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OVERVIEW OF THE EASTERN ALPS

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Introduction

This contribution provides a short overview of the tectonostratigraphy of the Eastern Alps with special emphasis on the internal, often metamorphic zones. Details of all these units are given in other contributions of the field guide.

Tectonostratigraphy of the Eastern Alps

A cross section through the eastern Alps displays the following major tectonic units from the North to the South, respectively from the footwall to the hangingwall (Fig. 1, 2; Janoschek and Matura, 1980; Oberhauser, 1980):

1) The European crust, exposed in the Bohemian Massif, which is sinking down to the South below the Eastern Alps. The European continental crust is covered by incomplete autochthonous Permian to Jurassic sediments, and the Oligocene - Neogene sediments of the molasse basin, a wedge-shaped foredeep.

2) The Molasse basin is overlain by the Helvetic Nappe Complex, a foreland thrust and fold complex which contains detached Jurassic to Eocene cover sediments from the southern margin of the European crust.

3) The Rhenodanubian Flysch Zone includes Cretaceous to Eocene orogenic flysch deposits.

4) The Penninic Nappe Complex which is exposed exclusively in tectonic windows in the central Eastern Alps (Tauern Window, Engadin Window, Rechnitz window). The Penninic Nappe Complex, always metamorphosed to greenschist to amphibolite facies, contains a lower unit with Variscan continental crust, only exposed in the Tauern Window, with a subautochthonous Permo-Mesozoic cover, and a higher unit with Mesozoic basinal deposits including ophiolites which form the essential suture zone in this part of the Alpine edifice.

5) The flat-lying Austro-Alpine Nappe Complex forms the backbone of the Eastern Alps, veiling all other units. The Austro-Alpine nappe complex largely contains basement units and few relics of Permo-Mesozoic cover sequences in the Central Alps, and an imbricated complex with Permo-Mesozoic cover sequences in the Northern Calcareous Alps.

6) The Periadriatic lineament separates the Austro-Alpine nappe complex from the South-Alpine tectonic unit south of it. The South-Alpine unit is basically regarded as an extension of the Austro-Alpine Nappe Complex. The South-Alpine unit is tilted to the South resulting in basement exposure along the Periadriatic lineament and southerly adjacent cover sequences (Late Carboniferous to Neogene).

In the Austrian usage, the Central Alps are the area between the Periadriatic Lineament and the Greywacke Zone, the northernmost Austro-Alpine basement unit.

Internal stratigraphy of the Penninic Nappe Complex

The lower portion of the Penninic Nappe Complex is composed of often foliated Variscan granitoids which are exposed in several domes within the Tauern window (Fig. 1). The granitoids are

