Mesozoic Metamorphic evolution of the Tauern Window

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Introduction

The oldest rocks in the Tauern Window are found in a volcano-sedimentary sequence comprising ophiolites, island arc volcanics and associated sediments of Late Proterozoic to Paleozic age (Habach Formation). A part of this sequence underwent pre-Mesozoic metamorphism, partly migmatisation and was intruded by Variscan granitoids.

The Postvariscan sequences start with Permotriassic quarzites, middle Triassic limestones and dolomites and late Triassic sandstones and shales (Keuper). The Triassic rocks are overlain by shales, marls and shaly limestones of Jurassic to early Cretaceous age (Bündnerschiefer Formation). Locally, sandstones, breccias and arcoses occur. Associated with the sediments are ophiolites and other basic intrusions and volcanics. The youngest sediments proven so far are of early Cretaceous age but by comparison with lithologically similar sediments in the Lower Engadin Window and the Penninic realm in the Western Alps the occurrence of younger sediments seems at least possible.

Tectonically two nappes are generally delineated (Frisch, 1976): the lower Venediger nappe comprising most of the pre-Mesozoic rocks and relatively little Mesozoic sediments and volcanics and the higher Glockner nappe including most of the Triassic rocks, the Bündnerschiefer and the ophiolites. Both nappes were later folded, forming a huge anticline with an axis following approximately the main ridge of the Alps. Apart from the pre-Mesozoic metamorphism three episodes of metamorphic events were recognized: an eclogite event, a blueschist metamorphism, and the final greenschist to amphibolite facies metamorphism called "Tauernkristallisation" by SANDER (1912). The eclogitisation affects only a relatively small strip mainly at the southern escarpment of the Tauern Window, the blueschist metamorphism is more widely distributed but restricted to the ophiolites, their immediate cover and the areas tectonically below. The Tertiary greenschist to amphibolite facies metamorphism can be seen in all rocks of the Tauern Window.

Eclogite event

The most conspicuous eclogite assemblages are found mainly in metabasic rocks. The most important minerals in the basic eclogites are: Omp, Grt, Ky, Tlc, Pg, Qtz, Rt, MgCld, and in metapelites: Omp, Grt, Cld, Ky, Zo, Phe Qtz, Rt. Based on the Fe/Mg distribution between coexisting clinopyroxenes and garnets in the eclogites temperatures were calculated between 550 - 570□C by Frank et al. (1987). The pressures were estimated as being close to 20 kbar. Comparable PT estimates are reported for the siliceous dolomites (T = 600 °C, P = 18 - 25 kbar), calc-micaschists (T = 590 ± 20 °C, P = 19 ± 2 kbar) and for metapelites (T = 600 °C, P = 21 kbar). More recently, higher pressures up to 25 kbars were published by Stöckhert et al. (1997).

Blueschist event

The minerals formed in the blueschist event survived only rarely. They can by traced by some singular mineral relicts and by pseudomorphs. The best preseved remnants are found in the vicinity of the eclogite zone. The most conspicuous relicts from this stage are the pseudomorphs after lawsonite. In basites the pseudomorphs consist mainly of Czo/Ep, Ab, Chl, Act, Bt in calcareous rocks of Zo/Czo, Cal, Ab, Chl. Despite a systematic search no preserved relicts of lawsonite were found up to now as e.g. in the Lower Engadin Window. Occasionally blue amphiboles such as glaucophane and/or crossite are preserved and probably barroisitic amphiboles. Associated with this stage are high Si phengites with Si = 3.30 - 3.40(3.70) pfu. From that data Frank et al. (1987) estimated the conditions of blueschist formation as T = 400 – 450 °C and P around 9 kbar. Zimmermann et al. (1994) calculated 10 kbar at 400 °C.

Greenschist to amphibolite facies event

In the whole Tauern Window a field of greenschist facies can be separated from an amphibolite facies area. The high temperature zone is characterized by oligoclase, magnesiohornblende(basic rocks), garnet and kyanite(metasediments); staurolite is rare.

