High-pressure metamorphism and deformation at Trescolmen, Adula nappe, Central Alps

Autor(en): **Meyre, Christian / Puschnig, André R.**

Objekttyp: **Article**

Zeitschrift: **Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie**

Band (Jahr): **73 (1993)**

Heft 2

PDF erstellt am: **11.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-55574

High-pressure metamorphism and deformation at Trescolmen, Adula nappe, Central Alps*

by *Christian Meyre*[1] and *André R. Puschnig*[1]

Abstract

The Adula nappe of the Central Alps represents a lower Penninic basement nappe within the Lepontine area and underwent four stages of Alpine deformation (D1–D4). D1 is characterized by a foliation preserved only within eclogites related to southward subduction and imbrication of crystalline basement and Mesozoic sedimentary rocks. During D1, the Adula nappe was subjected to prograde high-pressure metamorphism culminating under eclogite facies conditions. Top to the north stacking of the Penninic nappes (D2) started under peak pressure conditions and continued during uplift, most probably with increasing temperatures (eclogite facies to middle amphibolite facies conditions at the Trescolmen locality). D2 produced the NE dipping main foliation within the Adula basement and the surrounding rocks together with the predominant N–S oriented stretching lineation (L2). Isoclinal folding and boudinage of eclogitic layers, quartzites and marbles may also be attributed to D2. Open folds and crenulations are typical for D3, a deformation event that probably took place under lower amphibolite facies conditions. Kinking and slight undulation of the gneisses was produced during D4 under greenschist facies conditions. Extensive zones of steeply plunging, subvertical joints (post-D4, striking NE–SW) are associated with the latest stages of uplift of the Lepontine area.

Keywords: deformation, high-pressure metamorphism, eclogite, Adula nappe, Central Alps.

Introduction

The lower Penninic Adula nappe is the largest basement nappe complex in the eastern part of the Central Alps (Fig. 1). It predominantly consists of pre-Mesozoic leucocratic granitic gneisses and metapelitic micaschists with minor basic and ultrabasic rocks, marbles and quartzites. For the marbles and quartzites ("internal Mesozoic"), occurring as thin slices interleaving with pre-Mesozoic basement lithologies, a Mesozoic sedimentation age (Triassic) was postulated (Jenny et al., 1923, Probst, 1980). Based on geochemical data, Santini (1992) suggested that the majority of the basic rocks are derived from MOR basalts and minor amounts from "within plate" basalts. Mesozoic sedimentary rocks separate the Adula nappe complex from the Tambo nappe (hangingwall) and the Simano nappe (footwall). The Misox zone in its hangingwall consists of Bündnerschiefer, ophiolites and thin slices of Adula basement, the transition being a gradual one. The base of the Adula nappe, however, is marked by a discrete mylonite horizon.

The middle and southern part of the Adula nappe are overprinted by the mid-Tertiary Barrovian type regional metamorphism (Frey et al., 1980). Isogrades cross-cut the Alpine nappes in a NW-SE striking direction (Wenk, 1970). The metamorphic grade increases from middle greenschist facies in the Bündnerschiefer to the NE of the Adula nappe (Kupferschmid, 1977) to upper amphibolite facies in the southern part of the Adula nappe (Klein, 1976; Koch, 1982).

In the northern and middle Adula nappe and in the adjacent Cima Lunga unit, the Barrovian type metamorphism overprinted an older high pressure metamorphic event which was recog-

* Extended Abstract of a contribution presented at the Symposium "Metamorphism and Deformation", October 2, 1992, Basel.

[1] Mineralogisch-Petrographisches Institut, Universität Basel, Bernoullistr. 30, CH-4056 Basel, Switzerland.