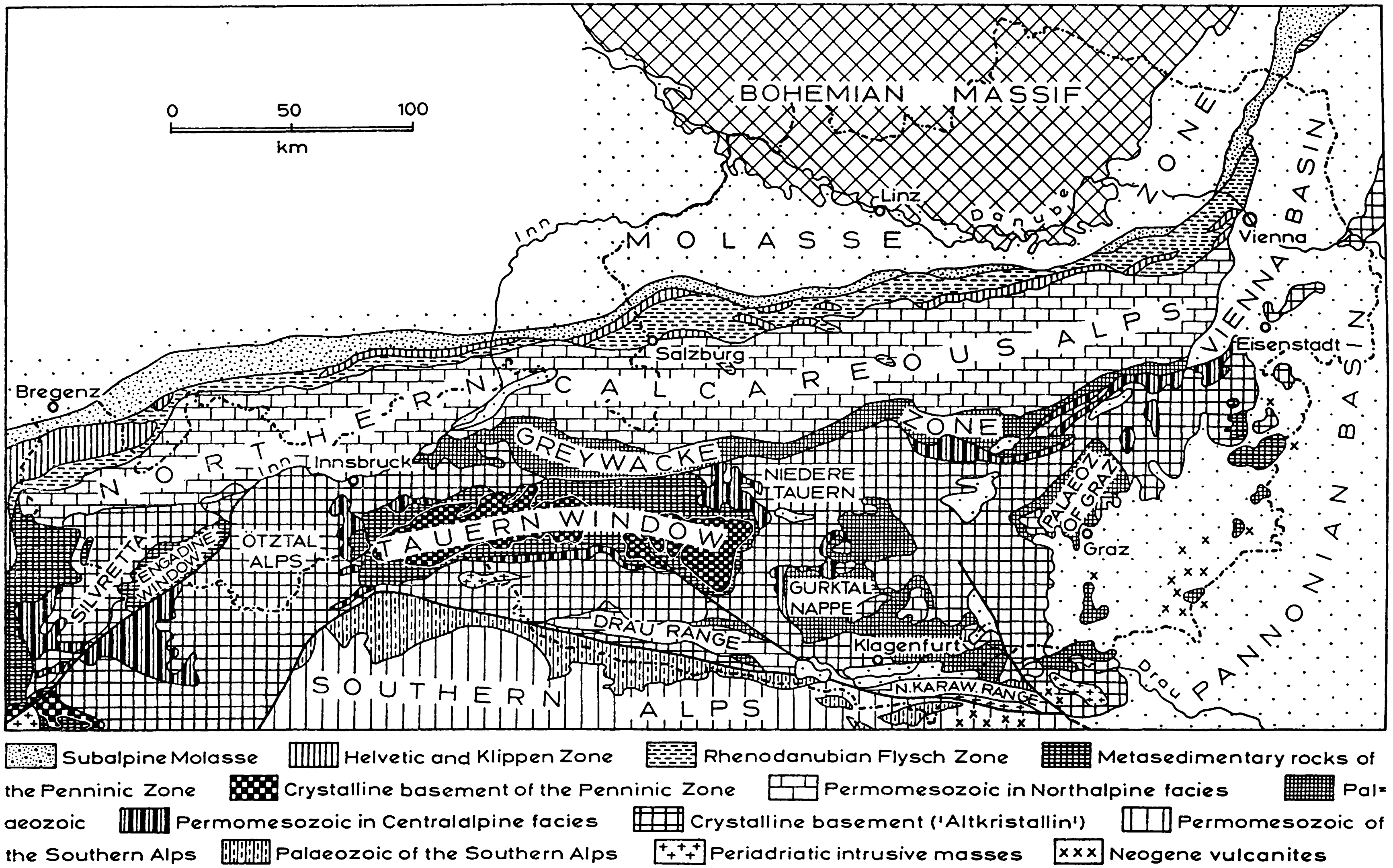
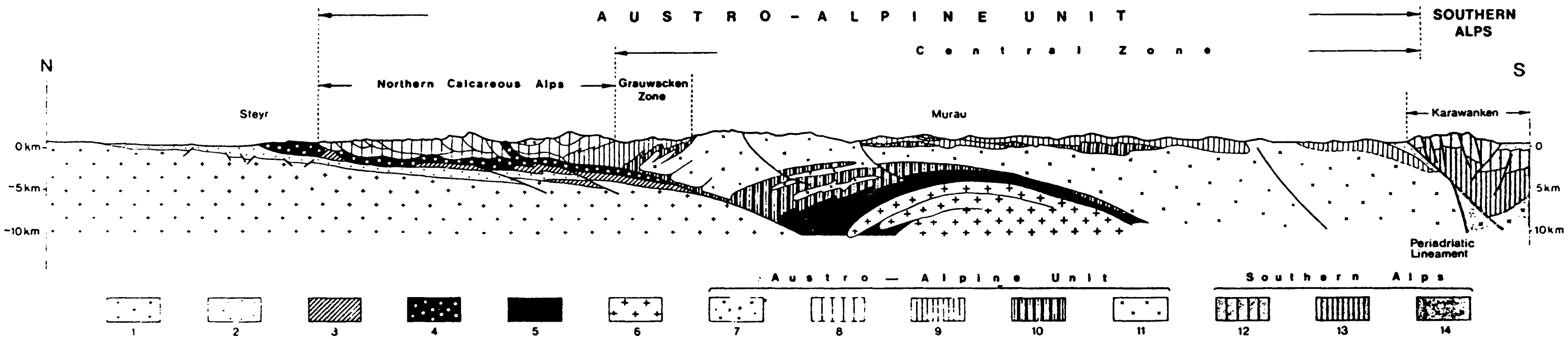


Fig. 1: Schematic structural map of the Eastern Alps (from Flügel and Faupl, 1987, p. 10).



Schematic cross-section of the Eastern Alps along the line Linz — Klagenfurt (modified after S. PREY, 1976; for exact position of the cross-section see fig. 1). 1 = Extra-Alpine basement of the Bohemian Massif; 2 = Molasse Zone and intra-Alpine Tertiary (post-upper-Eocene); 3 = Helvetic Zone and Klippen Zone; 4 = Flysch Zone; 5 = Metasedimentary rocks of the Penninic Zone; 6 = Crystalline basement of the Penninic Zone; 7—11 = Austro-Alpine Unit: 7 = Gosau Formation; 8 = Permomesozoic (unmetamorphic) in North-Alpine facies; 9 = Palaeozoic (low-grade metamorphic); 10 = Permomesozoic (low-grade metamorphic) in Central Alpine facies; 11 = Crystalline basement ("Altkristallin"); 12—14 = Southern Alps: 12 = Permomesozoic; 13 = Palaeozoic; 14 = Crystalline basement.

