Preliminary Eo-Alpine Thermobarometric Results of the Austroalpine Crystalline Basement Nappes in the Northwest of the Tauern Window Between the Zillertal and the Wipptal (Eastern Alps, Tyrol)

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In the frame of the TRANSALP project, this investigation addresses the thermobarometry of the crystalline basement nappes in the area to the northwest of the Tauern Window between the Zillertal in the East and the northern part of the Brenner Basis Tunnel line. The units to be studied in the course of investigation are the Innsbruck Quartzphyllite (IQP), the Kellerjochgneiss (KG) and the Patscherkofel Crystalline (PC) (Fig. 1). The Innsbruck Quartzphyllite and the Kellerjochgneiss show a polymetamorphic evolution with a pre-Alpine metamorphic overprint (Variscan and/or Permian) and a pervasive Eo-Alpine overprint under low to high greenschist facies conditions (PIBER, 2002). The Patscherkofel Crystalline shows evidence for a strong Variscan amphibolite facies overprint and also a pervasive Eo-Alpine overprint under low to high greenschist facies conditions.

The IQP contains the mineral assemblage muscovite + albite + chlorite + quartz. No pre-Alpine relics have been found so far. The intercalated greenschists of the IQP, which are metavolcanic rocks of few meters in diameter, contain the mineral assemblage albite + chlorite + muscovite + epidote + sphene + calcite + stilpnomelane ± ilmenite ± biotite ± amphibole. The KG, which is an augengneiss overlying the IQP, contains the mineral assemblage muscovite + biotite + albite + chlorite + quartz ± stilpnomelane. Additionally a sample from a pegmatite, crosscutting the KG, contains the assemblage garnet$_1$ (Alm_{68} $Spess_{27}$ Pyr_3 Gro_2) + garnet$_2$ ($Gros_{52}$ Alm_{33} $Spess_{15}$) + biotite + stilpnomelane + muscovite + chlorite + albite + quartz. This assemblage probably represents a remnant of an earlier metamorphic event (possibly Permian). The PC, which also lies in a tectonically higher position, is mainly composed of mica schists with the mineral assemblage albite + plagioclase + muscovite + biotite + chlorite + quartz ± chloritoid ± garnet$_1$ ± garnet$_2$ ± ilmenite ± clinozoisite ± staurolite ± margarite. Pre-Alpine relics are garnet$_1$ + staurolite, all other minerals are part of the Eo-Alpine mineral assemblage.

Thermobarometric data from this area are rare except for detailed information of the KG and the lower grade parts of the IQP from the northern Zillertal area so far (PIBER, 2002). Quantifying the PT conditions of the metamorphic zonation of the IQP as well as the overlying Patscherkofel Crystalline is essential for any geodynamic reconstruction of the Austroalpine basement nappes northwest of the Tauern Window.

Thermobarometry of the KG, the lower grade parts of the IQP from the northern Zillertal area and the greenschists in the IQP was performed by calculating invariant points with the program TWQ v1.02 (BERMAN, 1992) and the data base of MASSONNE (1997) and VIDAL (2002). In addition, the empirically calibrated muscovite + chlorite + stilpnomelane + quartz thermobarometer by CURRIE & VAN STAAL (1999) was applied. Thermobarometry of the samples of the Kellerjochgneiss with TWQ v1.02 with the data base of BERMAN (1992) yields pressures ranging from 4.0 to 11.0 kbar and temperatures ranging from 242 to 408°, whereas most of the calculations lie around pressures of 5 to 8 kb and temperatures of 250 to 360°C (Fig. 2). The calculations with TWQ v1.02 using the data base of MASSONNE (1997) yield pressures of 4.0 to 8.0 kbar and temperatures of 250 to 360°C. The thermobarometric calculations performed with THERMOCALC v2.07 with the data base of HOLLAND & POWELL (1998) yield pressures ranging from 3 to 11.0 kbar and temperatures of 280 to 400°C. Most samples yield pressures of 3 to 8 kb and temperatures of 280 to 380°C. Multi-equilibrium calculations involving Fe-stilpnomelane with the data base of MASSONNE (1997) yield pressures ranging from 5.8 to 7.8 kbar at temperatures of 310 to 400°C, which are in good agreement with the results from the other thermobarometers (Fig. 2).