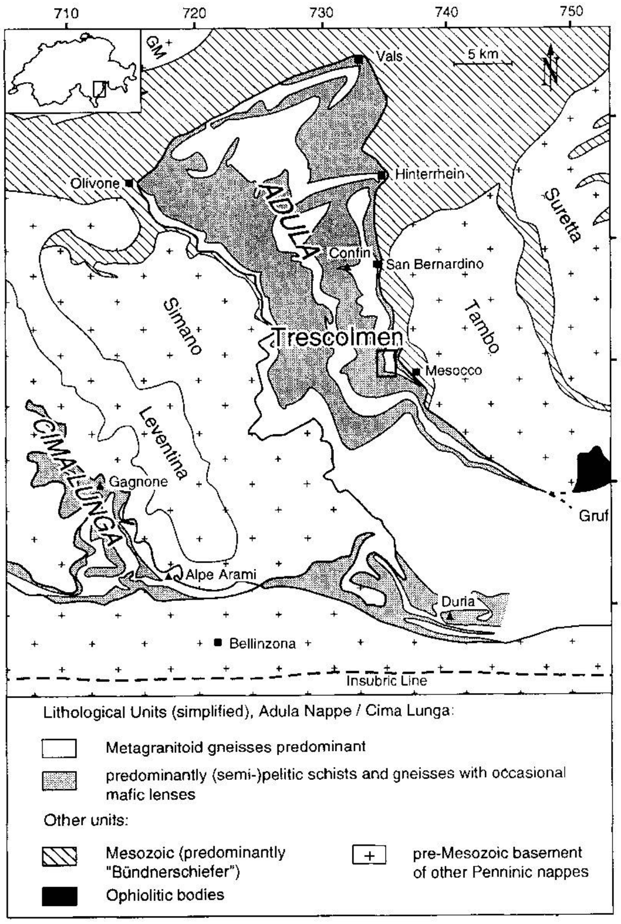

Fig. 1 Simplified geological map of the eastern Central Alps (modified after HEINRICH, 1983). The investigated area of Trescolmen is marked with a black lined rectangle.

nized in metabasic and metapelitic rocks of the Adula basement (HEINRICH, 1982), in the "internal Mesozoic" (VAN DER PLAS, 1959). The high-pressure metamorphism shows a pronounced zonation from north to south (HEINRICH, 1986; for locations see Fig.1):

Vals	450–550 °C / 10–13 kbar	north
Confin	450–550 °C / 12–22 kbar	
Trescolmen	550–650 °C / 15–22 kbar	
Gagnone	600–700 °C / 15–25 kbar	
Alpe Arami and Duria	750–900 °C / 18–35 kbar	south.

No evidence for this high-pressure metamorphism is found in the Simano nappe. Regarding the Tambo nappe elevated pressures are indicated by the Si-content of white micas (BAUDIN and MARQUER, 1993, p. 285–299 this volume). This suggests that eclogite facies metamorphism is restricted to the Adula nappe. The age of the high-pressure metamorphism in the Adula/Cima Lunga unit is controversial. U–Pb zircon data from Cima di Gagnone indicate an age of 28.5 Ma for a garnet-peridotite/eclogite high-pressure association (GEBAUER et al., 1992). This Oligocene age is slightly younger in respect to the late Eocene age (35 Ma) obtained for the gabbroic protoliths of the eclogites at Alpe Arami (GEBAUER et al., 1992). Sm–Nd dating of samples from Alpe Arami yield nearly identical garnet-clinopyroxene-whole rock ages of ca. 40 Ma for garnet-lherzolite, garnet-pyroxenite and eclogite (BECKER, 1992). On the other hand, a Sm–Nd garnet-clinopyroxene-whole rock isochrone determined for an eclogite of Trescolmen leads to an age of 92.5 ± 7.2 Ma which is significantly older (BECKER, 1992).

The structural and metamorphic evolution of mafic boudins and sourrounding rocks of the investigated Trescolmen area is generally in concordance with the tectono-metamorphic evolution proposed by LÖW (1987) for the northern Adula nappe. For the Trescolmen area, however, the second deformation phase D2 (introduced by LÖW, 1987 as "Zapport" phase) should be devided into two subphases (this study).

Deformation

The structural elements observed in the field can be assigned to four phases of deformation. These deformation phases are based on the structural classification and the nomenclature previously established for the northern part of the Adula nappe (LÖW, 1987). The orientation of the structures are shown in figure 2.