Fig. 2: Schematic cross section through the Eastern Alps (from Janoschek and Matura, 1980).

largeley surrounded by pre-Variscan basement units into which the granitoids intruded. The most important units are the Habach complex in the western part of the Tauern Window which basically contains a late Proterozoic to early Paleozoic island arc sequence, and the Storz complex in the eastern Tauern window which is interpreted as a migmatitic correlate to the Habach complex in the central and western Tauern window.

Mesozoic ophiolites are exposed in all major Penninic Windows occurring in a high structural level within these windows mostly. Deeper levels are composed of Mesozoic sediments which have been deposited, in part, on basement rocks.

Internal stratigraphy of the Austro-Alpine Nappe Complex

The Austro-Alpine Nappe Complex is composed of several thrust sheets which contain both pre-Late Carboniferous basement units and Late Carboniferous to Mesozoic cover sequences. For descriptive purposes we can use a conventional subdivision into a strongly imbricated Lower Austro-Alpine unit (LAA) with several internal nappes, a thick Middle Austro-Alpine unit (MAA) which is mainly composed of polymetamorphic basement rocks, the "Altkristallin", and the Upper Austro-Alpine unit (UAA). The MAA forms a coherent backbone of the entire Austro-Alpine body, the UAA occurs along the northern margin of the MAA (Greywacke Zone) and in large klippens (Graz Nappe Complex; Gurktal Nappe Complex). An alternative terminology and tectonostratigraphy (Fig. 3) was proposed by Frank (1987). The Austro-Alpine basement is divided into several units with distinct lithology and histories (Fig. 4).

