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5TH WORKSHOP OF ALPINE GEOLOGICAL STUDIES FIELD TRIP GUIDE E6 TECTONICS, METAMORPHISM AND MAGMA GENERATION BETWEEN PERIADRIATIC LINEAMENT AND TAUERN WINDOW (Vals Valley, close to TRANSALP Traverse)

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With 10 figures

1 Abstract

The Adriatic-African-plate motion during Oligocene-Miocene times released combined transpression and extrusion between the southwestern margin of the Tauern Window and the Periadriatic Lineament. Major structural elements include subvertical foliations and subhorizontal east-west oriented stretching lineations. These structures are related to coeval activity of shear deformation within an eastward widening wrench corridor and backthrusting of Penninic Tauern Window units to the south onto the Austro-Alpine block. Oligocene shear deformation was accompanied by intrusion of magmatic bodies, namely the Rensen and Rieserferner magmatic bodies (Müller et al., 2000, Borsil et al., 1978). Succession of magmatic and solid state structures within the Vals Area include: 1) emplacement of the Rensen Pluton coeval with sinistral shear deformation within mid-crustal levels; 2) shift from distributed sinistral shear towards localised dextral shear during progressive pluton cooling and emplacement of late magmatic dykes.

2 Introduction

The tectonic evolution of the Eastern Alps is a result of a complex and polyphase opening and closure of oceanic domains. However, subduction of oceanic domains was completed within the Eocene and the region south to the Tauern Window has since been dominated by a complex geometry of continent-continent collision. Continuous convergence between the Adriatic and European plates has been increasingly compensated by strike-slip movement

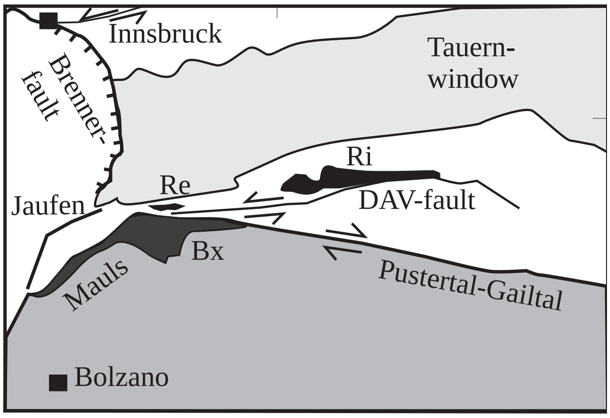
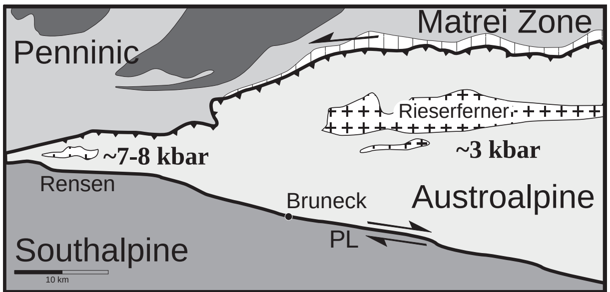


Fig. 1: Sketch of major tectonic units and tectonic lines along the southwestern part of the Tauern Window: Re: Rensen Pluton; Ri: Rieserferner Pluton, Bx: Brixen Pluton, DAV: Defereggen-Antholz-Vals Lineament.



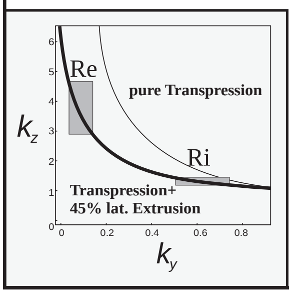


Fig. 2: Simplified sketch of the westward widening wrench corridor south to the Tauern window including barometric data from the Rensen and Rieserferner intrusions. Lower box: Results from kinematic modelling of combined transpression and extrusion including vertical stretch (kz) over horizontal north – south shortening (ky). Mention major amount of postulated stretch (exhumation) within western, narrow sections of the corridor (Re: Rensen; Ri: Rieserferner).

finally resulting in Oligocene-Miocene extrusion tectonics. Most prominent features that accompanied west - east flow during extrusion include the exhumation of the Penninic units exposed in the Tauern Window within a system of sinistral shear zones north and south of the Tauern Window. Finally anticlockwise rotation of the Adriatic indenter resolved in dextral displacement along the Periadriatic Lineament.

