

## Field Trip A2: Structural evolution of the Silvretta-Seckau nappe system in the area of the Schladminger Tauern

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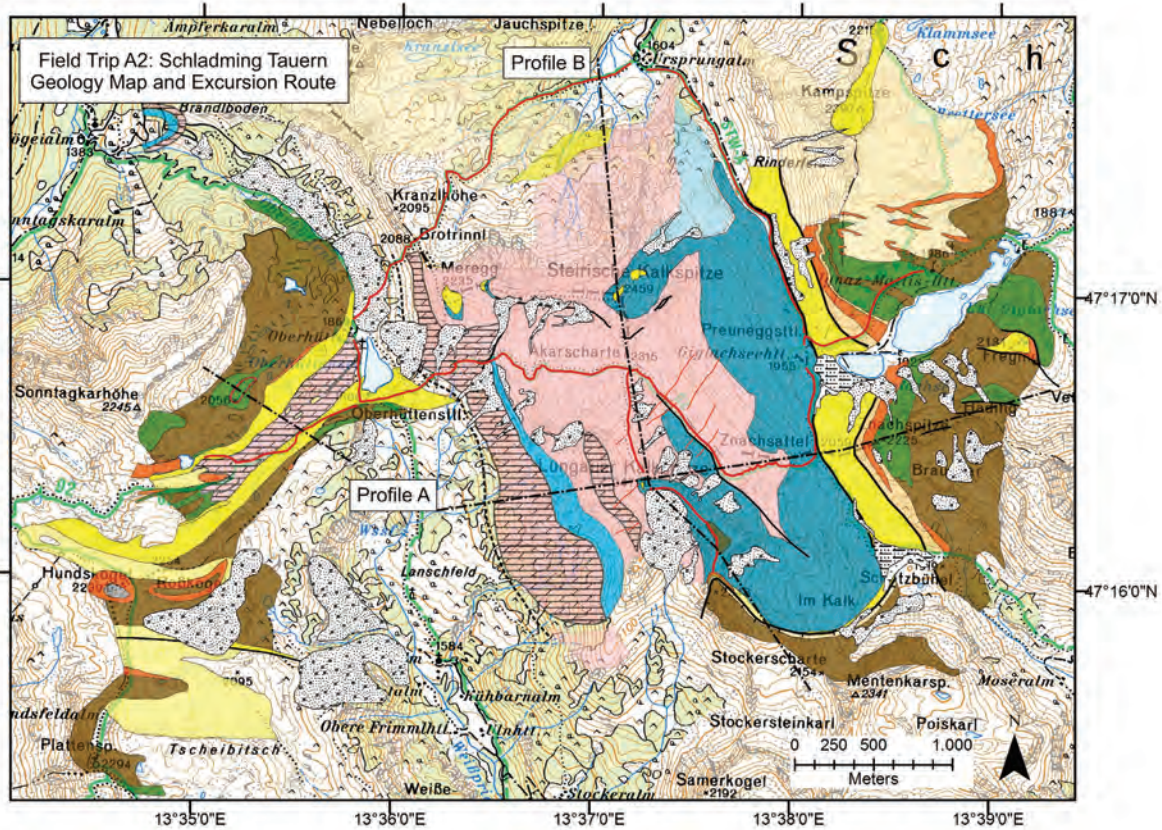
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The topic of this field trip is to visit and understand the structure of the Austroalpine nappes northeast of the Tauern Window. The excursion will start and end in Schladming. A transfer by minibuses to the Ursprungalm (47°17'47,44"N; 13°37'28,11"E) will be provided. From there, a cross section exposing the Silvretta-Schladming-Seckau nappes will be discussed during a two day walking tour (Figs. 1, 2). This, however, requires good weather conditions as well as experience in Alpine regions.

In the area of the Schladminger Tauern the Austroalpine nappes generally comprise a pre- Alpine basement and a Permian to Mesozoic cover. Both are overprinted by low-grade Eoalpine metamorphism. The basement units are additionally characterized by a pre-Alpine amphibolite facies metamorphic evolution. The Silvretta-Seckau nappe system in the area of the Schladminger Tauern is subdivided into two sub-units (Golling Complex and Riesach Complex). In the field trip area, the units of the Golling Complex are exposed. This Complex can be subdivided into two nappes. Within the higher unit, exposed in the area of the Giglachsee (47°16'55,00"N; 13°38'54,20"E), the basement and the cover sequences are exposed mainly in an inverted succession. An inverted sequence of probably Permian metaconglomerates, quartz phyllites, quartzites and lower Triassic carbonates is exposed below pre-Alpine amphibolite facies metamorphic basement units. The basement-cover contact is overprinted and sheared at greenschist facies metamorphic conditions. The Triassic platform carbonates are well exposed in the area of the Steirische Kalkspitze (47°16'59,72"N; 13°37'19,82"E) and Lungauer Kalkspitze (47°16'20,00"N; 13°37'29,42"E) (2456m and 2470m, respectively) (Fig. 1).