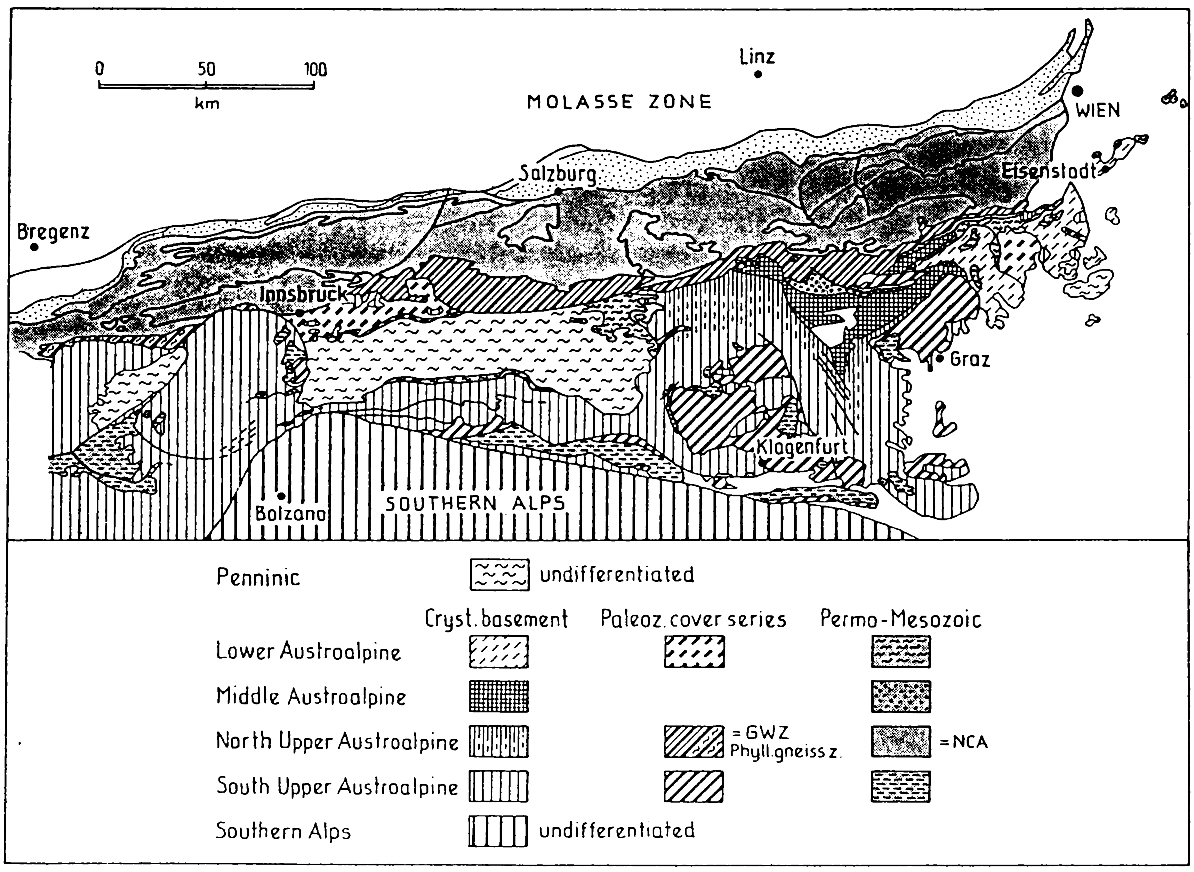


Fig. 3: Alternative structural map of the Eastern Alps (Frank, 1987).

Basic features of the internal structure of all these units are the occurrence of conformable cover sequences along the northern to northwestern edge of individual units and the increasing intensity of the Alpine metamorphic overprint from greenschist facies along the northern and upper units to amphibolite facies in lower units and central to southern parts (Fig. 4). The geochronological ages of this metamorphic event vary from Early to Late Cretaceous (Frank et al., 1987).

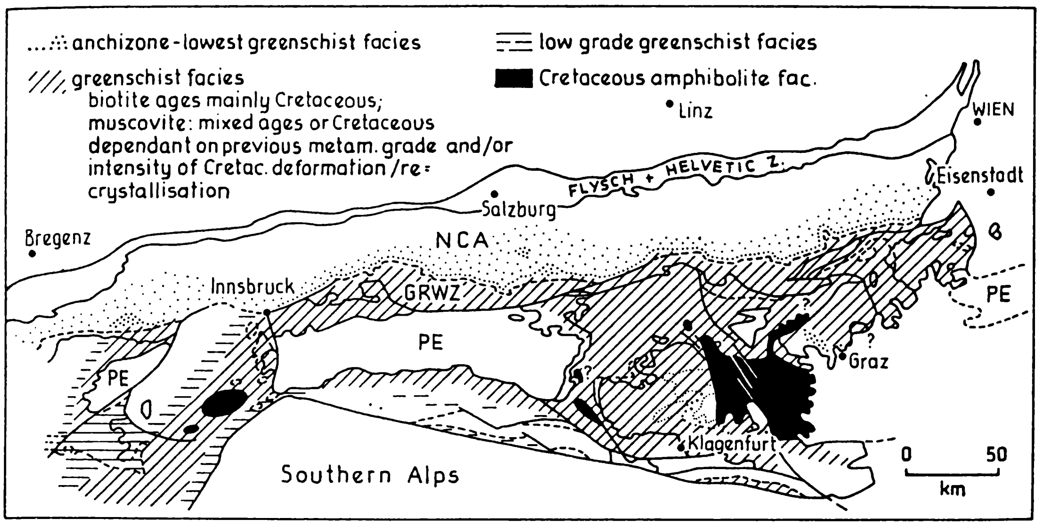


Fig. 4: Distribution of Cretaceous metamorphism in the Austro-Alpine Nappe complex.

Lower Austro-Alpine units

The Lower Austro-Alpine unit occurs in a rim around the Tauern Window and in the Grobgneiss/Wechsel/Waldbach units along the eastern margin of the Alps.

The Radstadt/Katschberg quartzphyllites mainly contain monotonous metapelites, black schists with some intercalations of greenschists, and calcitic and dolomitic marbles. The latter yielded conodonts of mainly Late Silurian age.

The cover sequences start with Permo-Scythian (?) Lantschfeld Quartzites, followed by dolomites and marbles of a Triassic platform sequence. The Jurassic sequence contains calcareous-schists, crinoidal limestones, breccias and metacherts mainly.

The Wechsel Window and several further windows east of it (Fig. 1) expose three distinct basement units: (Fig.5)

* the Wechsel Gneiss Complex,
* the Waldbach Complex,
* the Wechsel Phyllite.

These basement complexes are overlain by Permo-Triassic cover sequences, together forming the Wechsel System.

The Wechsel System is structurally overlain by the Semmering System which includes Semmering Permo-Triassic sequences and the polymetamorphic "Grobgneiss"/Raabalpen complex.

The Middle Austro-Alpine units

The Middle Austro-Alpine units (Fig. 5) contain polymetamorphic units with general amphibolite facies metamorphic overprint and minor, incomplete Permo-Scythian cover rocks along the northern margin and below the Gurktal Nappe System (Fig. 1).

The lithological composition of basement units varies within a broad range which allows to define distinct tectonostratigraphic units with distinct geodynamic histories. These units occur in a stack of thrust sheets which vary in composition from the West to the East.