DEFORMATION PHASE 1

D1 ("Sorreda" phase) is characterized by the imbrication of the Adula basement with Mesozoic sedimentary rocks of the Misox zone (marbles and quartzites). The sharp contacts between the metapelitic rocks and the granitic gneisses are also imbrication contacts. Because of the penetrative foliation and the strong shear component of the later D2 phase no signs for the transport direction in regard to imbrication could be observed.

The imbrication planes dip 20 to 45° to the ENE and lie parallel to the later main foliation S2. In mafic eclogites a S1-foliation is well preserved and consists of recrystallized, elongated omphacites and aggregates of recrystallized garnets. In all others lithologies only relics of a S1-foliation can be recognised (BAUMGARTNER and LÖW, 1983). At Trescolmen such relics are found within plagioclase porphyroblasts in granitic gneisses

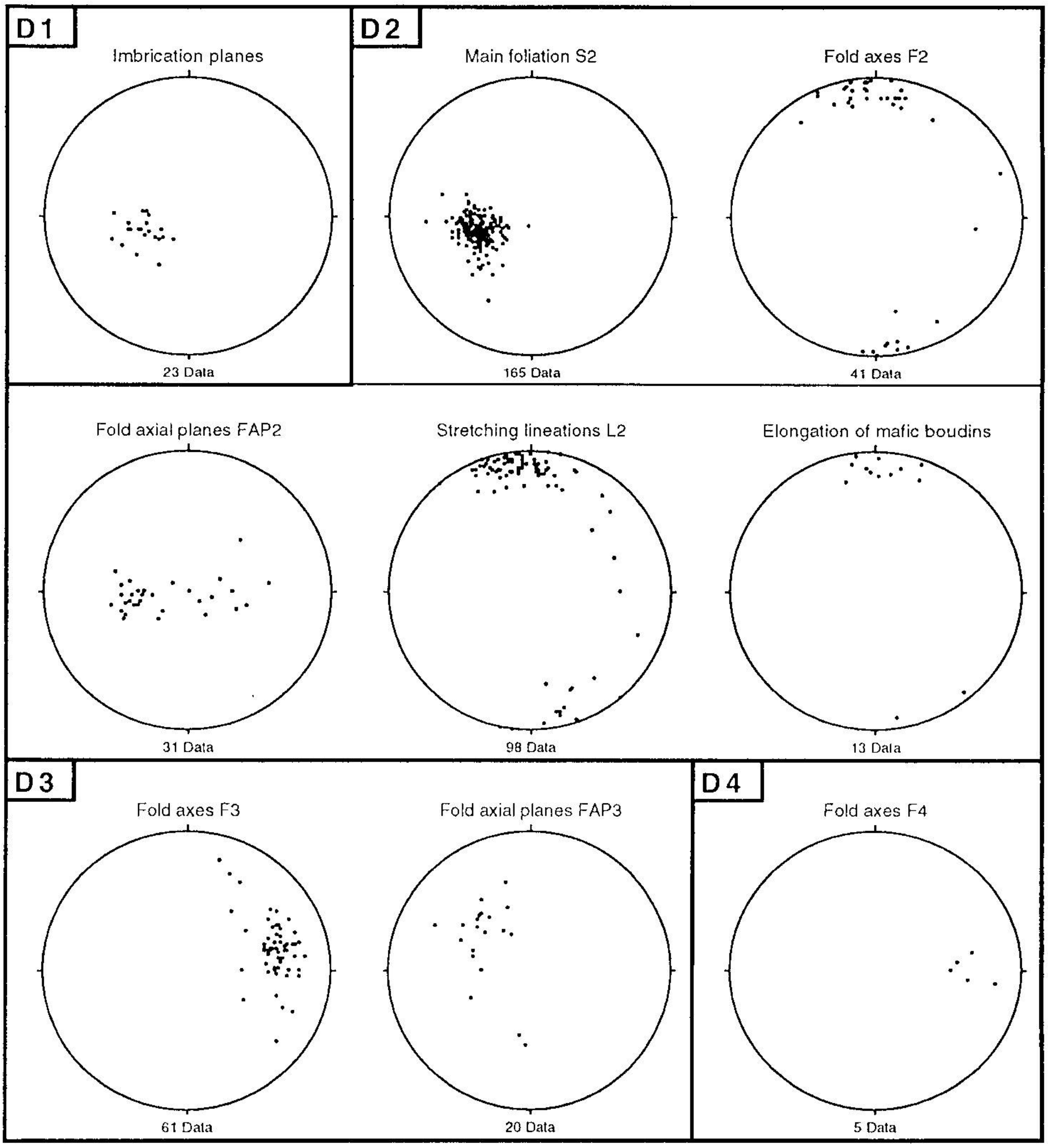

Fig. 2 Stereographic projection (equal area projection, lower hemisphere) of the observed structural elements at Trescolmen (D1–D4). For explanations, see text.