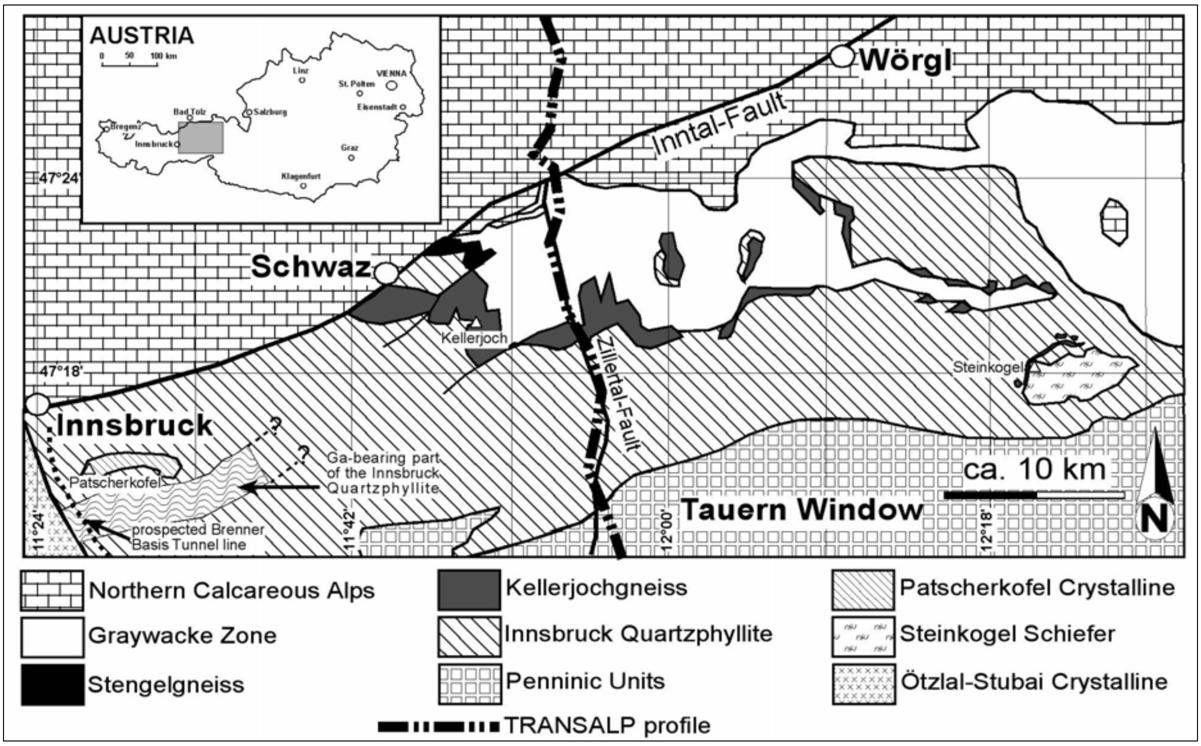

Fig. 1: Geological overview of the area of investigation which is bordered by the Zillertal in the east and western limit of the IQP in the west.