East of the Wechsel window, the "Grobgneis" complex is overlain by some klippen of the Sieggraben complex. The Middle Austro-Alpine basement west of the Wechsel Window is composed of several tectonostratigraphic units, especially the deeper Muriden complexes and the higher Koriden complexes.

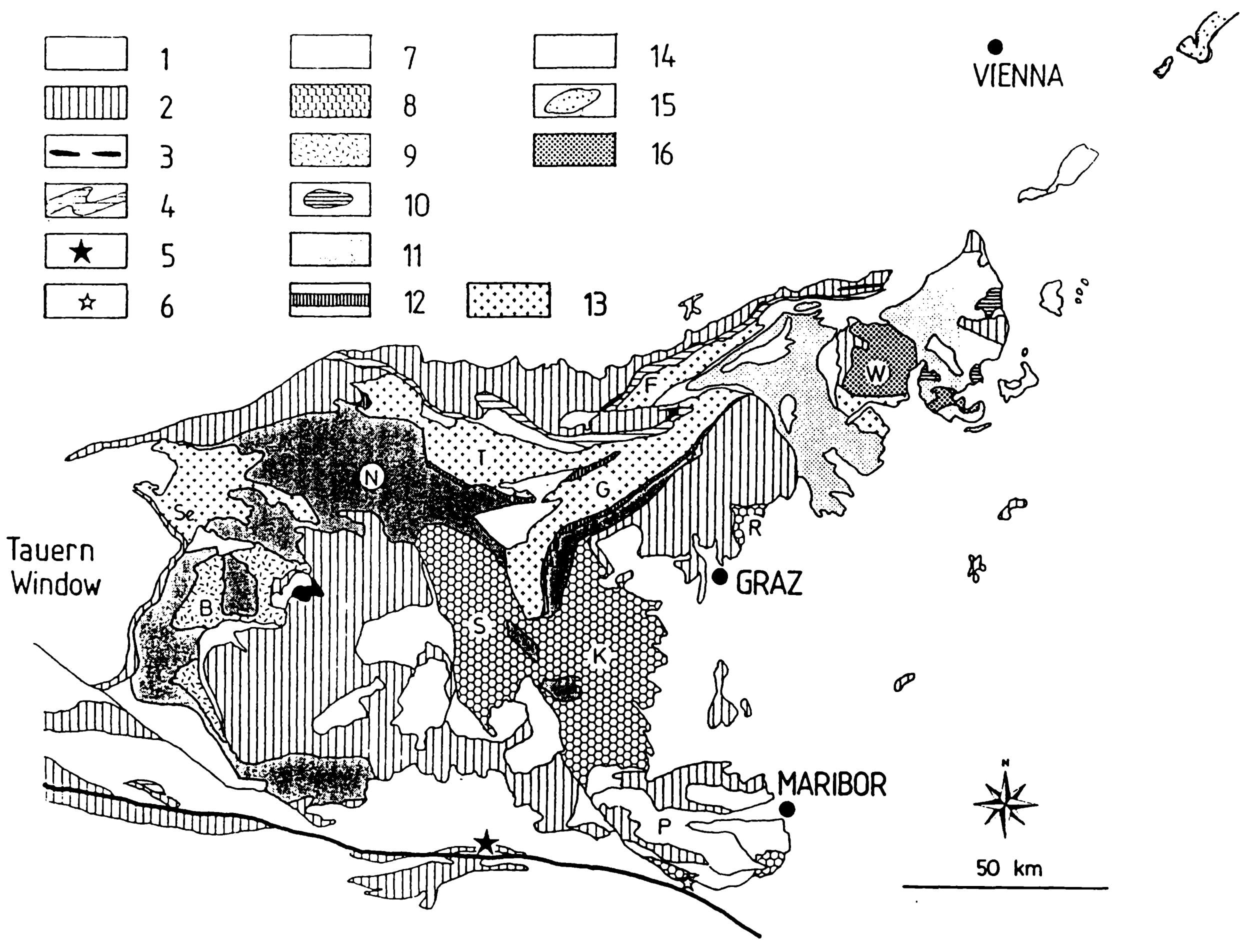


Fig. 5: Simplified map of Austro-Alpine basement units east of the Tauern window. Alpidic structures not shown. Legend: 1 - Permian to Cenozoic formations; 2 - fossiliferous Paleozoic formations and quartzphyllites; 3 - Kaintaleck slices and Ackerl complex (A); 4 - Carboniferous and Permian of the Veitsch nappe; 5 - Eisenkappel crystalline complex; 6 - Pohorje garnet-peridotite-granulite complex; 7 - Plankogel complex and related micaschist complexes; 8 - Koriden gneiss complex; 9 - Bundschuh complex; 10 - Sieggrabener complex; 11 - Micaschist-Marble complex; 12 - Speik complex; 13 - Core complex; 14 - "Grobgneis" complex; 15 - Tatric unit; 16 - Wechsel gneiss complex. Geographic signatures: B - Bundschuh; F - Troiseck-Floning mountains; G - Gleinalm; Gu - Gurktaler Alpen; K - Koralpe; L - Leithagebirge; N - Niedere Tauern; P - Pohorje mountains; R - Rennfeld; S - Saualpe; Sc - Schladminger Tauern; T - Seckauer Tauern; W - Wechsel.

The term Murides was created for basement units which differ from Koriden and Raabiden (Raabalpen Complex). This complex contains three major lithotectonic units, from top to bottom (Fig. 1, 3):

* the Micaschist-Marble Complex,
* the Speik Complex,
* the "Core Complex" which appears in several structural domes or cores below the first two complexes in the area east of the Tauern window.

The Koriden Complex is an eclogite-bearing basement complex ("Gneiss Group"), exposed in Koralpe and Saualpe mainly. It is overlain by the "Micaschist Group" which includes the ophiolitic Plankogel Complex. The "Micaschist Group" grades into a Phyllitic Micaschist which makes the distinction from UAA tectonic units uncertain often, especially if, as usual in southern portions of Austro-Alpine units, Permo-Mesozoic cover sequences are missing.