and metapelitic rocks, defined by the orientation of biotite within these porphyroblasts.

DEFORMATION PHASE 2

D2 is the dominant phase in the studied area, characterized by the main foliation S2, a stretching lineation L2 and a subhorizontal generation of folds F2 parallel to L2. In the northern Adula nappe, D2-deformations ("Zapport" phase) are overprinting the imbrication contacts within the nappe (Löw, 1987). For Trescolmen we devide D2 into two subphases:

i) D2a under eclogite facies conditions ("Trescolmen" phase),

ii) D2b due to ± isothermal uplift from eclogite to middle amphibolite facies conditions ("Zapport" phase).

D2a: In the cirque of Trescolmen the mafic eclogites are less overprinted by the later amphibolite facies metamorphism than the surrounding metapelitic rocks. Thus, isoclinal eclogite facies folding of S1 in the metabasic rocks is still observable. In the axial plane of the D2a-fold shown in figure 3, the metapelitic rock preserves the high-pressure assemblage Qtz-Grt-Ky-Phe ± Omp (mineral abbreviations after KRETZ, 1983; Phe = phengite). The limbs of the F2-folds, and therefore, also the S1-foliation within the eclogites lie parallel to the S2-schistosity (D2a) within the enclosed high-pressure metapelitic rocks. This only apparently suggests a transition of the foliation of the eclogites into that of the metapelitic rocks. In fact the two foliations belong to different deformation phases. In addition several N–S oriented isoclinal folds within metapelitic rocks (D2b) are present, clearly overfolding an older foliation (D2a).

D2b: The isoclinal mesoscopic fold axes (F2b) are subhorizontal and strike NNW to SSE. The fold axial plane dips 20 to 50° to the ENE. Subparallel to the axial plane a penetrative foliation is developed. This foliation is the main foliation S2, which dips 40° to the ENE. The subhorizontal stretching lineation is parallel to the fold axes F2b. Shear bands, antithetically rotated asymmetric boudins and oblique grain shapes of recrystallized quartz indicate a top to the north movement, which probably reflects the direction of the main nappe transport. Microscopic investigations support the top to the north movement by the existence of microscopic shear bands, mica fish in metapelitic rocks and granitic gneisses, and d-structures of garnet with asymmetric pressure shadows of quartz in metapelitic rocks. Feldspar clasts in the granitic gneisses do not represent clear indicators for the shear sense. K-feldspars show myrmekites which are probably deformation-induced (SIMPSON and WINTSCH, 1989).

Boudinage of the mafic rocks also belongs to the D2-phase. The stretching direction indicated by the lined up boudins is also parallel to the stretching lineation L2. In the pressure shadows isolated quartz segregations with white mica and kyanite may be found.

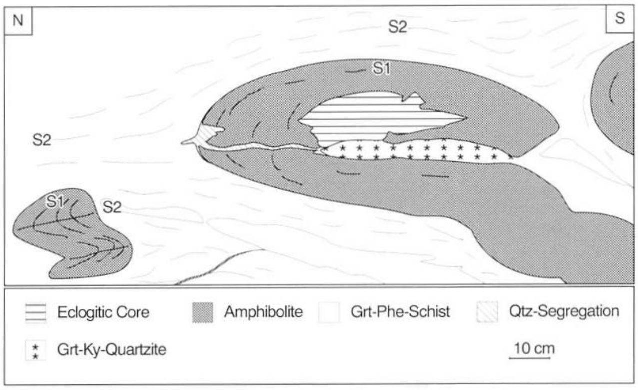

Fig. 3 Mafic eclogite boudin (Swiss coordinates 733.600/139.600) showing an isoclinal, eclogite facies folding of S1 during D2a which is less overprinted by the later amphibolite facies metamorphism than the surrounding metapelitic rocks. The enclosed metapelitic rock preserves the high-pressure assemblage (Qtz-Grt-Ky-Phe ± Omp) in the axial plane of the D2a fold. The dehydration of the metapelitic rocks occurred after D2a and lead to marginal hydration of the previously folded eclogitic mafic boudins during D2b (amphibolite facies).