The calcareous metasediments are variable in comosition and include besides the voluminous calc-

micaschists (with minerals such as Cal, Dol, Phe, Pg, Mrg, Chl, Cld, Zo, Grt. Bt, Qtz) carbonate quartzites and impure marbles. Mineral assemblages indicate temperatures between 450 °C and 510 °C at 6 kbar in the central part of the Tauern Window (Höck and Hoschek, 1980; Frank et al., 1987; Dachs et al., 1991). In the western part univariant assemblages in the TX space such as Bt, Zo, Chl, Cal, Dol, Qtz can be mapped, but invariant assemblages are rare. Temperatures between 500 to 550 °C at a pressure around 6 kbar describe the appropriate physical conditions (Hoschek, 1984).

Fluid inclusions studied in quartz, epidote and other minerals indicate that the cooling path of the greenschist to amphibolite facies event passed through a T intervall of 430-500 °C and P between 2 and 4 kbar.

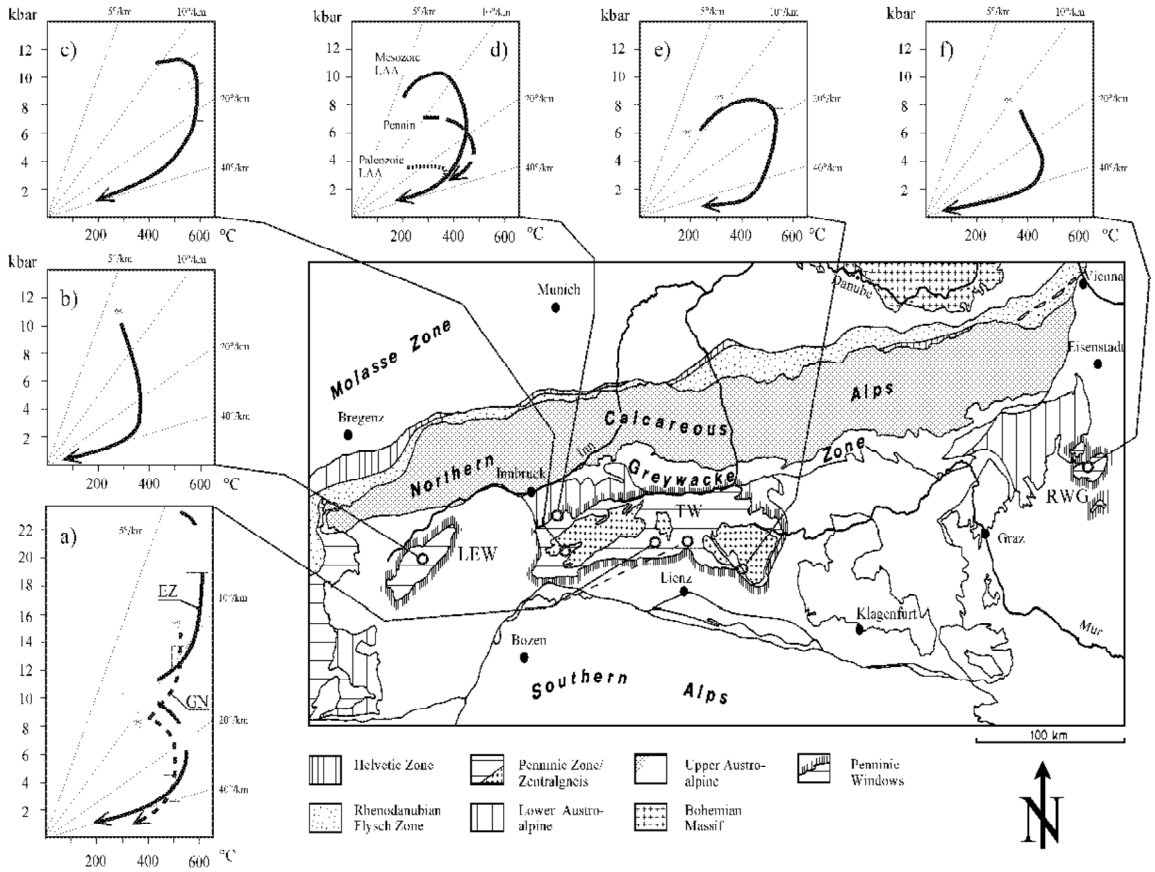

Fig.1. Geological sketch map of the Eastern Alps depicting the three Penninic windows. They are from the west to the east marked by a hatched boundary: ***Ew*** *Lower Engadin Window,* ***Tw*** *Tauern Window and* ***Rwg*** *Rechnitz Window group. Inserted are six characteristic PT paths (a-f):* ***a: Tauern Window; Eclogite Zone, b:*** *Lower Engadin Window,* ***c: Western Tauern Window, d:*** *Lower Austroalpine Nappe, Tarntal Mtns.,* ***e: Tauern Window; Glockner Nappe, f:*** *Rechnitz Window Group.*

Age dating

The first ages determined in the Tauern Window were based on K/Ar and Rb/Sr dating of biotite and white mica. The biotite ages cluster in the eastern Tauern Window between 15 and 22 Ma, the muscovite ages between 21 and 28 Ma and in the western part around 13 Ma and 15-20 Ma respectively. They lower ages are interpreted as cooling ages of the greenschist to amphibolite grade metamorphism, some of the higher Oligocene ages from the structurally lowest parts as approximation of the metamorphic climax. Few ages, mainly in the western part of the Tauern Window and in the northeastern corner are older than 30 Ma (Eocene/Oligocene boundary).