The area along the southern margin of the Tauern Window as discussed here (Fig. 1) comprises from north to south Penninic, Austroalpine and Southalpine units. The Penninic units consist of several nappes including pre-Alpine basement (Zentralgneiss, Lower Schieferhülle) and Mesozoic cover sequences that were deposited either within the oceanic South Penninic basin or on the continental passive margin (for an overview see: Kurz et al., 1998). Within the discussed area upper structural units (Glockner nappe) including metasediments and serpentinites of the oceanic basin as well as turbiditic trench-slope sediments that formed in an active continental margin environment are exposed. The southerly adjacent Matrei Zone marks the transition between the Tauern Window and marginal Austroalpine units. It occurs at a thin east - west trending zone that can be traced over approximately 80 kilometres (Fig. 2).

The Austroalpine unit south to the Tauern Window constitutes paragneisses hosting Ordovician metagranitoids (for an overview see: Stöckhert, 1982) and Oligocene/Miocene granitoids. This block can be subdivided mainly on the basis of degree of Tertiary thermal and tectonic overprint (e.g., Stöckert et al., 1999). Three distinct blocks, separated by Oligocene/Miocene shear zones, namely the Defereggen-Antholz-Vals line (DAV) and Kalkstein-Vallarga line (KV), are distinguished. The Austroalpine block to the south of the KV remained unaffected by Tertiary thermal overprint and preserved ca. 300 Ma cooling ages (Rb/Sr data on biotite), whereas Alpine cooling ages (approximately 100-30 Ma K-Ar ages from white mica) have been reported from the area north to the DAV (Borsi et al., 1973, 1978a, b; Borsi et al., 1979; Stöckhert et al., 1999). Along the strike of the DAV, there occurs a chain of elongated plutons, namely the Rieserferner Pluton, the Rensen Pluton and some smaller magmatic bodies that have been emplaced at ca. 30 Ma (Borsi et al., 1978a, 1979; Deutsch, 1984). Pluton emplacement interferes roughly with tectonic activity of the DAV (Müller et al., 2000). Magma generation has been related to break-off of the Penninic oceanic slab after final continental collision (Blanckenburg & Davies, 1995).

The southern margin of the Austroalpine is defined by the Periadriatic lineament where Southalpine units of the Adriatic microplate are juxtaposed against Austroalpine units. Within the discussed area Southalpine units constitute of the undeformed Permian Brixen granodiorite and elongated lamellae of Oligocene tonalites. Although the structural history of the Periadriatic lineament is complex the most obvious displacement is right lateral and resulted from oblique indentation of Southalpine units.

2.1 Kinematics and Pluton emplacement

Dominant structural element within the Vals section is a distributed sinistral shear deformation including steeply northward dipping foliation and horizontal stretching lineation. Sinistral shear deformation appears to reach as far as the Periadriatic Lineament (PL). A zone of enhanced deformation intensity between Rensen Pluton and PL is the only hint for the existence of a DAV in this section (see description of stop 2). Synkimenatic temperatures during sinistral shear as estimated from quartz textures increase gradually towards the Tauern Window. This goes along with increase of coaxial flow component towards north.

Emplacement of the Rensen Pluton interferes roughly with sinistral shear deformation (Müller et al., 2000, 2001; Mancktelow et al., 2001). The pluton represents a sheet like granodioritic body with a tonalitic precursor phase along its northern rim. Northern pluton portions crystallised at conditions of approximately 7–8 kbars. The contact aureole was itself affected by sinistral shear (see stop 4). Data on anisotropy of magnetic susceptibility (AMS: see stop 3 and 4) include a steep magmatic foliation and horizontal west-east trending magmatic lineation within northern pluton portions. Towards south the magmatic foliation gradual shifts towards a flat lying northward dipping orientation.