DEFORMATION PHASE 3

Folding of the main foliation S2 is characteristic for mesoscopic folds formed during D3 ("Leis" phase). F3 overfolds the lined up mafic boudins. The fold axes dip 35° to the ENE. In phyllosilicate-rich domains (metapelitic rocks) a crenulation is observed, while open folds are typical for quartz-rich domains (granitic gneisses). A new foliation S3 develops only locally in the form of a crenulation cleavage. Parallel to the F3-fold axes, D3 produces an E–W-oriented mineral stretching lineation formed by biotite, muscovite, chlorite and epidote. Microstructural investigations (shear bands, mica fish, asymmetric clasts) point to an extensional phase with top to the east movement (PARTZSCH, pers. comm.). Plastic deformation of plagioclase suggests temperatures above 500 °C (TULLIS, 1983). F3-folds are parasitic structures on a flat-lying north-closing megafold to be found north of the Trescolmen area (LÖW, 1987) with a core consisting both of both basement and internal sedimentary rocks of the Adula nappe, surrounded by North Penninic Mesozoic (Bündnerschiefer). The investigation area lies in the upper limb of this megafold, hence only one vergency (north) is developed.

DEFORMATION PHASE 4

In some rare cases a slight undulation and kinking of the gneisses may be observed (D4, "Carassino" phase). The fold axes show the same orientation as F3. This phase can be located in the transition zone between ductile and brittle conditions. The associated structures are parasitic structures of a flexure in the northern part of the Adula nappe (LÖW, 1987). According to LÖW (1987) the temperatures for this deformation phase are above 300 °C (microstructural evidences).

Extensive zones of steeply plunging to subvertical joints (striking NE–SW) of a brittle deformation are related to the uplift of the Lepontine (post-D4 deformation).

Metamorphism

In mafic boudins occurring within metapelitic rocks, the eclogite paragenesis Omp + Grt + Ky + Qtz + Hbl + Rt can be observed. This assemblage could be the product of a dehydration reaction (1) described by HEINRICH (1986):

$$Pg + Ep + Hbl + Qtz = Omp + Ky + H_2O. \quad (1)$$

The eclogite boudins are marginally transformed into amphibolites, due to retrograde reactions during uplift of the Adula nappe (D2b). It is noteworthy that this retrogression which is observed in most metabasic rocks seems to be a static process whereas the main foliation in the metapelitic rocks and gneisses was produced during the same deformation phase. This clearly indicates that the eclogites essentially remained rigid during D2b. The hydration of the metabasic rocks can be attributed to the dehydration of the surrounding metapelitic rocks (HEINRICH, 1982) during the temperature peak at about 600 °C (D2b). In addition to the retrograde reaction

$$Omp + Grt + H_2O = Hbl + Pl + Chl \quad (2)$$

proposed by HEINRICH (1982), thin section observations suggest that the assemblage of the Ky-eclogites is completely transformed by barroisite, quartz and clinozoisite in the amphibolites. This could be described by the (qualitative) retrograde reaction (3) described by MEYRE (1993):

$$Omp + Ky + H_2O = Bar + Czo. \quad (3)$$

In the amphibolite sample CHM 37 clasts of Zo rotated during the main foliation stage are epitactically overgrown by Czo (syn- to post-D2b). Thus, the orthorhombic Zo belongs to an earlier eclogite facies assemblage, while the Czo was formed under amphibolite facies conditions, during the ± isothermal uplift of the Adula nappe. A similar transformation of Zo into Czo was reported by FRANZ and SELVERSTONE (1992).

