Metamorphic structure of the Alps: Metamorphic evolution of the Eastern Alps

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INTRODUCTION

The Eastern Alps are the product of two orogenies, a Cretaceous orogeny followed by a Tertiary one (FROITZHEIM et al., 1996). The former is related to the closure of an embayment of the Neotethys ocean into Apulia (Meliata ocean), the latter is due to the closure of the Alpine Tethys oceans between Apulia and Europe.

The result of the orogenic movement is a complex nappe stack, which is built up from north to south and from bottom to the top by the following units (Fig.1A) (Plate 1 in SCHMID et al., 2004): The proximal parts of the Jurassic to Cretaceous European margin built up the northern Alpine foreland and the Helvetic nappes, whereas the distal margin is represented by the Subpenninic nappes. The Penninic nappes comprise the Piemont-Ligurian and Valais ocean (Alpine Tethys) and the Briançonnais Terrain. Apulia consists of the northern Austroalpine nappes and the Southern Alpine unit (STAMPFLI & MOSAR, 1999). Remnants of the Neotethys embayment occur as slices within the eastern part of the Austroalpine nappe stack. Both orogenic events are accompanied by regional metamorphism of variable extent and P-T conditions. The Cretaceous (Eo-Alpine) metamorphism effects mainly the Austroalpine nappes, the Penninic domain by the Tertiary metamorphism, some units of the Lower Austroalpine Nappes show signs of both events.

The distribution of the metamorphic facies zones in the Eastern Alps is mainly controlled by the northwards transport of the Austroalpine nappes (Fig. 1B). They show a Cretaceous metamorphism and are thrusted over the Penninic domains with Tertiary metamorphism (Fig. 1B). The latter are exposed in the Eastern Alps only as tectonic windows.

THE TERTIARY ALPINE METAMORPHIC EVENT

The Tertiary Alpine metamorphic event is due to the closure of the Jurassic to early Tertiary Briançonnais and Valais oceans (Alpine Tethys). According to WAGREICH (2001) the re-arrangement of the Penninic-Austroalpine border zone from a passive to an active continental margin starts at about 120 Ma. From that time on the oceanic lithosphere and slices from the northern margin of the Austroalpine unit (Lower Austroalpine units) were subducted towards the south below (Upper) Austroalpine units.

The Tertiary event reaches blueschist facies conditions in some Mesozoic parts of Penninic windows and some units of the Lower Austroalpine (Tarntal nappe). Eclogite facies conditions followed by a blueschist event occur only in a narrow zone of the Tauern Window. The thermal peak ranges from greenschist to amphibolite facies, the latter was only reached in the central part of the Tauern Window (Fig 2).

After the thermal peak at about 30 Ma (BLANKENBURG et al., 1989) uplift and cooling is recorded by K-Ar and Ar-Ar ages on white micas and fission track ages on zircon and apatite (LUKSCHEITER & MORTEANI, 1980; GRUNDMANN, & MORTEANI, (1985); FÜGENSCHUH et al., 1998). In the lower nappes of the Lower Austroalpine units the Tertiary Alpine metamorphism overprints the Cretaceous metamorphic event.