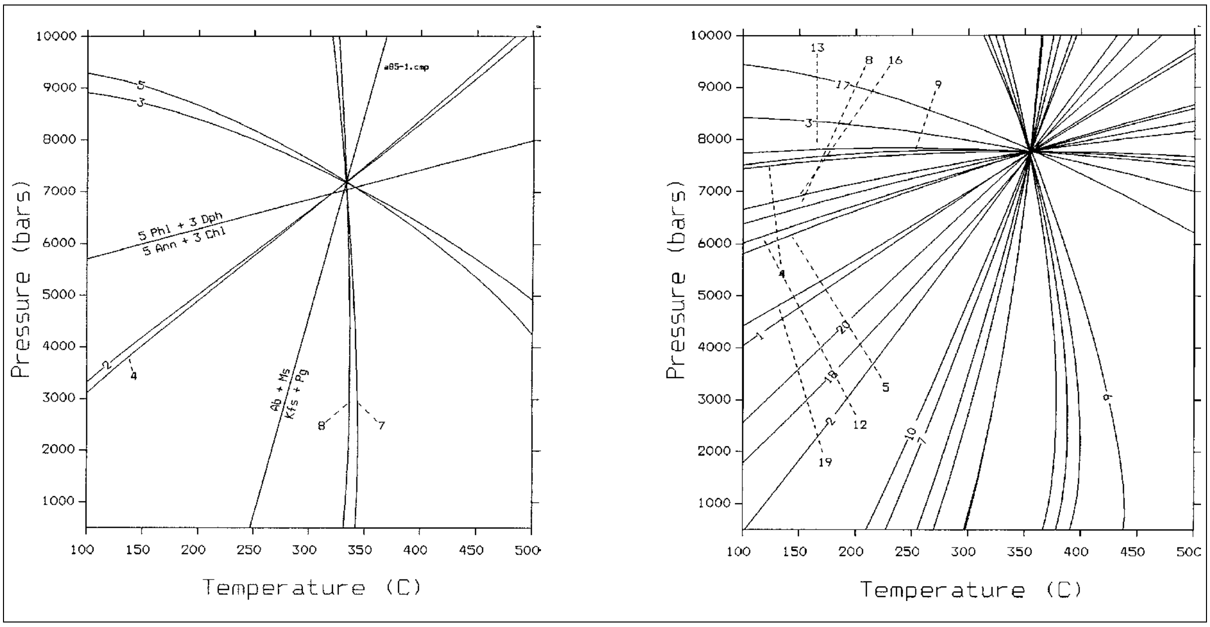

Fig. 2: This figure illustrates two examples of multi-equilibrium calculations of the Kellerjochgneiss. The left plot shows the result of sample A-85, calculated with TWQ v1.02 with the data base of BERMAN (1988) in the system KNMFASH. The figure right depicts the result of sample A-77, calculated with TWQ v1.02 with the data base of MASSONNE (1997) in the system KMFASH including Fe-stilpnomelane.

Due to the lack of suitable mineral phases for thermobarometric calculations PT data of the Innsbruck Quartzphyllite are rare. At temperatures ranging from 300 to 400°C, pressures could be obtained with TWQ v1.02 with the data base of MASSONNE (1997); they lie at 4.8 ± 1.2 kbar. The calculations with TWQ v1.02 using the data base of MASSONNE (1997) of the greenschists yield average pressures of

5.6 ± 1.1 kbar and average temperatures of 389 ± 33°C for the assemblage muscovite + chlorite + feldspar + quartz + titanite + rutile. The thermobarometric calculations performed with THERMOCALC v2.07 with the data base of HOLLAND & POWELL (1998) yield average pressures of 5.9 ± 2.5 kbar and average temperatures of 408 ± 50°C for the same mineral assemblage. The results obtained with the empirical thermobarometer of CURRIE & VAN STAAL (1999) involving Fe-stilpnomelane + muscovite + chlorite yield slightly lower pressures and temperatures ranging from 4.3 ± 1 kbar and 368 ± 62°C and are in good agreement to the PT data obtained with the multi-equilibrium calculation programs mentioned above. Results with TWQ v2.02b (BERMAN, 2002) using the data base of VIDAL (2002) yield pressures of 2.6 to 4.2 kb and temperatures of 280 to 390°C for the mineral assemblage muscovite + chlorite + quartz which are in agreement with the results of previous PT calculations (Fig. 3).