**Figure 1:** View from the Lungauer Kalkspitze (2470 m) towards northwest to the Steirische Kalkspitze (2456 m), and to the Dachstein (2797m) (Northern Calcareous Alps) the back.



### Legend Geology Map

#### Pleistozän

- Block-Glacier
- Talus
- Moraine
- Lake deposit

#### Schladming Basement

- Amphibolit / banded
- Orthogneis
- Paragneis

— ···· Fault, assumed

#### Sedimentary Cover

- (Carbonat)Phyllit
- Conglomerat
- Rauhwanke
- Quartzite
- Limestone, Marble ("Plattenkalk")
- Dolomite, Dolomite Marble
- Slate, Phyllite
- Tuffite
- Dolomite (banded)

— open ruptures

#### Assumed Age

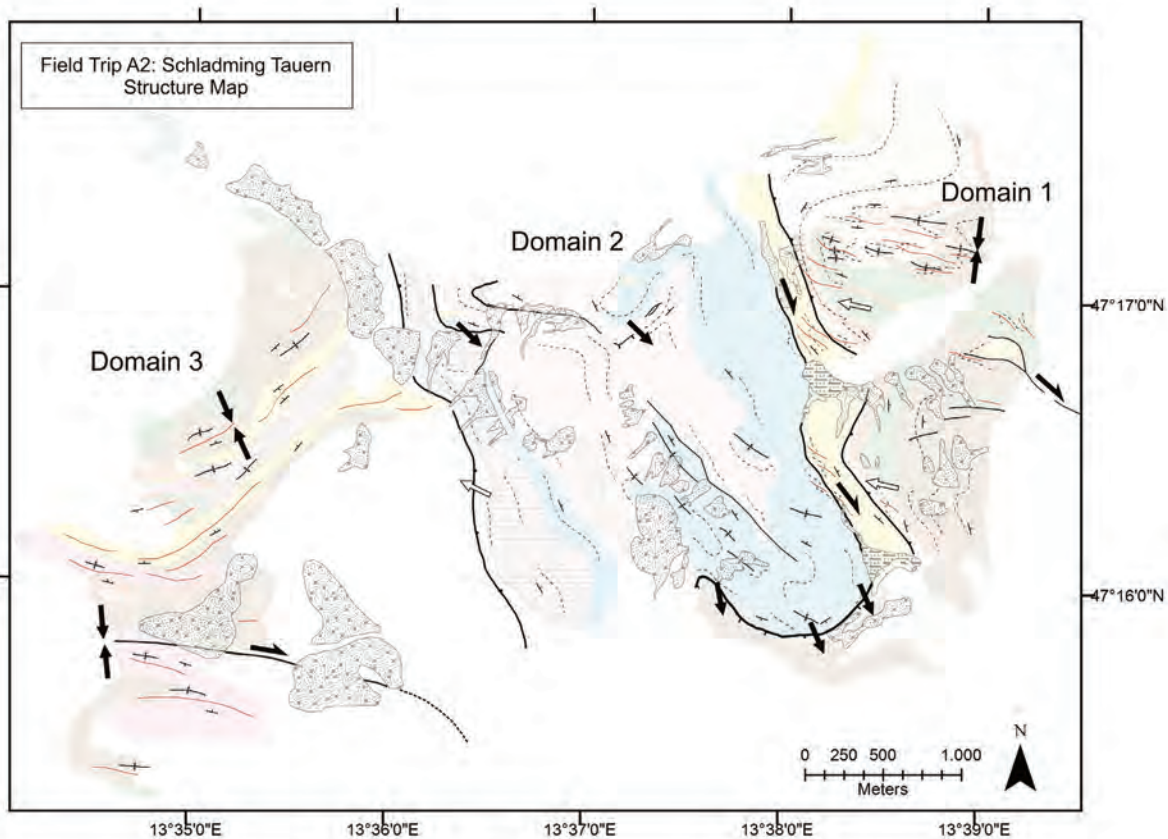
- Permian
- Anisian
- Ladinian
- Carnian
- Norian