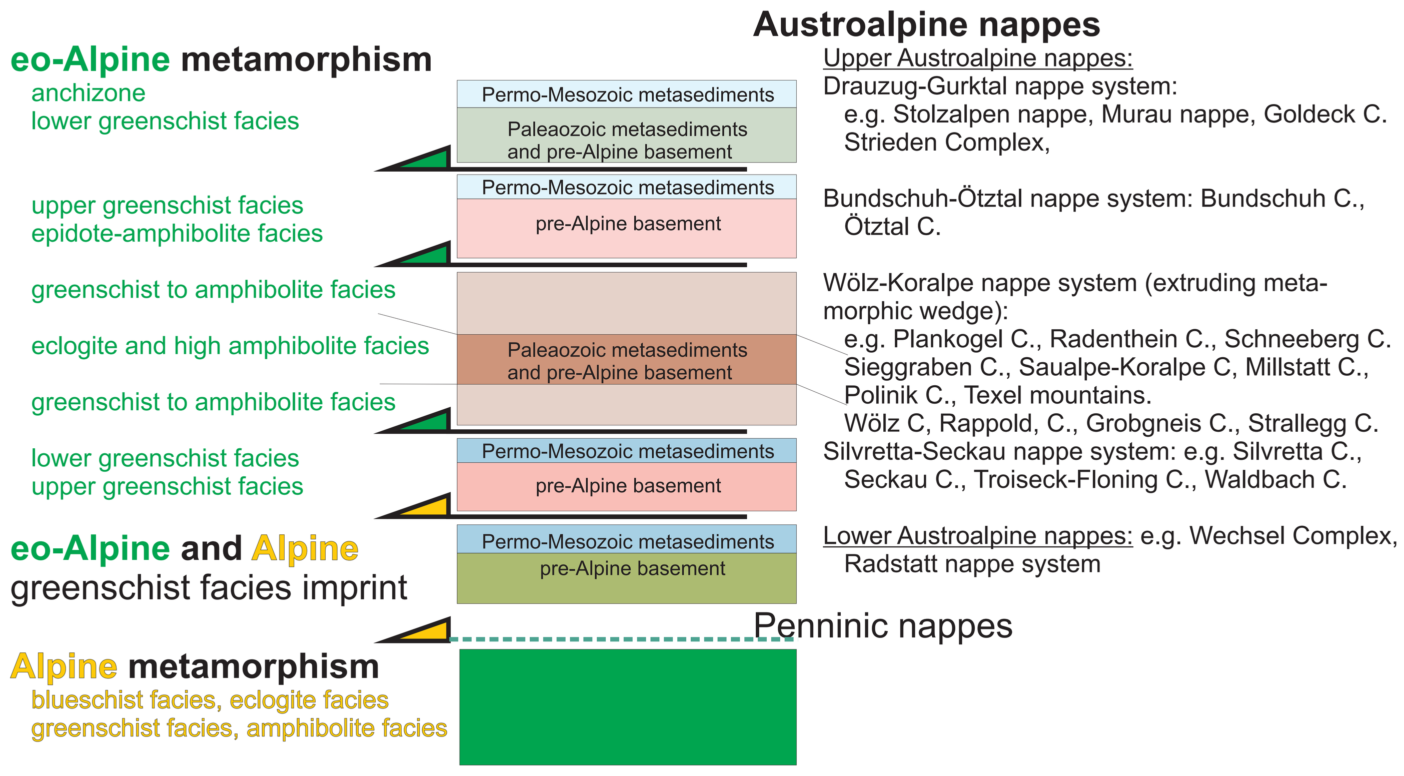

Fig. 3: Schematic nappe stack of the SE part of the Eastern Alps with the metamorphic evolution. Further the posible correlation to individual Austroalpine nappes from the western part of the Eastern Alps are show together with their metamorphic evolution.

Photo A: Alpine blueschist facies metapelite, Piz Mundin Unit, Lower Engadine Window (parallel Nicols, width 0.4 mm): alkalipyroxene and blue amphibolies in a matrix of quartz and phengite.
Photo B: Alpine blueschist, Matrei Zone, southern Tauern Window (parallel Nicols, width 0.4 mm): alkalipyroxenes and blue amphiboles in a matrix of quartz and albite.
Photo C: Alpine blueschist, Reckner Complex, northwestern rim of the Tauern Window (parallel Nicols, width 0.4 mm): deformed blue amphiboles in a matrix of albite and quartz. Calcite red coloured.
Photo D: Eo-Alpine Paragonite-bearing amphibolite, Wölz Complex, Koralpe-Wölz nappe system (parallel Nicols, width 10 mm): paragonite, Ca-amphibolite, garnet, plagioclase and ilmenite forming an epidote-amphibolite facies assemblage. Fine-grained muscovite and plagioclase are present as reaction rims between paragonite and amphibole.
Photo E: Eo-Alpine retrograde eclogite, Saualpe-Koralpe Complex, Koralpe-Wölz nappe system (parallel Nicols, width 10 mm): eclogite facies assemblage of phengite, garnet, zoisite, clinopyroxenen and hornblende with symplctites composed of hornblende, plagioclase and biotite.
Photo F: Permo-Triassic amphibolite facies metapelite, Jenig Complex, Drauzug-Gurktal nappe system (parallel Nicols, width 10 mm): staurolithe, garnet, andalusite and biotite formed during the Permo-Triassic high temperature / low pressure event.