Solid state tectonic overprint is best seen in variably deformed dykes (see stop 7). High temperature deformed dykes that include dynamically recrystallized feldspar suffered sinistral shear deformation, low temperature deformed dykes with conditions

Fig. 3: Topographic map with excursion points.

down to brittle deformation were deformed during dextral shear. This is interpreted to reflect shift from sinistral to dextral shear during progressive cooling of the pluton which goes along with anticlockwise rotation of the Adriatic plate motion vector in respect to Europe during Oligocene-Miocene times.

2.2 West-east evolutionary trends between Periadriatic Lineament and Tauern Window

The area between Periadriatic Lineament and Tauern Window can be visualised as an eastward widening wrench corridor (Fig. 2). The width of the corridor increases from west to east from ca. 5 km (Vals section) to ca 30 km (Ahrn valley). This is interpreted as a result from indentation of the Southalpine plate and goes along with a variable amount of north-south shortening and variable amount of exhumation. Lateral west-east variations include:

1) The style of the most prominent strike-slip faults (DAV) changes from east to west. In the east (Staller Sattel, Austrian-Italian border) the DAV appears as a discrete shear zone that includes semibrittle and occasionally cataclastic features (Schulz, 1989). In the west the same fault widens to a distributed shear domain now including dislocation glide and climb mechanisms within quartz. Thus, we suggest an upper structural level deformation in the east and middle structural levels of exposure in the west. This is also consistent with the degree of Oligocene/Miocene metamorphism. In the east, Pre-Alpine metamorphism is well preserved between the shear zones, whereas in the west, the ca. 30 Ma tectonothermal event overprinted and destroyed older fabrics.

2) The decreasing crystallisation depth of the plutons between the west (Rensen, ca. 8 kbar) and the east (Rieserferner, ca. 3 kbar; Cesare, 1992) correlates well with observed variations of the spatial extent of the contact aureole. The western Rensen Pluton intruded into relatively hot rocks in middle crustal levels, the eastern Rieserferner into cold host rocks at shallow levels (Steenken et al., 2000). Lateral, east-west variation of vertical and horizontal displacement components within an eastward widening wrench corridor was modelled using information on the flow geometry from textures and the relative plate motion vector between European and Adriatic plates. Results account for exhumation of rocks from variable depth (Fig.2: kz-vertical stretch, ky-horizontal shortening).

3 Description of stops

The excursion is a one-day foot walk from South-Alpine over Austro-Alpine units to the Tauern Window. It crosses major tectonic lines including the Periadriatic Lineament and the distributed shear zone along the Tauern Window margin. In addition the Rensen Pluton, its contacts to Austro-Alpine host rocks and the associated late intrusive dyke system will be seen. All stops are found on sheet ÖK 50, 176 (Mühlbach) and are labelled on the enclosed topographic map (Fig. 3). For regional geology see enclosed geological map of the Vals Valley (Fig. 4).

Stop Nr. 1: Lat. 46,5120°, Long. 11,3720°
Introduction at chair-lift station and ascent with lift.

Stop Nr. 2: Valser Joch, Lat. 46,5100°, Long. 11,3570°

Periadriatic pluton along the Periadriatic Lineament at the boundary to Austro-Alpine micaschists.

South-Alpine units within the Vals section are defined by the undeformed Permian Brixen granodiorite. Along the margin of the granodiorite a tonalitic magmatic body intruded coevally with strike-slip tectonics along the Periadriatic lineament. The tonalite was retrogressed during faulting, with biotite and hornblende replaced by chlorite. Low temperature shear deformation is seen in cataclastic deformation within the tonalite. The Periadriatic Lineament (PL) can be traced morphologically by a pronounced west-east trending array of saddles.