**Figure 2:** Geological map and excursion route (red line) of field trip A2.

Within the lower unit, exposed in the area of the Oberhüttensee (47°16'47,46"N; 13°36'03,50"E), a normal sequence of Permian to probably Triassic metasediments discordantly overlies a pre-Alpine basement. Also here, the basement (orthogneisses, paragneisses, amphibolites) is characterised by a pre-Alpine metamorphic evolution at amphibolite facies conditions, and by (lower) greenschist facies Eoalpine metamorphic overprint.

### Structural evolution

The area is subdivided into three domains with distinctly different structural inventory and separated by major tectonic boundaries (Fig. 3). The eastern part (domain 1), between Ignaz Mattis- and Giglachsee-Hütte exposes retrogressed Schladming basement conformably overlain by Permo-Triassic clastic sediments. Both, the upright and inverted limbs of a map-scale NW-vergent fold are mapped. A narrow-spaced axial plane foliation dominates this domain, associated second order folds being responsible for a lense-shaped geometry of units exposed in fold hinges. The inferred thrust direction was top-to-the NW during the first Alpine deformation phase followed by N-S shortening in a subsequent stage. The tight axial plane cleavage is overprinted by a prominent dextral shear zone along the contact to domain 2.



#### Legend Structure Map

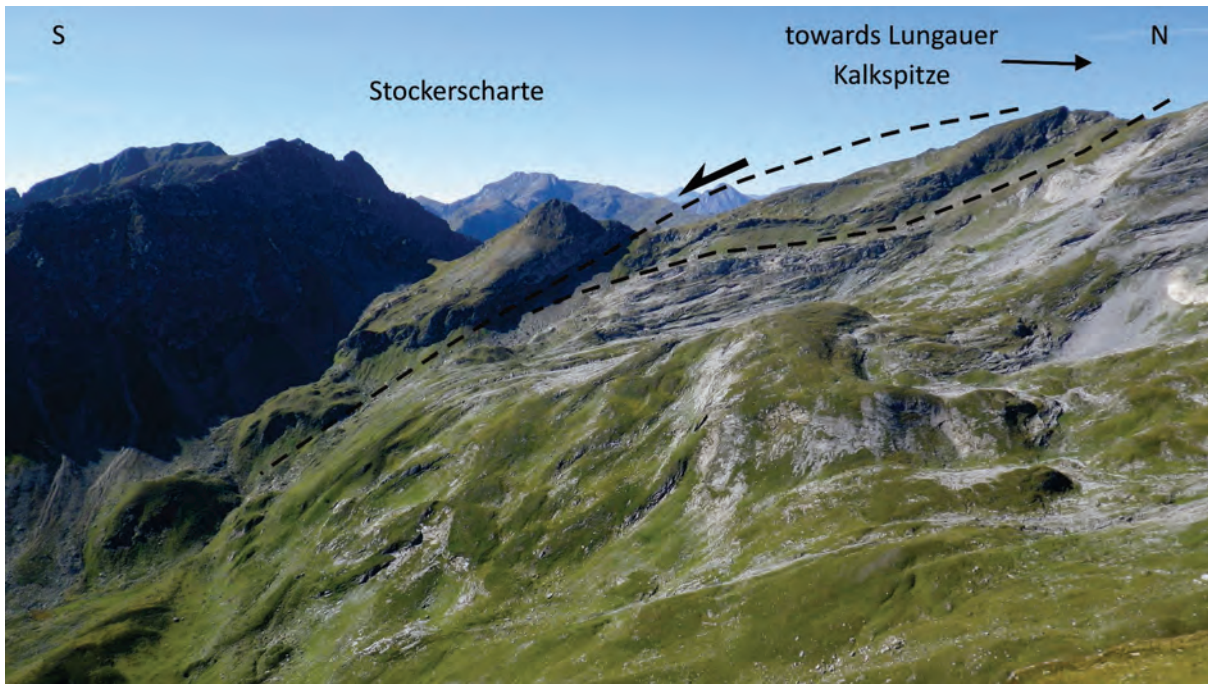
- |  |                               |  |                                    |
|--|-------------------------------|--|------------------------------------|
|  | Thrust and displacement       |  | Foliation trace, S1-Alpine         |
|  | Normal fault and displacement |  | Foliation trace, S2-Alpine         |
|  | Strike-slip Shear Zone        |  | Fold-axis trend                    |
|  | General Shortening            |  | Orientation of prevalent foliation |
|  | Fault                         |  |                                    |

**Figure 3:** Structure map with main structural features and lithology in pale colours (see Fig. 2 for legend of lithologies).