THE EO-ALPINE (CRETACEOUS) METAMORPHIC EVENT

The eo-Alpine (Cretaceous) metamorphic event is widespread within and restricted to the Austroalpine unit. It is related to the continental collision following the closure of an embayment of the Tethys ocean during late Jurassic to Cretaceous times. Recent investigations indicate that the northern part of the Austroalpine unit forms the tectonic lower plate. The southern parts and the north-eastern margin of the Southalpine unit acted as the tectonic upper plate during the continental collision following the disappearance of the oceanic embayment (SCHMID et al., 2004).

The peak of the eo-Alpine metamorphic event was reached at about 100 Ma, the youngest cooling ages are recorded at 65 Ma (THÖNI, 1999). The eo-Alpine metamorphism starts at the base of the lower plate with greenschist facies and increases structurally upwards the nappe piles until eclogite facies is reached. It decreases again in the uppermost nappes to sub greenschist facies. The whole section represent a transported metamorphism (Fig. 3).

THE PERMO-TRIASSIC METAMORPHIC EVENT

The Permo-Triassic imprint reflects lithospheric extension after the late Variscan orogenic collapse. It may be due to the anticlockwise rotation of Africa and the southern part of the Apulian microplate with respect to Eurasia and the northern part of the Apulian microplate and caused extension within the Austroalpine and South Alpine realm. Accompanied thinning of the lithosphere resulted in a high temperature metamorphic imprint (HT/LP, Fig. 2) (SCHUSTER et al., 2001).

The Permo-Triassic imprint is widespread in the Austroalpine unit (Fig. 4) and affects pre-Permian rocks of different metamorphic grade (HABLER & THÖNI, 2001; SCHUSTER et al., 2001).