More recent studies based on $^{40}Ar/^{39}Ar$ dating confirmed the Eocene/Oligocene ages for Si rich phengites (Zimmermann et al., 1994). They come from the Lower Schieferhülle, the eclogite zone and few from the Upper Schieferhülle. Most of the analyzed micas are associated with the blueschist event. Zimmermann et al., 1994 argue that the blueschist metamorphism has taken place between 36 and 32 Ma. and the cooling of the subsequent greenschist to amphibolite facies event after 27 Ma, accoding to a minimum age revealed from a phengite in the Upper Schieferhülle. It is noteworthy that recently even higher ages from calc-micaschists from the Upper Schieferhülle were reported by Dingeldey et al. (1997) with $^{40}Ar/^{39}Ar$ ages between 42 -38 Ma

measured from phengites in Bündnerschists, which have obviously experienced only the greenschist facies event.

A completely different method was used by Christensen et al. (1994) to determine the growth rate and age of garnets in two garnet bearing micaschists from the upper and the lower Schieferhülle respectively. Measurement of the Rb-Sr isotopes at individual segments of single garnets from the the upper Schieferhülle revealed an age of 35Ma for the core and 30.5 to 31 Ma for the rim. The oldest age measured in the core of a garnet from the lower Schieferhülle yielded 55 Ma, the youngest 32 Ma. Extrapolating from the calculated growth rate they inferred the onset of garnet crystallisation as old as 62 Ma.

Fission tracks in apatites record a very late stage of exhumation with rocks passing through a temperature interval of approximately 80 – 100 °C. This varies in the western Tauern Window from 5 - 10 Ma with a systematic increase in age values from the mineral zones in the core towards the rim of the Tauern Window.

Conclusions

From the presented PT data it is clear that the alpine metamorphic evolution cannot be described in a single retrograde PT loop. The eclogite, formed originally at 20 (25) kbar and between 550 to 600°C, cooled first to the blueschist event at 9 - 11 kbar and 350 - 450°C (Fig. 1a). There the eclogite path joined the loop for the ophiolites and all rocks structurally below in the Lower and Upper Schieferhülle wich reached its Tmax between 450 to 550°C (>600°C in the eastern TW according to DROOP, 1985) at pressures between 5 - 7 kbar and cooled later down to 375 - 400°C at 2 - 4 kbar as indicated by the fluid inclusions (Fig. 1e).