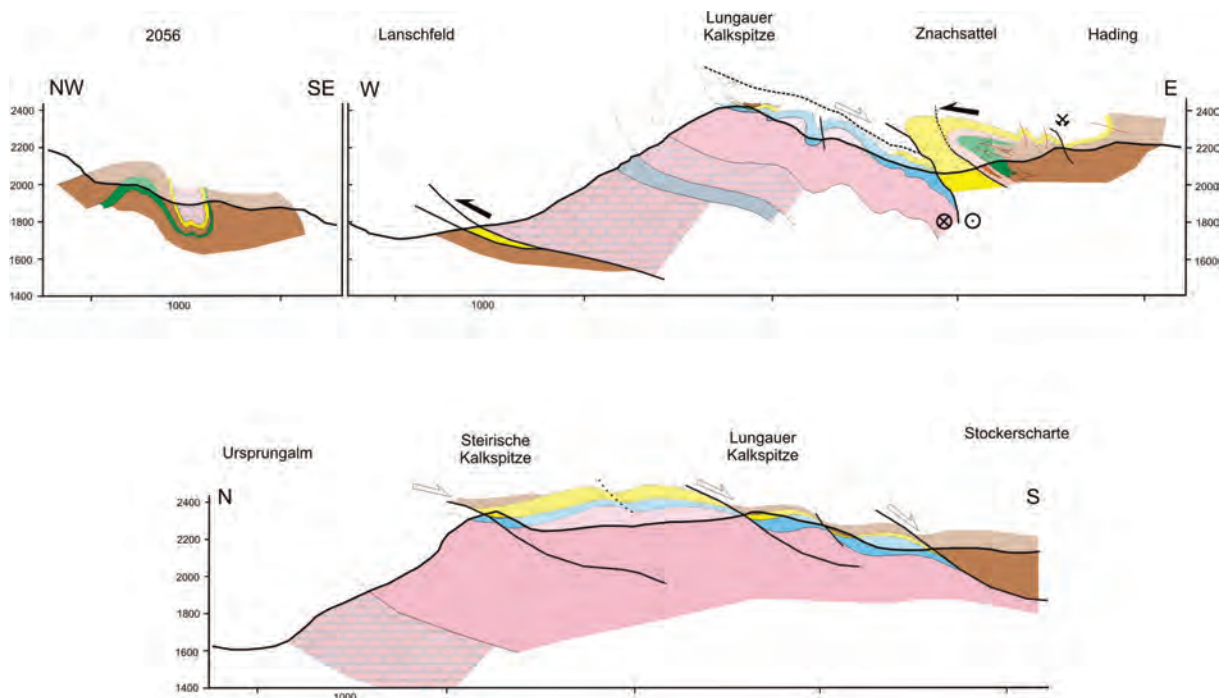
The central part (domain 2) constitutes a fault bounded and inverted section with slivers of Schladming basement (now exposed on the summits of Lungauer Kalkspitze), underlain by Permian clastic rocks and Triassic carbonates (Fig. 3). A prominent south- to southeast-dipping ductile normal fault marks the boundary between domains 1 and 2 in the south (Fig. 4). The western boundary constitutes the above mentioned shear zone. The eastern border

of domain 2 is not exposed but assumed to be a thrust separating domain 2 from domain 3. Internal portions of domain 2 contain localized top-SE extensional shears and NNW-SSE trending folds.

The western domain (domain 3) exhibits tight folding of Permian to Mesozoic cover units and basement. Fold traces trend NE-SW and occupy high angles to structural elements and lithology trends of domain 2. Younger dextral shear zones evolved preferentially within tight limbs of folds.



**Figure 4:** The southern low-angle normal fault separating domain 1 from domain 2. View from Znachspitze towards west.



**Figure 5:** W-E (upper panel; location of the section: Profile A in Fig. 2) and N-S (lower panel; location of the section: Profile B in Fig. 2) sections from the excursion area. For legend see Fig. 1 and 2.