Immediately north to Stop Nr. 2 we enter Austro-Alpine micaschists that exhibit cm-spaced dextral shear bands. Quartz-C-axes pattern (Fig. 5) exhibit low-temperature cross-girdle distribution related to dextral shear. The pattern of quartz textures across the Vals section displayed in Fig. 5 show following trends: 1) Dextral shear is limited to the vicinity of the PL, all other textures show sinistral sense of shear. 2) Sinistral shear is distributed over the section. However the pattern midway between PL and Rensen Pluton defines a high strain domain that may represent the DAV zone. 3) Syndeformative temperatures increase towards North, i.e. the Tauern Window as evident

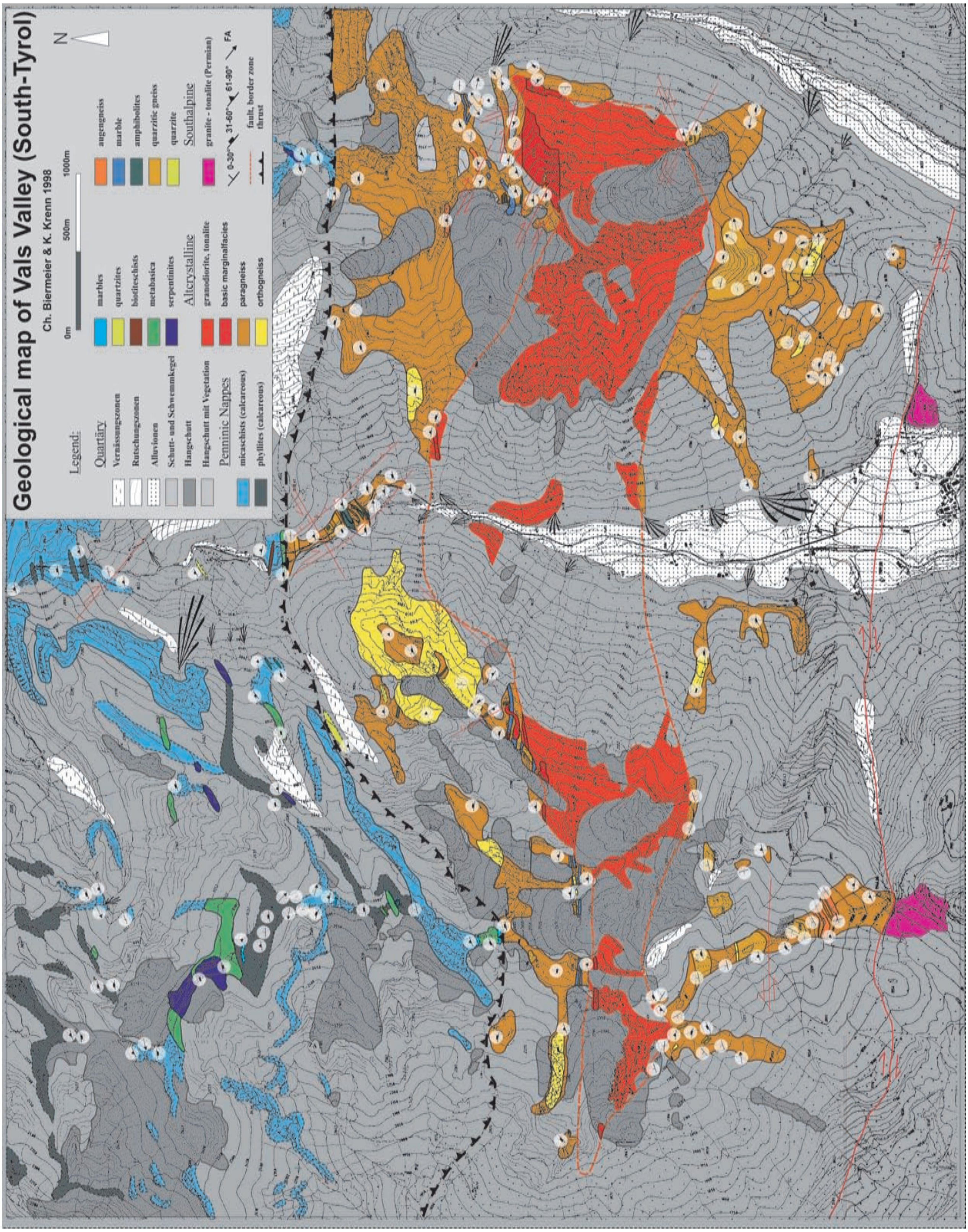


Fig. 4: Geological map of the Vals area after Biermeier and Krenn (1998).

