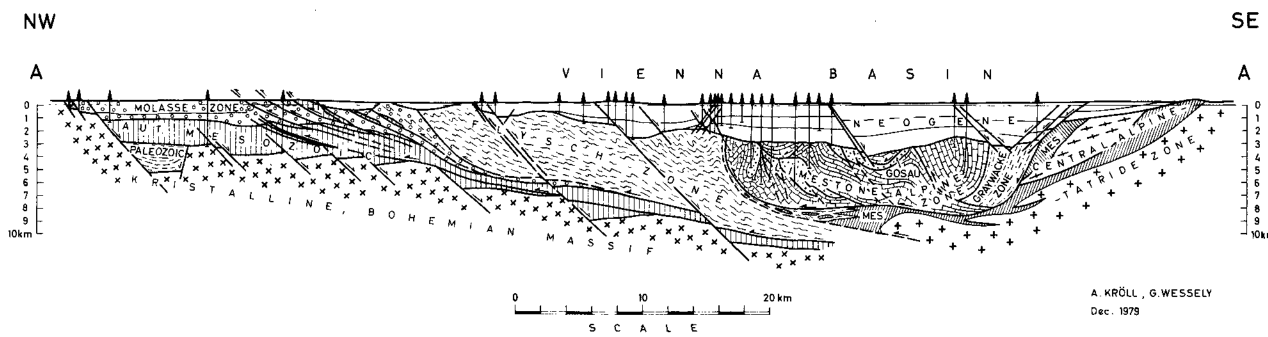


Fig. 52: Section across the northern part of the Vienna Basin (A. Kröll and G. Wessely).

The Neogene sediments do not show any disturbance by Alpine movements.

The largest payers of oil and gas are sandstones of the Badenian and Sarmatian. The most important oil and gas fields are Matzen, Aderklaa, the group of pools near Zistersdorf and the gasfield Zwerndorf.

The traps are anticlines, monoclines in connection with faults and some sedimentary closures. The only important reservoir rock in the floor of the Vienna basin is the Norian Hauptdolomit. Its porosity is caused by fracturing. Production comes from the oil- and gasfield Schönkirchen Tief, the oilfield Prottes Tief and from the gasfields Aderklaa and Reyersdorf. Some gas is produced from the dolomitic Dachstein limestone of Baumgarten. These fields represent buried hills sealed by Neogene marls. In the "Internal types of reservoir" within the Limestone Zone the thick series of flyschoid Paleocene of the Syncline of Gießhübl functions as a caprock and causes the gasfields in the Hauptdolomit of Schönkirchen Übertief and Gänserndorf Übertief.

Oil and gas also occurs in the Paleocene Glauconite sandstones of the Flysch Zone in the area of Hauskirchen-Steinberg and Hochleiten (Upper Cretaceous).

The investigation of possible reservoir rocks in favourable structures underneath the Alpine-Carpathian nappes within the Vienna basin is subject of present and future drilling projects with depths of 7000—8000 m.