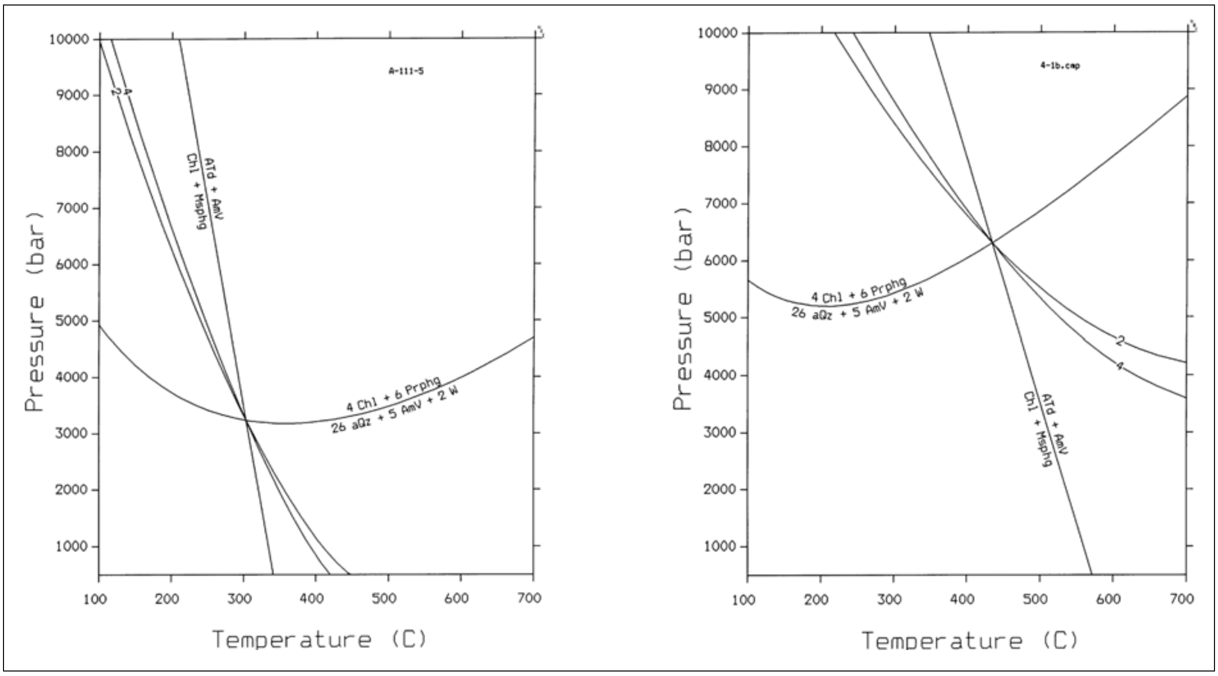

Fig. 3: The figures above illustrate the difference in pressure and temperature of two samples, one from the IQP of the northern Zillertal area (sample A-111) and one from the Patscherkofel Area from the westernmost part of the IQP (sample IQP-P4). Both were calculated with TWQ v. 2.02b with the data base of VIDAL (2002) using the mineral assemblage muscovite + chlorite + quartz in the system KMASH. The right figure (sample IQP-P4) depicts higher PT conditions for the IQP from the westernmost part.

Thermobarometry of the PC and the westernmost part of the IQP was performed by calculating invariant points with the program TWQ v1.02 (BERMAN, 1992) and TWQ v2.02b (BERMAN, 2002) and the data base of BERMAN (1992) and VIDAL (2002). These calculations yield pressures ranging from 5.2 to 6.1 kbar and temperatures ranging from 360°C to 476°C (Fig. 3). Application of the garnet biotite thermometer yields temperatures of 500°C to 524°C at pressures in the range of 5-6 kbar for the biotite- and garnet zone within the IQP. The calculations of samples from the Patscherkofel Crystalline with TWQ v1.02 using the data base of BERMAN (1992) yield an invariant point with pressures of 10.6 ± 0.3 kbar and temperatures of 504.6 ± 7.6°C (Fig. 4) for the Eo-Alpine mineral assemblage albite + biotite + muscovite + $garnet_2$ + chlorite. Application of the garnet - biotite thermometer and the garnet - plagioclase - muscovite - quartz barometer, yields temperatures of 498°C to 580°C and pressures ranging from 8.2 to 12.2 kbar (Fig. 5). These data are in good agreement with the results from the other thermobarometers.

The geothermobarometric investigations of the Austroalpine units located in the northern Zillertal area reveal a wide range of pressures. This can be the result of a mixture of two metamorphic stages, where the first one might be a pre-Alpine event (Variscan or Permian) with low pressures and the second one might be correlated to an early Eo-Alpine HP event. The second scenario might be, that the PT-data are the result of an Eo-Alpine event with high pressures of >6 kb and a strong retrograde overprint which affects the rocks to various degrees. The lower pressure estimates in the Innsbruck Quartzphyllite could indicate that the Kellerjochgneiss is the crystalline basement of the Innsbruck Quartzphyllite although the contact between them is of tectonic nature.