While for a wide area the separation of an earlier low T blueschist event at relatively high pressures is well established, the metamorphic evolution in parts of the western TW, especially in the Lower Schieferhülle seems to be different. (Selverstone et al., 1984). Their systematic study of zoned garnets, plagiocase and amphiboles from hornblende garbenschists allowed condstructing a PT path significantely different from previous PT paths. Their PT loop indicates a maximum pressure of 10 kbar at 530°C and passes through 550°C at 7 kbar. The lowest determined point on this loop is constrained by fluid inclusions at 375°C and 1.5 kbar (Fig. 1c).

Literature

Christensen, J.N., Selverstone, J., Rosenfeld, J.L., Depaolo, D.J.: Correlation by Rb-Sr geochronology of garnet growth histories from different structural levels within the Tauern Window, Eastern Alps. - Contrib. *Mineral. Petrol., 118, 1994, 1-12.*

Dachs, E., Frasl, G., Hoinkes, G.: Mineralogisch-petrologische Exkursion ins Penninikum des Tauernfensters (Großglockner Hochalpenstraße/Südliches Großvenediger Gebiet) und in das Ötztalkristallin (Timmelsjoch/Schneebergerzug). - *Europ.J. Mineralogy, 3, Beiheft 2, 1991, 79-110.*

Dingeldey, Ch., Dallmeyer, R.D., Koller, F., Massonne, H.-J.: P-T-t history of the Lower Austroalpine Nappe Complex in the „Tarntaler Berge“ NW of the Tauern Window: implications for the geotectonic evolution of the central Eastern Alps. - Contrib. *Mineral. Petrol., 129, 1997, 1-19.*

Droop, G.T.R.: Alpine metamorphism in the south-east Tauern Window, Austria: 1. P-T variations in space and time. - *J. metamorphic Geol., 3, 1985,371-402.*

Frank, W., Höck, V., Miller. Ch., Metamorphic and tectonic history of the central Tauern Window. - In: Flügel, H.W., Faupl, P. (Eds): *Geodynamics of the Eastern Alps. Deuticke: Wien, 1987 ,34-54.*

Höck, V. Hoschek, G.): Metamorphism of calcareous metasediments in the Hohe Tauern, Austria. - Mitt. Österr. *Geol. Ges., 71/72, 1980, 99-118.*

Hoschek, G.: Alpine metamorphism of calcareous metasediments in the Western Hohe Tauern, Tyrol: mineral equilibria in COHS fluid. - Contrib. Mineral. Petrol., 87, *1984*, 129-137.

Sander, B.: Über einige Gesteinsgruppen des Tauernwestendes. - *Jb. k.k. geol. Reichsanst., 62, H. 2, 1984, 219-287.*

Selverstone, J., Spear, F.S., Franz, G., Morteani, G. :High-pressure Metamorphism in the SW Tauern Window, Austria: P-T Paths from Hornblende-Kyanite-Staurolite Schists. - *J. Petrology, 25, Part 2, 1984, 501-531.*

Stöckhert, B., Massonne, H.-J., Nowlan, E.U.: Low differential stress during high-pressure metamorphism: The miscrostructural record of a metapelite from the Eclogite Zone, Tauern Window, *Eastern Alps. - Lithos, 41, 1997*, *103-118.*

Zimmermann, R., Hammerschmidt, K., Franz, G.: Eocene high pressure metamorphism in the Penninic units of the Tauern Window, Eastern Alps): evidence from ^{40}Ar-^{39}Ar dating and petrological investigations. - *Contrib. Mineral. Petrol, 117*, 1994, *175-186.*