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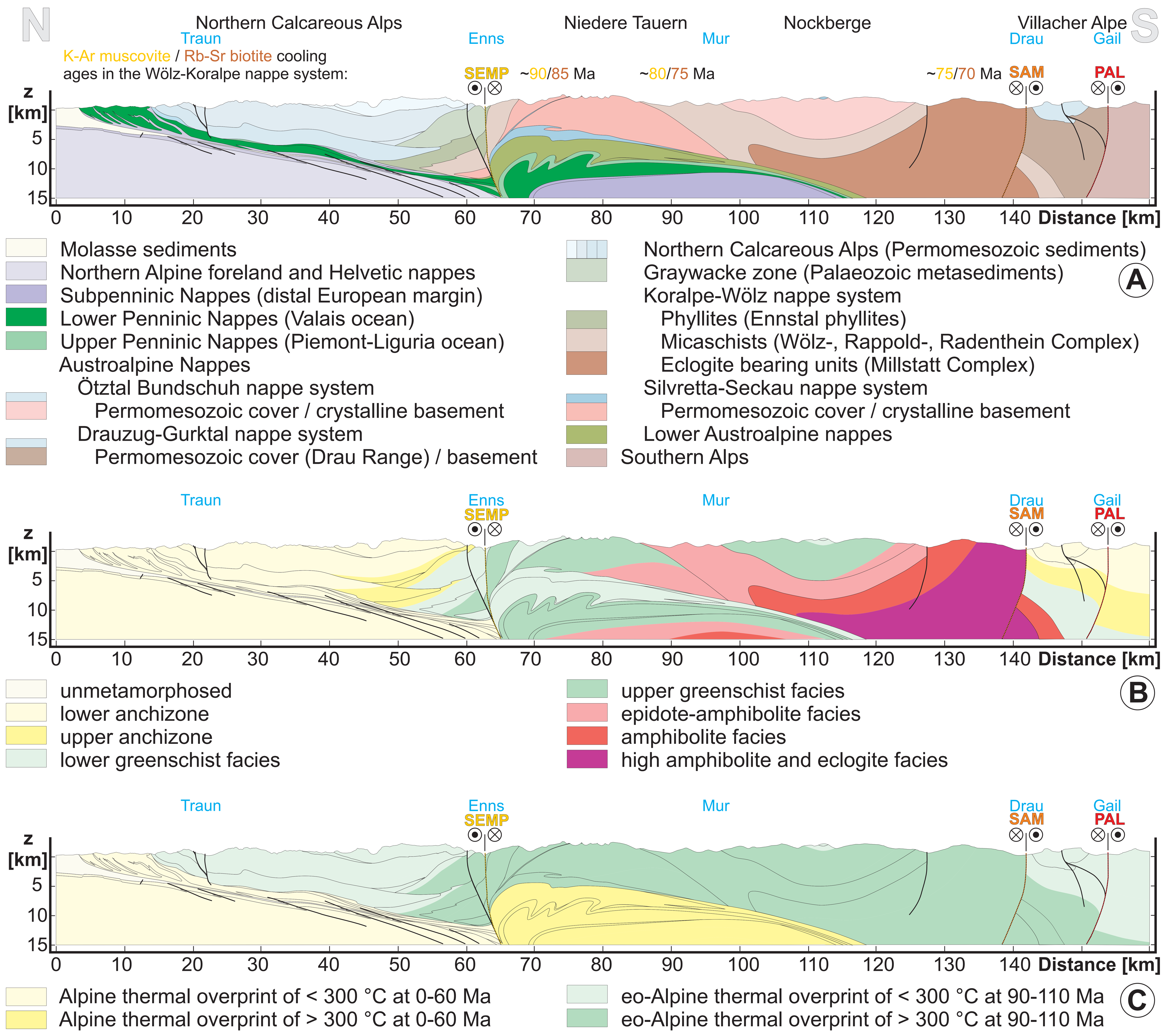
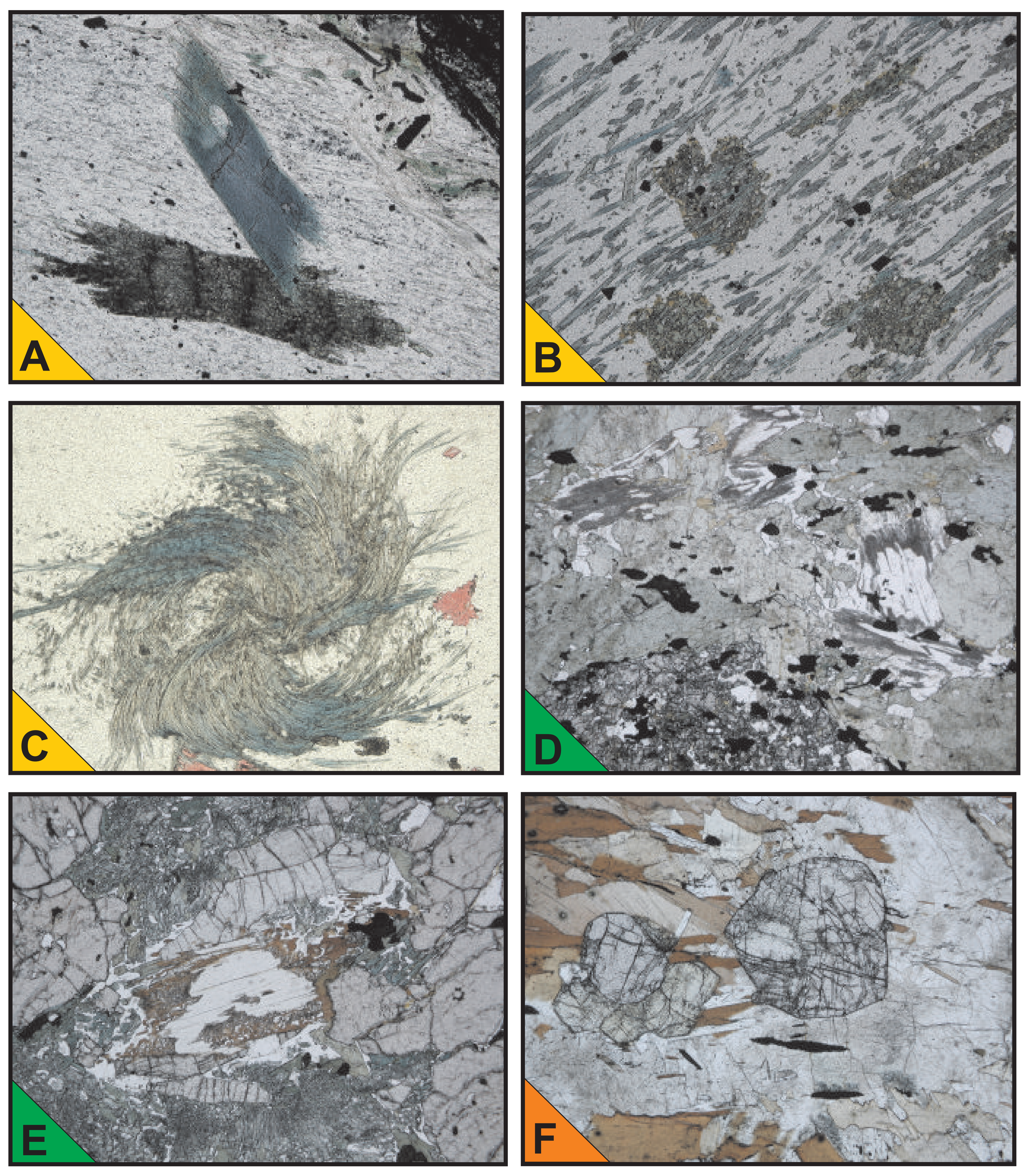