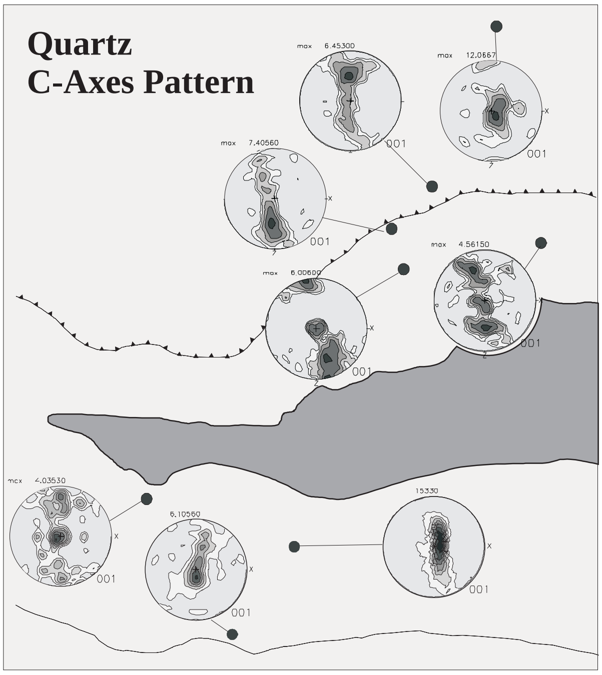


Fig. 5: North - south profile with quartz C-axes pattern in the Vals section. See text for details.

from enhanced contribution of rhomb and prism glide systems. 4) Contribution of coaxial component of flow increases towards north. 5) Especially the margin between Tauern Window and Austro-Alpine unit is defined by a sinistral high strain domain.

Stop Nr. 3: Lat. 46,5165°, Long. 11,3618°

Contact between south margin of Rensen Pluton and Austro-Alpine unit.

The main granodioritic facies of the Rensen with tonalitic xenolites is exposed along a north dipping contact. Data on anisotropy of magnetic susceptibility have been established. The major mineral sensitive to AMS is biotite and the macroscopically visible foliation parallels the magnetic foliation (kmin). The magnetic lineation is interpreted to reflect direction of magma flow. Within northern pluton portions where the mafic precursor phase is exposed the magmatic foliation is steeply dipping to the north and the lineation is W-E trending (Fig. 6). Towards the southern pluton margin the angle of foliation decreases and the direction of flow changes towards south. This goes along with a shift in the geometry of the AMS ellipsoid from flattening type in the north towards plane strain and constrictional type in the south. We interpret this as magma emplacement during sinistral shear (northern precursor phase) and later stage southward magma emplacement (southern main granodioritic phase).

Stop Nr. 4: Lat. 46,5210°, Long. 11,3630°

North contact of Rensen Pluton to the Austro - Alpine unit.

Along the northern rim of the Rensen Pluton the tonalitic marginal facies is exposed. Mineral assemblages are suitable to constrain crystallisation pressure of hornblende in the presence of melt by Al(tot) in hornblende barometry. Unzoned hornblende from 6 different samples distributed along the north margin vary in its alumina content between 9,8 and 13,6 weight percent per formula unit and give very consistent pressures around 8 kbar (Fig. 7).

A very small contact aureole is developed within marble lithologies. Using KCMASCH (CaO saturated) and CMASCH (SiO_2 saturated) petrogenetic grids with the major contact metamorphic mineral phases (Cc-Wo-Di-Kf-Phl and Qu-Grs-Vsv-Di-Sph) plotted in a T/X(CO_2) graph (Fig. 8) gave temperatures of 590°–670°C for a pressure around 7,5 kbar. We interpret this data as intrusion of the Rensen maginal facies within mid-crustal levels. The contact aureole itself suffered sinistral shear deformation.