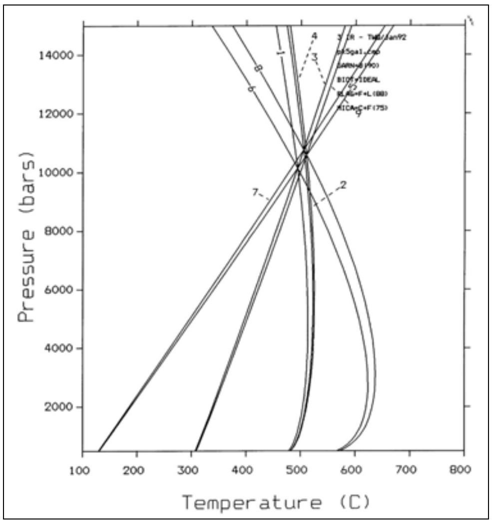

Fig. 4: This figure illustrates an example of multi-equilibrium calculations of the Patscherkofel Crystalline. The plot shows the result of sample PK-5, calculated with TWQ v1.02 with the data base of BERMAN (1988) in the system KMFASH.

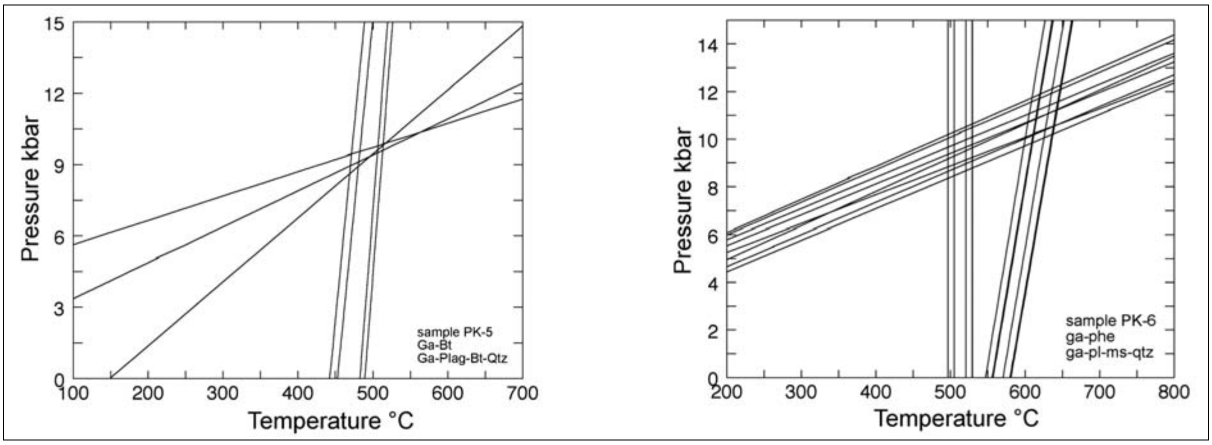

Fig. 5: Thermobarometric results for the Eo-Alpine metamorphic conditions of garnet-bearing mica schists from the Patscherkofel Crystalline. The left plot shows results from sample PK-5 based on the following equilibria: garnet-biotite Fe-Mg exchange (PATINO-DOUCE, 1993; KLEEMAN & REINHARDT, 1994) and garnet-plagioclase-muscovite-biotite (GHENT & STOUT, 1981; POWELL & HOLLAND, 1988; HOISCH, 1990). The right figure illustrates the results from sample PK-6 based on the following equilibria: garnet-phengite Fe-Mg exchange (HYNES & FOREST, 1988; GREEN & HELLMAN, 1982) and garnet-plagioclase-muscovite-quartz (HOISCH, 1990).