Fig. 1: Schematic transect through the eastern part of the Eastern Alps. The transects show the main tectonic units in (A), the metamorphic grade in (B) and the age distribution of the metamorphic imprint based on HANDY & OBERHÄNSLI (2004) in (C).



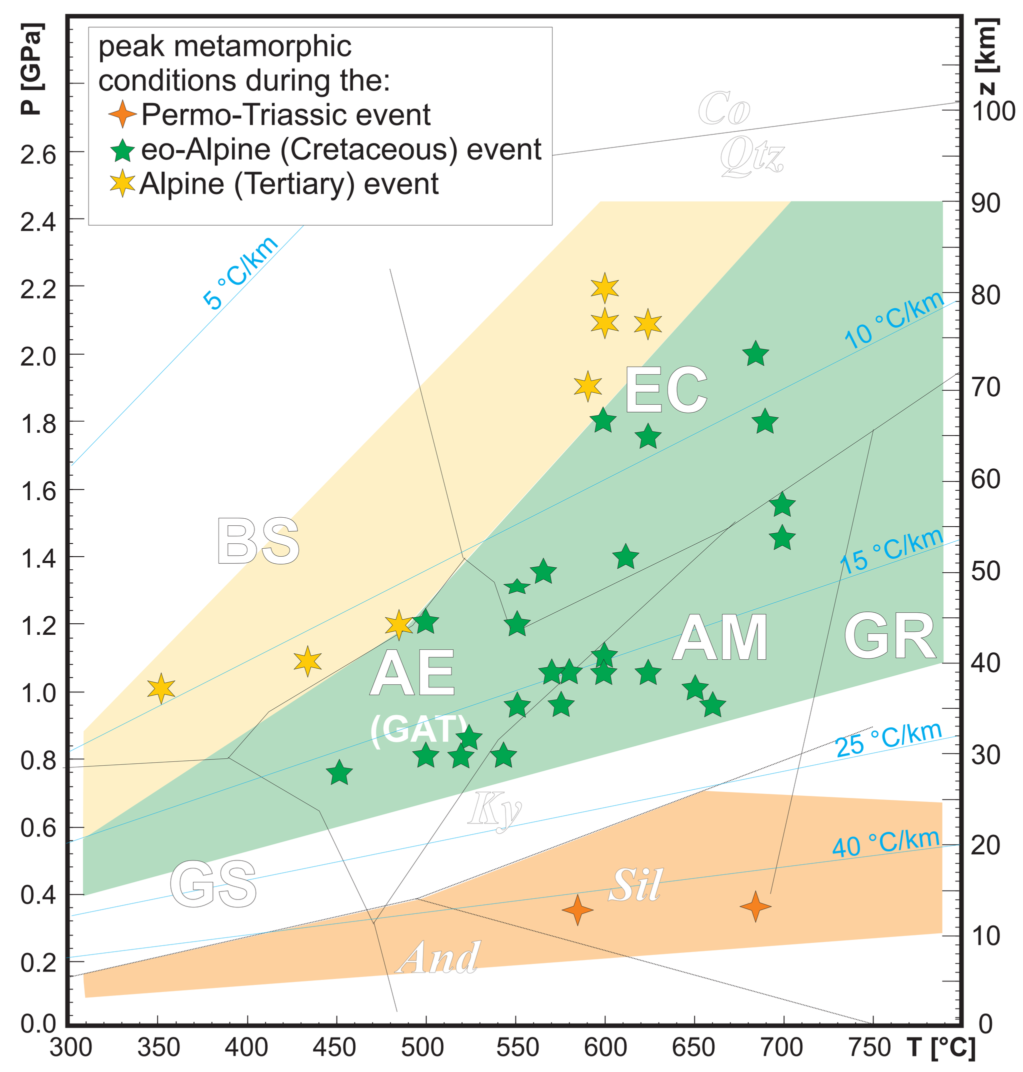


Fig. 2: Diagram showing the peak metamorphic P-T data referred in SCHUSTER et al. (2004). The Permo-Triassic, Eo-Alpine and Alpine metamorphic event are characterised by different geothermal gradients during the metamorphic peak.