Stop Nr. 5: Lat. 46,5230°, Long. 11,3650°
Orthogneiss of type "Antholz".

Highly sheared Ordovician orthogneiss within the Austro-Alpine unit. Three phases of magmatic bodies occur within Austro-Alpine units. 1) Earliest intrusions are of Ordovician age and include gneisses of type "Sand in Taufers" and type "Antholz". From the latter an age of ca. 434 Ma had been obtained. 2) Widespread Permian magmatic activity (ca. 262 Ma: Borsi et al., 1980) is evident from pegmatites of type "Uttenheim" that are exposed mainly south to the Rensen Pluton. 3) The chain of elongated Oligocene plutons along the DAV Zone date closely to 30 Ma (Borsi et al., 1979).

Stop Nr. 6: Lat. 46,5366°, Long. 11,3695°
South margin of Tauern Window.

Carbonate schist of the Glockner Nappe within the Tauern Window are exposed. Both, west-east

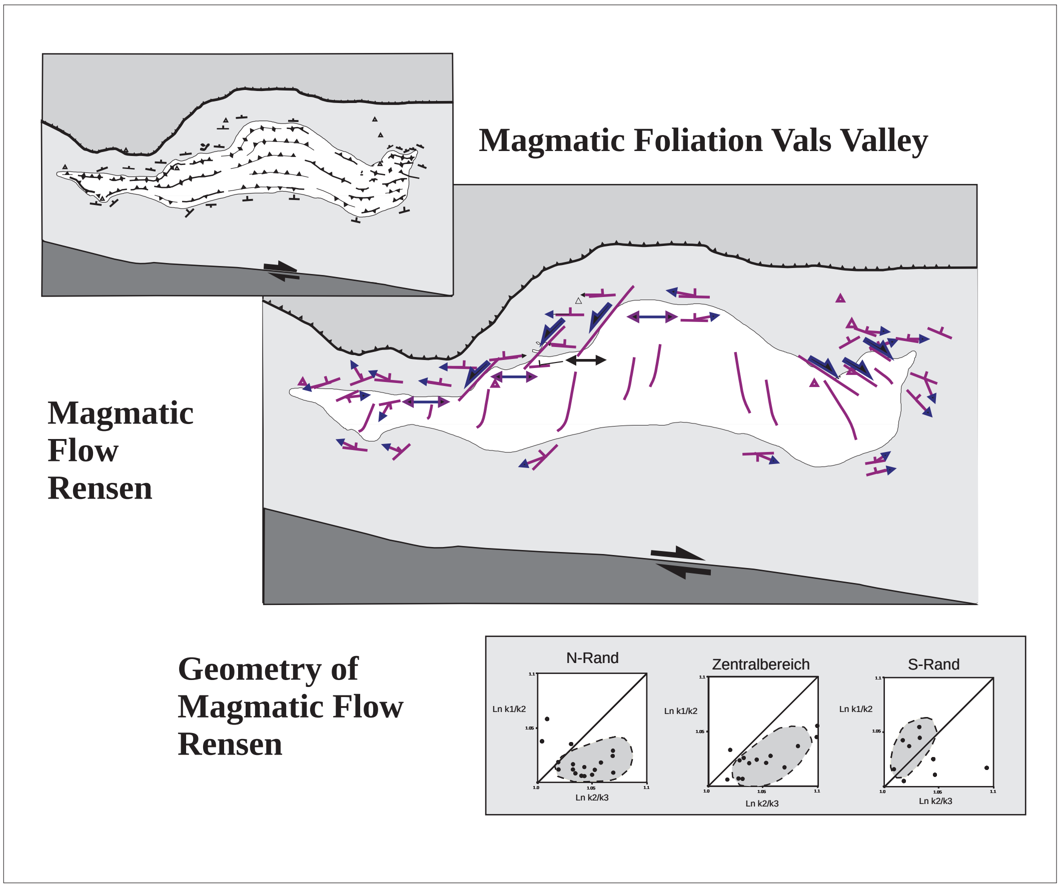


Fig. 6: Interpretation of AMS data from the Rensen Pluton. Upper left: Magmatic foliation of pluton and orientation data from host rock. Central: Magmatic lineation interpreted as flow field within pluton and shear zones along pluton margin. Lower right: AMS data plotted in a Flinn graph.