Metapelitic rocks exhibit two parageneses according to HEINRICH (1982): (i) Grt + Phe + Qtz + Ky + Rt developed under eclogite facies conditions; (ii) less phengitic Ms + Bt + Pl + Qtz. Bt + Pl + Qtz are present in a fine-grained coronae around large flakes of Phe, sometimes small Bt replaces Phe. This reaction is considered as the result of a dehydration reaction in the transition from eclogite to amphibolite facies conditions (HEINRICH, 1982, Fig. 5).

Granitic gneisses contain the following paragenesis: Qtz + Mc + Pl + Phe + Bt + Ep ± Grt. No relics of an older plagioclase-free and jadeite-bearing paragenesis were found. The only indicator for a possible high-pressure metamorphism of the granitic gneisses are 3T phengites (FREY et al., 1983, Fig. 3; PUSCHNIG, 1992). Replacement of coarse Phe by fine-grained Bt is the same feature as mentioned above for the metapelitic rocks.

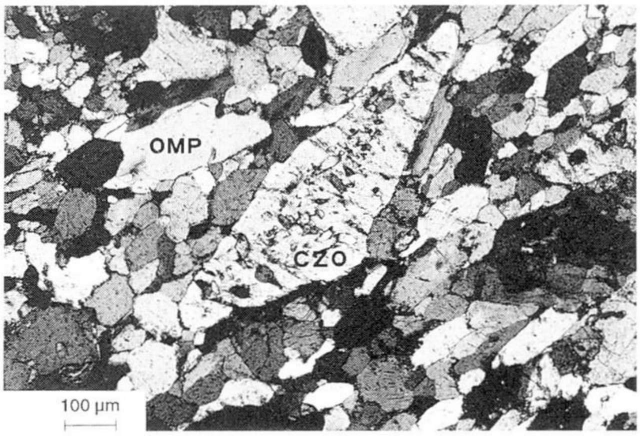

Fig. 4 Thin section photograph of a metagabbro sample from Trescolmen (CHM 10). Ep/Czo formed as pseudomorph after Hbl shows anomalous bluish colors of interference (crossed nicols). The matrix consists of Omp and Rt.

At Trescolmen a metagabbro was found, occurring as megaboudin (100 m × 40 m; Swiss coordinates 733.310/139.130). The mesoscopic gabbroic fabric is well preserved: cm-large Ep/Czo crystals surrounded by a matrix of dark green Omp. Grt appears irregularly in aggregates. The Ep/Czo likely was formed as pseudomorphs after amphibole (Fig. 4), suggesting that the Trescolmen gabbro represents the metamorphic equivalent of a hornblende-gabbro protolith.

Conclusions

The structural observations combined with data on the metamorphic history lead to a qualitative P-T-d path (Fig. 5) which is proposed for the investigated area of Trescolmen. The first deformation stage (D1) is probably N–S oriented assuming south-directed subduction of the Adula nappe. At Trescolmen a S1-foliation consisting of elongated omphacites and garnet aggregates is preserved within the eclogites. During D1 the Adula nappe underwent prograde high-pressure metamorphism culminating under eclogite facies conditions. The P-T conditions for eclogite formation during D2a are taken from HEINRICH (1986) calculated with the Cpx-Grt Fe-Mg exchange geothermometer of ELLIS and GREEN (1979). Calculations of the same data with the calibration of KROGH (1988) yield to slightly lower