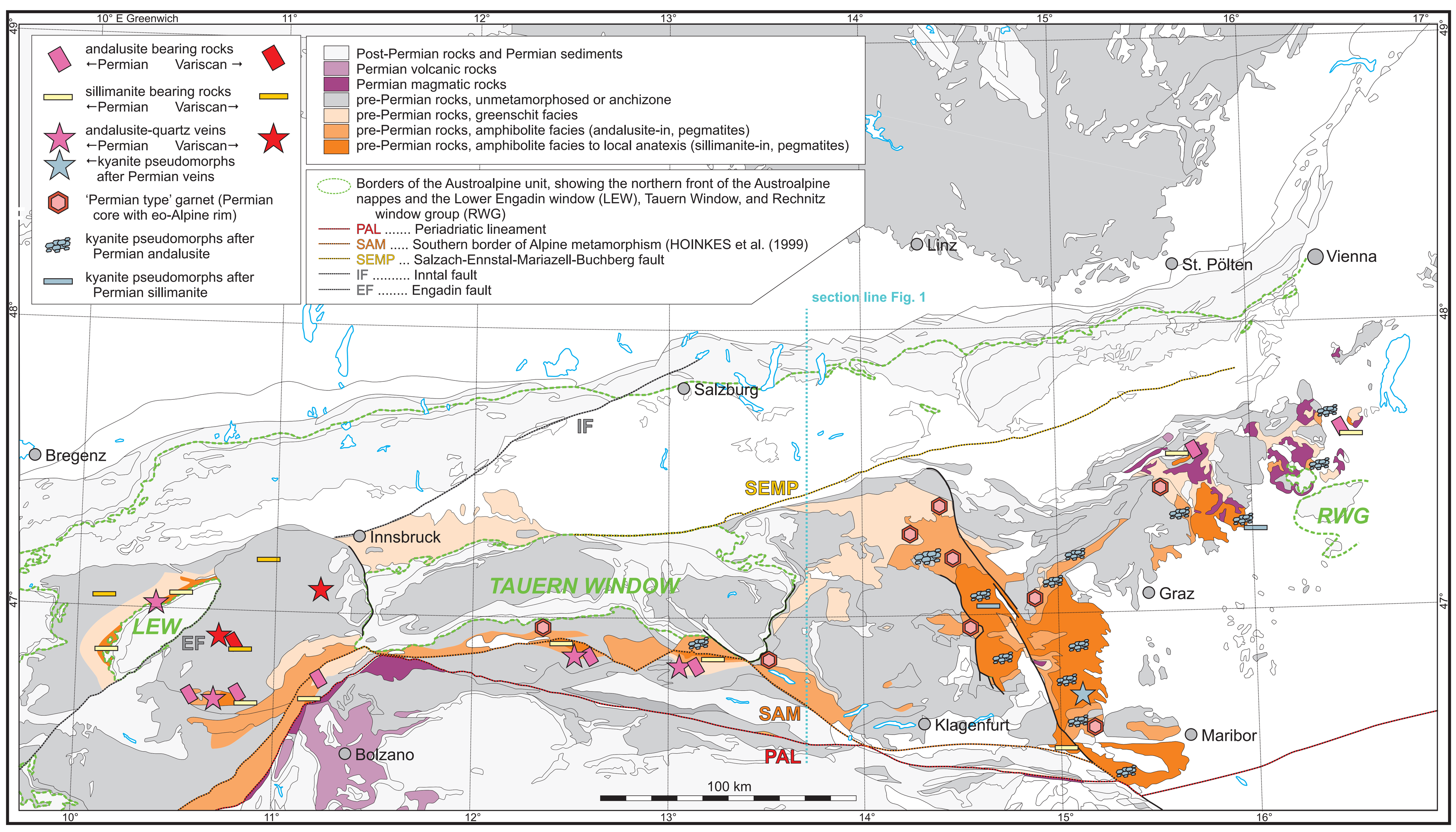


Fig. 4: Tectonic map of the Eastern Alps showing the distribution of the Permo-Triassic metamorphic imprint. Additionally the section lines of the transsects in Fig. 1 is given.