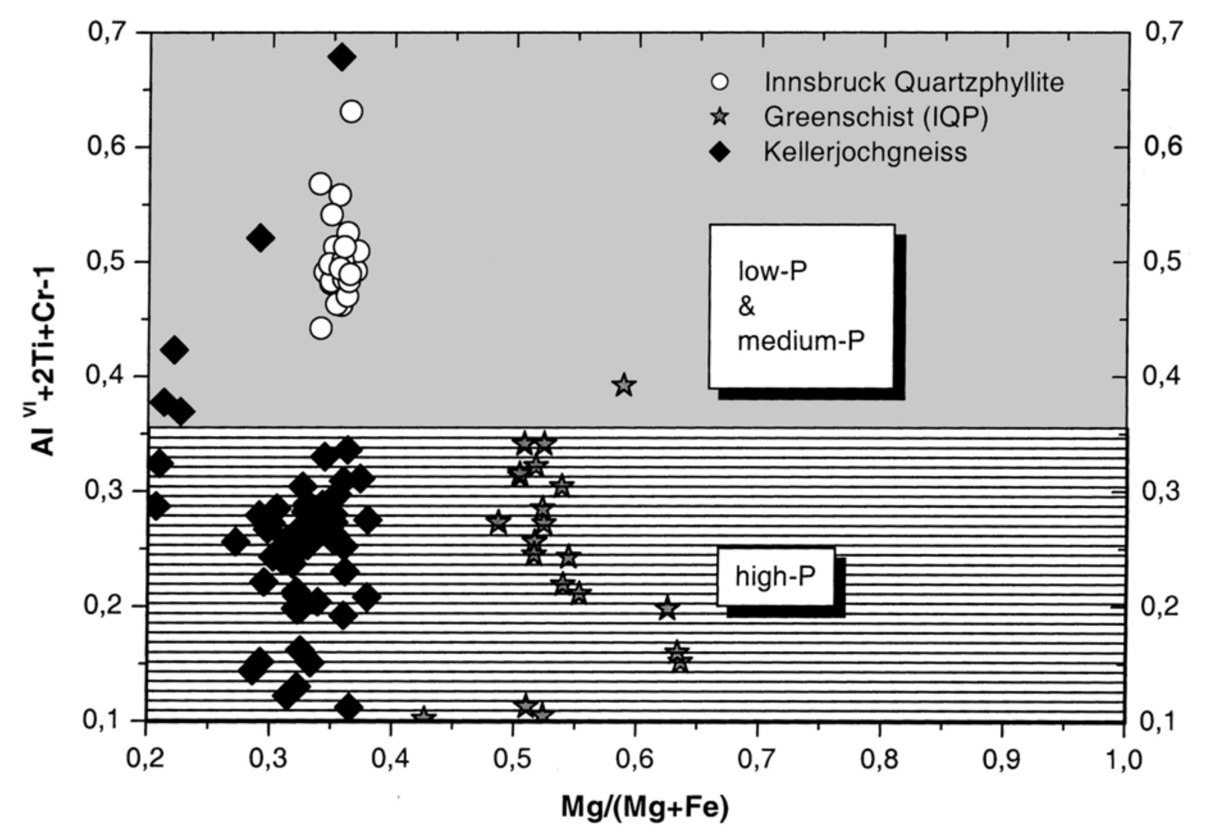

Fig. 6: The diagram shows the chlorite composition of the Kellerjochgneiss, the Innsbruck Quartzphyllite and the intercalated Greenschists [formula proportion Al^{VI} + 2Ti + Cr - 1 versus Mg/(Mg + Fe)] from the northern Zillertal Area. This plot also depicts an empirical correlation of chlorite composition with pressure in metamorphosed rocks.

Chemically, hints for a possible high pressure event are manifested through high Si contents in phengites of the Kellerjochgneiss (Si 3.24-3.50 apfu) and in the greenschists of the Quartzphyllite (Si 3.24-3.33 apfu). The low Al^{IV} contents in chlorites of the Kellerjochgneiss (Al^{IV} 1.00-1.40 apfu) and the greenschists (Al^{IV} 1.00-1.31 apfu) are also possible indicators for high pressure metamorphism (LAIRD, 1991) (Fig. 6). Whether the indicators for a high P event of the greenschists are in a chronological correlation to those of the Kellerjochgneiss or not, can not be distinguished without geochronological investigations. The phyllites of the Innsbruck Quartzphyllite show clearly lower pressures at low temperatures as the Kellerjochgneiss. Chemical and mineralogical indicators for a high P event are also absent. The Si contents of the muscovites of the phyllites in the northern Zillertal Area range from 3.06 to 3.20 apfu (Fig. 7). The Al^{IV} contents of the chlorites lie between 1.29 and 1.50 apfu.