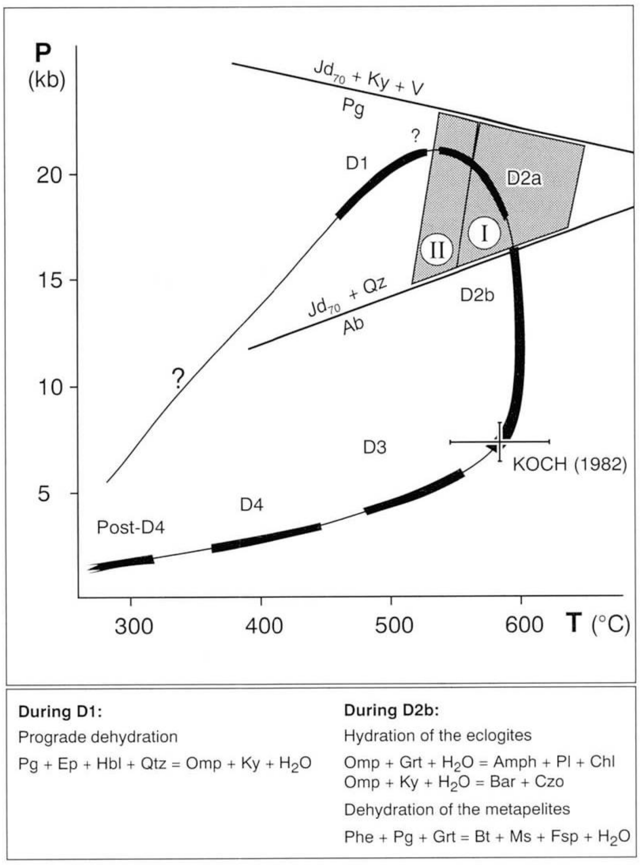

Fig. 5 Schematic P-T-d path of Trescolmen derived from microstructural investigations, geobarometric calculations after HEINRICH (1986) and geothermometric data for the eclogite facies metamorphism in the metabasites from Trescolmen (I: HEINRICH, 1986 based on calibration of ELLIS and GREEN, 1979; II: MEYRE, 1993 based on calibration of KROGH, 1988 and data of HEINRICH, 1986). The conditions for amphibolite facies metamorphism of the metapelitic rocks from the central Adula nappe are based on KOCH (1982). For more details, see text.

temperatures (MEYRE, 1993). These conditions are interpreted here as representative for the D2a event. The main foliation S2b developed in the transition zone between eclogite and amphibolite facies conditions. The highest temperatures of about 600 °C are reached under amphibolite facies conditions (D2b) with dehydration of the metapelitic rocks and hydration of the metabasic rocks. Grt-Bt geothermometry for metapelitic rocks from the Middle Adula nappe (KOCH, 1982) indicates amphibolite facies conditions, possibly representing the lower limit of the D2b phase. During the D3 an extensional event (top to the east) occurred with plastic deformation of plagioclase under lower amphibolite facies conditions. Microstructural investigations (LÖW, 1987) suggest temperatures above 300 °C for D4. Brittle deformation (Post-D4) probably belongs to the uplift of the Lepontine area.

Acknowledgements

This work is based on the diploma theses of the authors which were supervised by M. Frey and S.M. Schmid. We would like to thank M. Frey, S.M. Schmid and R. Gieré for their help and constructive critical review. The authors are also grateful to C. De Capitani, J. Partzsch, N. Froitzheim, C. Davidson, J. Mullis, H. Stünitz and T. Thoenen for fruitful discussions.

References

BAUDIN, TH. and MARQUER, D.(1993): Métamorphisme et déformation dans la nappe de Tambo (Alpes centrales suisses): Evolution de la substitution phengitique au cours de la déformation alpine. Schweiz. Mineral. Petrogr. Mitt. 73, 285–299.

BAUMGARTNER, L.B. and LÖW, S. (1983): Deformation und Metamorphose der Adula-Decke südwestlich San Bernardino. Schweiz. Mineral. Petrogr. Mitt., 63, 215–232.

BECKER, H. (1992): Garnet peridodite and eclogite Sm–Nd mineral ages from the Lepontine dome (Ticino, Switzerland): New evidence for an Eocene high-pressure metamorphism in the Central Alps. Eur. J. Mineral., 4, Berichte DMG, Beiheft 1, 22.

ELLIS, D.J. and GREEN, D.H. (1979): An Experimental Study of the Effect of Ca Upon Garnet-Clinopyroxene Fe–Mg Exchange Equilibria. Contrib. Mineral. Petrol., 71, 13–22.

FRANZ, G. and SELVERSTONE, J. (1992): An empirical phase diagram for the clinozoisite-zoisite transformation in the system $Ca_2Al_3Si_3O_{12}(OH)$–$Ca_2Al_2FeSi_3O_{12}(OH)$. Amer. Mineral., 77, 631–642.

FREY, M., BUCHER, K., FRANK, E. and MULLIS, J. (1980): Alpine metamorphism along the Geotraverse Basel–Chiasso – a review. Eclogae geol. Helv., 73, 527–546.