stretch associated with sinistral shear and vertical extension is evident from sets of folded and sheared veins. Sinistral shear is seen in asymmetric boudinage-structures and sinistral shear bands (Fig. 9). Quartz C-axes pattern suggest a major amount of noncoaxial flow during deformation (see Fig. 5). Within sections perpendicular to the lineation and foliation pronounced horizontal shortening up to 70 percent was obtained by line balancing.

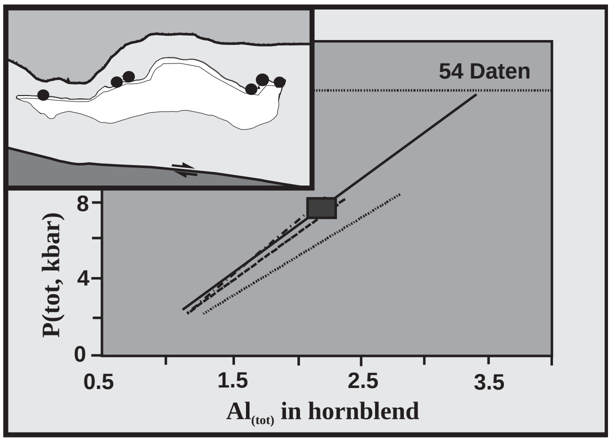


Fig. 7: Sample locations and barometric data relevant for intrusion depths of the mafic marginal facies of the Rensen Pluton.

Stop. Nr. 7: Lat. 46,5285°, Long. 11,3750°
Section across Tauern Window/Austro-Alpine boundary.

The immediate contact between these major tectonic units is well exposed along the road down to Vals. An important age constraint for the penetrative deformation during sinistral shear is that late tectonics aplitic dykes associated with Rensen emplacement penetrate both, Austro-Alpine and Tauern Window units. Moreover these veins had been sheared and were progressively rotated parallel to the foliation. Aplitic veins are widespread in the area

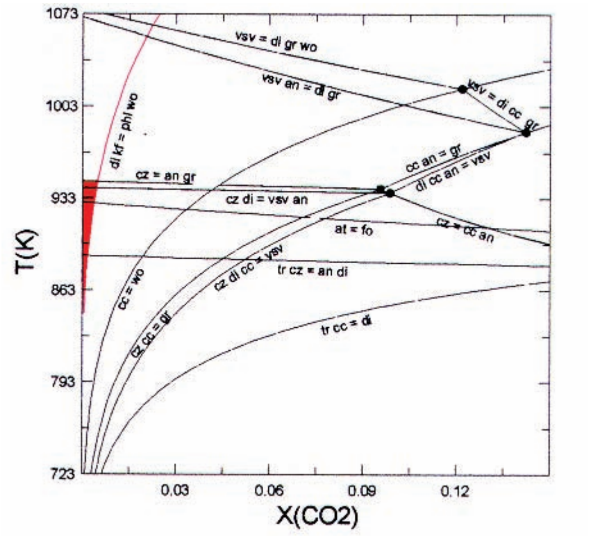


Fig. 8: Petrogenetic grid and temperature conditions (shaded) from contact metamorphosed rocks at the northern part of the Rensen Pluton.