The thermobarometric data and the Si contents in phengite of the Innsbruck Quartzphyllite (Si 3.07-3.28 apfu) reveal a decrease in metamorphic grade from the west to the east of the westernmost part of the Innsbruck Quartzphyllite during the Eo-Alpine metamorphic overprint (Fig. 7). The obtained PT - data from the Patscherkofel Crystalline indicate higher metamorphic conditions during an Eo-Alpine event, which suggest that the Patscherkofel Crystalline was subsequently thrusted onto the Innsbruck Quartzphyllite after the peak of Eo-Alpine metamorphism.

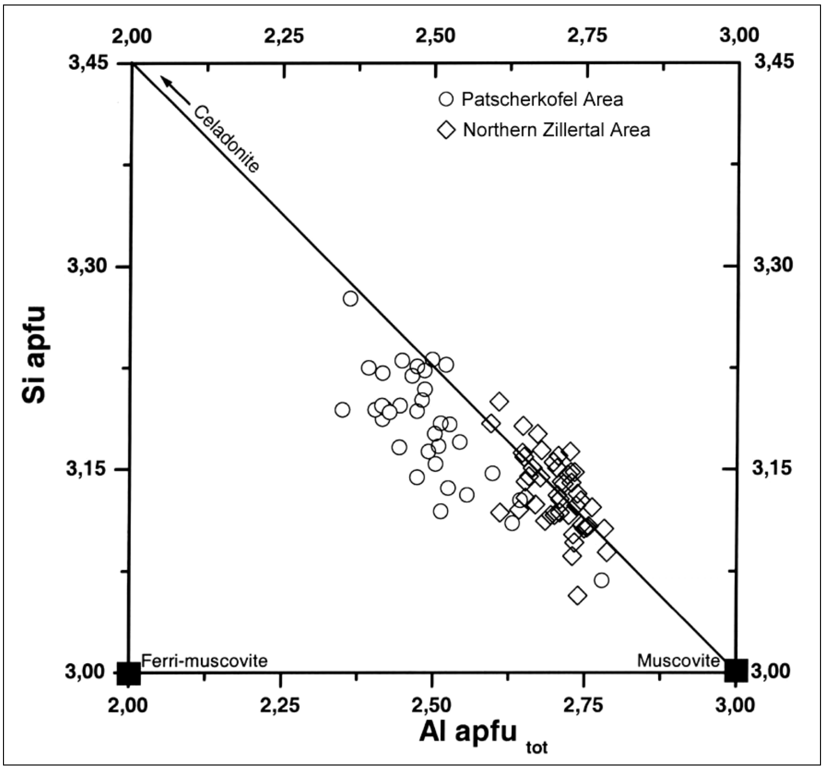

Fig. 7: The diagram shows the difference of celadonite amounts between the muscovites of the IQP from the northern Zillertal Area and the Patscherkofel Area. The higher Si contents of the muscovites from the westernmost part of the IQP are indicative for higher pressures during the Eo-Alpine metamorphic overprint.

References

BERMAN, R.G. (1992): Written comm.

BERMAN, R.G. (2002): Written comm.

CURRIE, K.L. & VAN STAAL, C.R. (1999): The assemblage stilpnomelane-chlorite-phengitic mica: a geothermobarometer for blueschist and associated greenschist terrains. - J. Metamorphic Geol., 17, 613-620.

HOLLAND, T.J.B. & POWELL, R. (1998): An internally-consistent thermodynamic data set for phases of petrological interest. - Journal of Metamorphic Geology, 8, 89-124.

LAIRD, J. (1991): Chlorites: Metamorphic petrology. - In: BAILY, S.W. (Ed.): Hydrous phyllosilicates (exclusive of micas), Rev. Minerl., 19, 405-447.

MASSONNE, H.J. (1997): Written comm.

PARRA, T., VIDAL, O. & AGARD, P. (2002): A thermodynamic model for Fe-Mg dioctahedral white micas using data from phase-equilibrium experiments and natural pelitic assemblages. - Contrib. Mineral Petrol, 143, 706-732.

PIBER, A. (2002): Tectonometamorphic evolution of the Austro-Alpine nappes in the northern Zillertal Area, Eastern Alps. - Unpubl. MSc Thesis, University Innsbruck, 269 p.

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