FREY, M., HUNZIKER, J.C., JÄGER, E. and STERN, W.B. (1983): Regional Distribution of White K-Mica Polymorphs and Their Phengite Content in the Central Alps. Contrib. Mineral. Petrol., 83, 185–197.

GEBAUER, D., GRÜNENFELDER, M., TILTON, G., TROMMSDORFF, V. and SCHMID, S.M. (1992): The geodynamic evolution of garnet-peridotites, garnet-pyroxenites and eclogites of Alpe Arami and Cima di Gagnone (Central Alps) from Early Proterozoic to Oligocene. Schweiz. Mineral. Petrogr. Mitt., 72, 107–111.

HEINRICH, C.A. (1982): Kyanite-Eclogite to Amphibolite Facies Evolution of Hydrous Mafic and Pelitic Rocks, Adula Nappe, Central Alps. Contrib. Mineral. Petrol., 81, 30–38.

HEINRICH, C.A. (1983): Die regionale Hochdruckmetamorphose der Aduladecke, Zentralalpen, Schweiz. Unpubl. Diss., ETH Zürich.

HEINRICH, C.A. (1986): Eclogite Facies Regional Metamorphism of Hydrous Mafic Rocks in the Central Alpine Adula Nappe. J. Petrol., 27, 123–154.

JENNY, H., FRISCHKNECHT, G. and KOPP, J. (1923): Geologie der Adula. Beitr. geol. Karte Schweiz N.F. 51.

KLEIN, H.-H. (1976): Metamorphose von Peliten zwischen Rheinwaldhorn und Pizzo Paglia (Adula-

und Simano-Decke). Schweiz. Mineral. Petrogr. Mitt., 85, 457–479.
KOCH, E. (1982): Mineralogie und plurifazielle Metamorphose der Pelite in der Adula-Decke (Zentralalpen). Diss., Univ. Basel.
KRETZ, R. (1983): Symbols for rock-forming minerals. Amer. Mineral., 68, 277–279.
KROGH, E.J. (1988): The garnet-clinopyroxene Fe–Mg geothermometer – a reinterpretation of existing experimental data. Contrib. Mineral. Petrol., 99, 44–48.
KUPFERSCHMID, C. (1977): Geologie auf der Lugnezer Seite der Piz-Aul-Gruppe. Eclogae geol. Helv., 70, 1–58.
LÖW, S. (1987): Die tektono-metamorphe Entwicklung der nördlichen Adula-Decke (Zentralalpen, Schweiz). Beitr. geol. Karte Schweiz NF 161.
MEYRE, C. (1993): Metamorphose und Deformation der Metabasica von Trescolmen (Adula, Zentralalpen/Schweiz). Unpubl. Diplomarbeit, Univ. Basel.
PROBST, P. (1980): Die Bündnerschiefer des nördlichen Penninikums zwischen Valsertal und Passo di San Giacomo. Beitr. geol. Karte Schweiz NF 153.
PUSCHNIG, A.R. (1992): Strukturgeologie und Petrographie von Trescolmen (Adula-Decke / GR). Unpubl. Diplomarbeit, Univ. Basel.
SANTINI, L. (1992): Geochemistry and geochronology of the basic rocks of the Penninic Nappes of East-Central Alps (Switzerland). Unpubl. Diss., Univ. Lausanne.
SIMPSON, C. and WINTSCH, R.P. (1989): Evidence for deformation-induced K-feldspar replacement by myrmekite. J. Metamorphic Geol., 7, 261–275.
TULLIS, J. (1983): Deformation of feldspars. In: RIBBE, P. H. (ed.). Feldspar mineralogy. Reviews in Mineralogy, Mineral. Soc. Amer., Vol. 2, 297–323.
VAN DER PLAS, L. (1959): Petrology of the northern Adula region, Switzerland (with particular reference to the glaucophane-bearing rocks). Leidse geol. Meded., 24, 413–603.
WENK, E. (1970): Zur Regionalmetamorphose und Ultrametamorphose im Lepontin. Fortschr. Miner., 47, 34–51.

Manuscript received and accepted as extended abstract April 18, 1993.