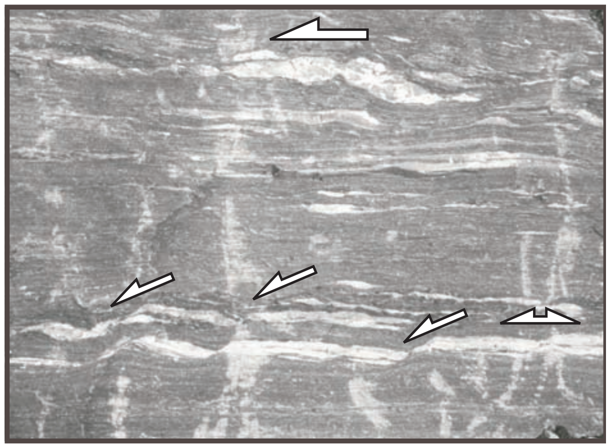


Fig. 9: Sinistrally sheared and boudinaged layers within the Glockner nappe at the southern margin of the Tauern Window. Long side of photo ca. 2 meters.

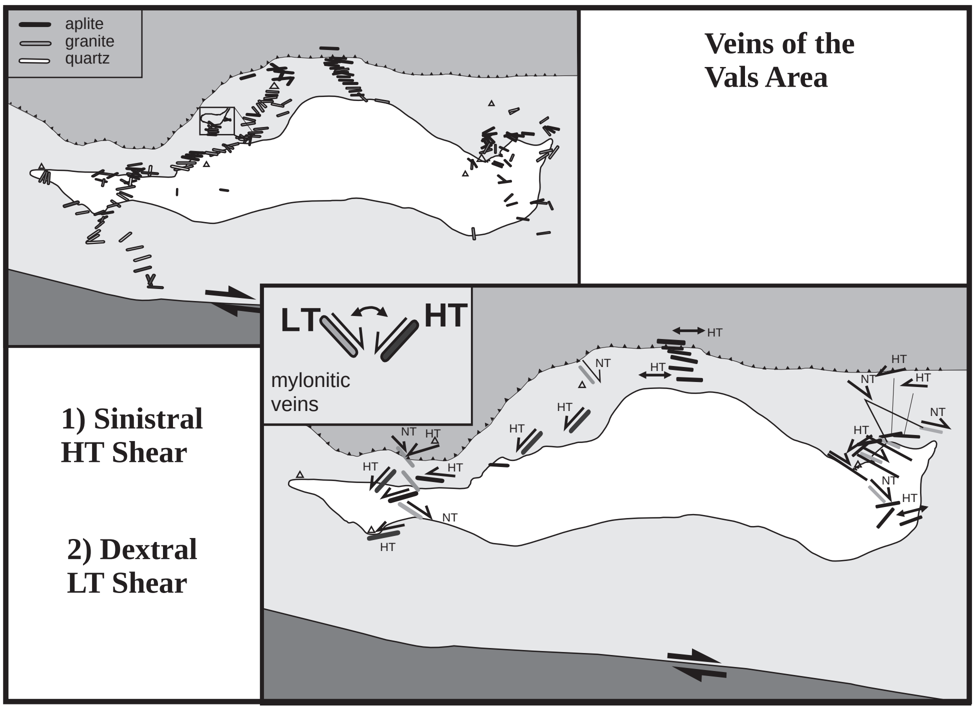


Fig. 10: Upper left: Distribution and orientation of late magmatic veins around the Rensen Pluton. Lower right: Older vein sets trend northeast – southwest and are high tempereture deformed, younger low temperature deformed veins trend northwest – southeast.

north to the Rensen Pluton and occur subordinate to the south. Microstructurally three different types are distinguished: 1) North to the central part of the Rensen Pluton aplitic veins are concordant (west east oriented) to the foliation and exhibit predominantly coaxial high temperature deformation (mylonitic fabric with feldspar recrystallisation). Within western and eastern pluton portions high temperature deformed veins trend northeast-southwest and show sinistral sense of shear. Youngest sets of veins with dextral shear deformation trend northwest-southeast and exhibit exclusively low temperature deformation including brittle behaviour of feldspar and low-temperature plasticity of quartz.

This is interpreted as shift from high temperature sinistral shear towards low temperature dextral shear in the course of pluton cooling. The overall shape of the Rensen with stair step geometry is result of these late-to-post granitic deformation events. For a recent direct dating on succession of fault systems see Mancktelow (2001), Müller et al. (2000, 2001).

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