The MAA units are primarily covered by Permo-Triassic sequences of which only basal portions are preserved in the Rannach Fm. along the northern margin and by the Stangalm Group west of the UAA Gurktal Nappe System. The cover sequence includes basal clastic formations ("Alpine Verrucano", quartzite), rauhwacke, and Middle Triassic marbles and dolomites.

The Upper Austro-Alpine units

The Upper Austro-Alpine units contain several, mostly weakly metamorphic, often fossiliferous basement units which range from Middle Ordovician to Mid-Carboniferous (Gurktal Nappe Complex, Graz Nappe Complex, Noric Nappe of the Greywacke Zone). All these units, except the Paleozoic of Graz are covered by Late Carboniferous to Mesozoic sequences. Such covers occur along the northwestern margin of the Gurktal Nappe System and in the eastern part of this unit (Eberstein and St. Paul Permo-Triassic). A further polymetamorphic basement complex is the Kaintaleck Complex in the eastern Greywacke Zone which occurs underneath the Noric Nappe. Other metamorphic basement complexes also occur in the Gurktal Nappe System (Ackerl Complex and Pfannock gneiss).

Carboniferous sequences which occur in the Veitsch Nappe of the Greywacke Zone (constituted by Early Carboniferous to Permian sequences) and near Nötsch (Carboniferous) have a special importance because of otherwise not occurring marine clastic/carbonatic sequences.

Timing of Alpine metamorphism

Geochronological ages for timing of the Alpine metamorphic overprint are known since the Sixties. Geochronology yielded clear evidence that major portions of the southern Middle Austro-Alpine basement (e.g., the Koralm Gneiss Group, major portions of the Micaschist-Marble Complex) have been overprinted within Cretaceous amphibolite facies (Fig. 4; Frank et al., 1987b). Cyanite-bearing paragneisses are often associated with eclogites. Finally, Sm-Nd mineral isochrons of the Koralm eclogites clearly suggest a Cretaceous age of eclogite metamorphism (Thöni and Jagoutz, 1991).

However, the distribution of metamorphic isogrades is not well established although the boundary between Alpine amphibolite to greenschist facies is approximately known (Fig. 4).

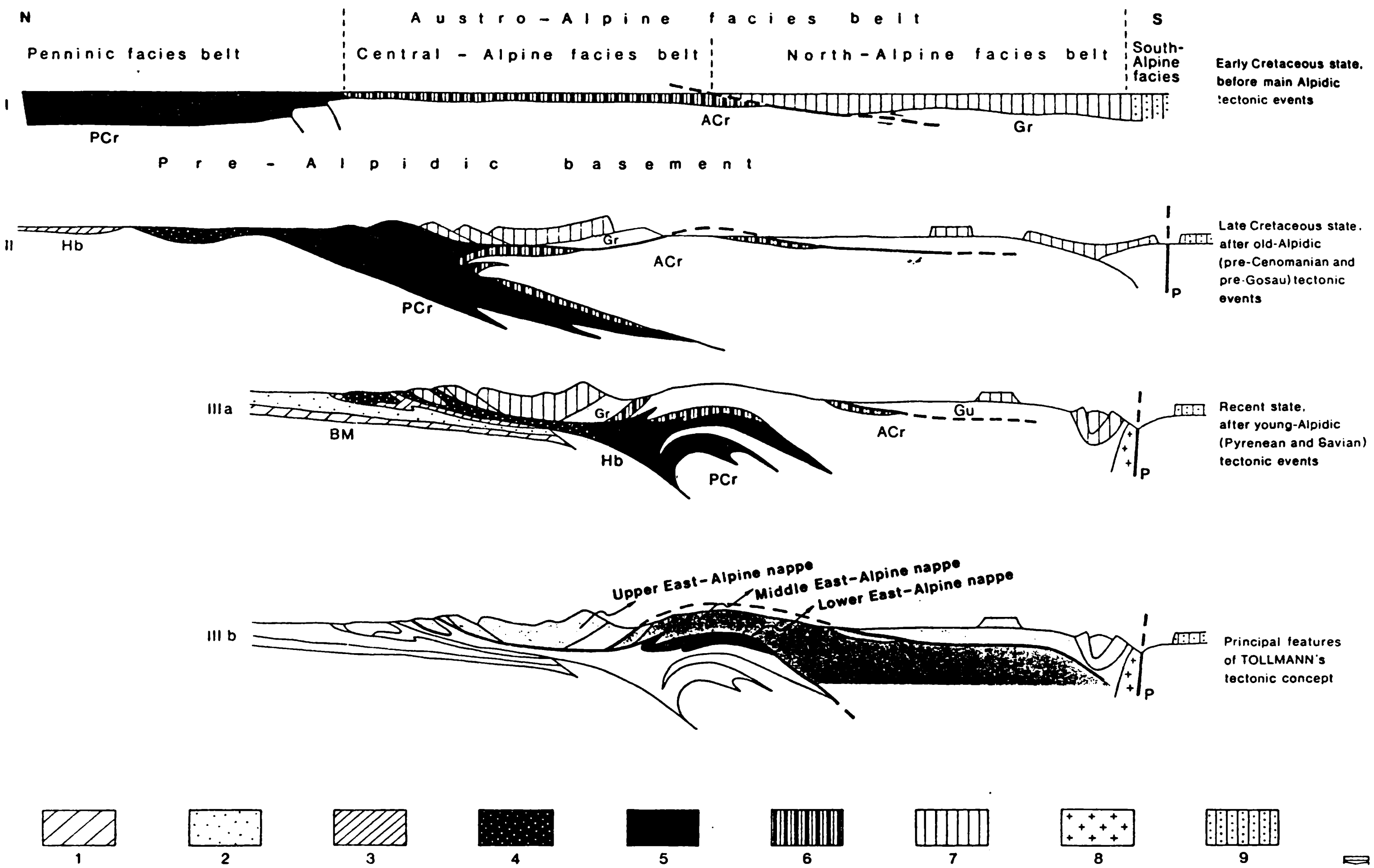
Of major interest is the feature that ages of post-metamorphic cooling varies in a systematic way from higher to lower tectonic levels. The white mica ages of the greenschist facies areas of the Upper Austro-Alpine tectonic units range from 140 to 120 Ma. These ages can be interpreted as formation ages because temperatures did not exceed 400°C. In the Middle Austroalpine unit the white mica cooling ages cluster at around 80 Ma (Frank et al., 1987b).

In contrast,the climax of metamorphism in the Penninic units is of Paleogene age, imprinting high pressure assemblages which are commonly interpreted to represent the high pressure belt to the Austro-Alpine medium pressure belt (see Frank et al., 1987a).

Paleogeographic and structural evolution

The Alpine geodynamics are interpreted in the following way: Permotriassic rifting resulted in subsidence and thinning of the Austro-Alpine crust. The open, Tethyan oceanic realm is thought to have been situated towards the Southeast. A second period of rifting during Jurassic times formed the South Penninic oceanic realm between the (Middle) Penninic continental crust and the LAA units (Frisch, 1979). Consumption of distinct units started with intra-Austro-Alpine nappe stacking during Early Cretaceous times (Fig. 6, 7).

The Alpine deformation within the Austro-Alpine and Penninic units is polyphase with large complexities by inversions on displacement surfaces. A sequence of Alpine deformation events is



Hypotheses of the tectonic evolution of the Eastern Alps (sections I, II, and III a; modified after E. Clar, 1973) and a schematic section (III b) showing the subdivision of the "East-Alpine" (= Austro-Alpine) Unit supported by A. Tollmann (1963).

Legend for the sections I, II, and III a: 1 = Tertiary rocks of the Molasse Zone; 2 = Extra-Alpine post-Variscan sedimentary rocks; 3 = Helvetic Zone and Klippen Zone; 4 = Flysch Zone; 5 = Permomesozoic of the Penninic Zone; 6 = Permomesozoic of the Central-Alpine facies belt; 7 = Permomesozoic of the North-Alpine facies belt; 8 = Periadriatic Intrusion; 9 = South Alpine facies; BM = Bohemian Massif; Hb = Basement of the Helvetic Zone; PCr = Crystalline Basement of the Penninic Zone; Gr = Palaeozoic rocks of the Grauwackenzone; Gu = Palaeozoic rocks of the Gurktal Sheet; ACr = Crystalline basement of the Austro-Alpine Unit; P = Periadriatic Lineament.

Fig. 7: Interpretation of the tectonic evolution of the Eastern Alps (from Janoschek and Matura, 1980).

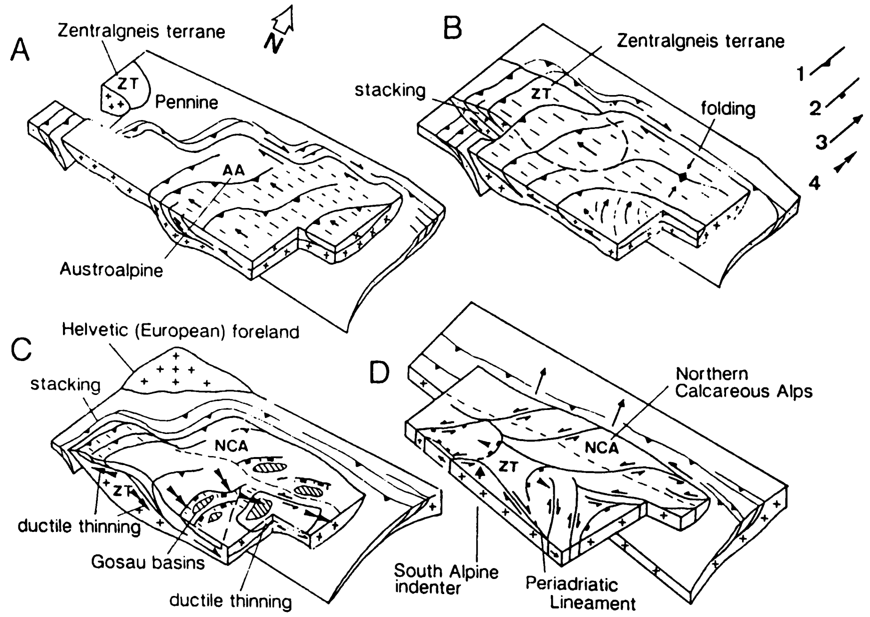
recognized with the following major steps (Ratschbacher et al., 1989; Neubauer and Genser, 1989; Behrmann, 1990):

The oldest structures are ductile thrusts which climb from within southern basement areas to basement-cover contacts into the cover rocks in the north (Fig. 6). The general displacement direction of Austro-Alpine units is towards the W, varying from WSW to WNW. The essential arguments for this interpretation are both stratigraphic distributions (climbing of the thrust surface to higher stratigraphic levels towards NW) and meso- to microscale structures.

Most of the important internal thrust surfaces within the Austro-Alpine unit are reactivated by subsequent ductile low-angle normal faulting during the Late Cretaceous. A system of normal faults with predominant top-to-the NE displacement is interconnected by steep sinistral shear zones. The Middle Austro-Alpine unit has been uplifted in domes. Therefore cooling, operation of normal and strike-slip faults and exhumation of metamorphic domes are coeval with subsidence of the Late Cretaceous Gosau basins.

Structures which are associated with the subsidence of Eocene basins are not known with certainty. Some N-S trending cataclastic fault zones may belong to such a system.

The next system of structures is a set of E-W to NE-SW trending faults. These faults form a broad sinistral wrench corridor along the northern part of the Austroalpine unit and led to the escape, respectively extrusion of the eastern Central Alps towards east against the Carpathians.



Orogenic wedge evolution in eastern Alps. A: Stacking and orogen-parallel extension during simple shear crustal imbrication. B: Underplating of Zentralgneis terrane. C: Unroofing extension and formation of Gosau basins. D: Continental escape. 1—Thrusts and shear zones. 2—Normal faults and extensional shear zones. 3—Thrust and shear directions during compression. 4—Motion directions during crustal thinning.

Fig. 6: Steps of Alpine kinematic evolution (from Ratschbacher et al., 1989).

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