The upper panel in Fig. 5 shows a W-E section across the three domains. The eastern sector (domain 1 – from Hading to Znachsattel) illustrates the older Alpine thrusting and folding phase overprinted by normal and strike-slip folds. Domain 2, between Znachsattel and Lanschfeld is the inverted Permian to Mesozoic section underlain by folded basement and cover units of domain 3 (point 2056 m).

The lower panel from the Urprungalm (south) to the Stockerscharte (north) displays southward extensional shearing as typical for domain 2 (compare Fig. 4). All in all domains 1 and 3 are characterized by N-S shortening structures, domain 2 by N-S extensional structures.

## Day 1

We start the excursion at Ursprungalm (1604m) (47°17'47"N; 13°37'10,5"E) and take the footpath to the Giglachseehütte (1955m) (47°16'46,62"N; 13°38'15,38"E). The trail mainly follows the boundary between lower Triassic quartzite and "Plattenkalk" that is also the right lateral shear zone separating domain 1 from domain 2. From Giglachseehütte we proceed to Ignaz Mattis Hütte (1986m) (47°17'05,88"N; 13°38'54,90"E).

The cross section from the Ignaz Mattis Hütte to the Giglachseehütte shows an inverted section from basement rocks of the Schladming basement to Permian to Mesozoic metaclastic rocks of the cover suite. In this area the Schladming crystalline basement consists of fine grained biotite-plagioclase gneiss and fine grained amphibolite, both contain occasionally garnet (for detailed description of basement rocks see day 2). Characteristic is the strong retrogression during Eo-Alpine deformation and replacement of amphibole by chlorite within amphibolites. At 47°16'55,8"N; 13°38'22,7"E the contact between basement and cover rocks is exposed, here represented by pebble bearing carbonate phyllite and conglomerate. This boundary is heavily fluid infiltrated as to be recognized from numerous carbonate veins within basement rocks and the sedimentary cover. On the opposite side of Giglachsee red debris from the dump of the Giglachsee mine is seen that aligns with a shear



**Figure 6:** Stretched and sheared pebbles within carbonate bearing phyllite.

zone close to the basement-cover contact and continues from Freying (2131m) (47°16'49,8"; 13°39'4,7"E) eastwards to the mines at Vetter-Zinkwand. Polymetallic sulphide ore was mined for Ni-Co-Ag-Cu since the 13th century with variable activities and ended 1875.

The inverted sedimentary succession starts with carbonate - sericite - phyllite and reddish - brown conglomerate composed mainly of quartz pebbles with a size up to 10cm. In all, a fining upward sequence is present, although meta-sandstone and phyllite beds alternate with meta-conglomerate beds. Stratigraphically upwards pure quartzite, described in different terms in different areas (e.g., Semmering Quartzite, Lantschfeld Quartzite,...), with characteristic pale green colour occurs. Apparently, the metasedimentary suite conformably overlays the basement rocks. Both basement and cover experienced NW-directed shear (Fig. 6) as evidenced from stretched pebbles that include numerous shear sense indicators. The Giglachseehütte is close to the contact between Anisian quartzite and Triassic carbonate platform sediments.

From the Giglachseehütte to Znachsattel (2059m) (47°16'29,4"N; 13°38'6,3") the trail leads along the boundary between quartzite and platy limestone (Plattenkalk) of presumably Anisian age. This boundary represents a shear zone where early formed folds were transposed into dextral shear structures (close to Giglachseehütte). At Znachsattel S-vergent folding is seen as expression of this shearing. From Znachsattel we climb up to Akarscharte (2315m) (47°16'47,15"N; 13°37'9,2"). Anisian platy limestone contain nests of dolomite and are followed by Ladinian dolomite (Wetterstein Dolomite ?) with rare occurrences of tuffite in between. Half way up (47°16'29,4"N; 13°37'30,6") an alternation of steeply dipping limestone and dolomite is seen as expression of tight folding around NNW trending axes (Figs. 3, 5)

The top of the Lungauer Kalkspitze exposes Anisian quartzite and biotite gneiss (Schladming basement). Heading towards south we reach the prominent SE-dipping semi-ductile normal fault close to point 2348 (47°16'2,07"N; 13°37'36,63"). Here the sedimentary cover of the Schladming basement appears to be extremely reduced by low-angle normal faulting. Numerous shear sense indicators are found in carbonate phyllite and conglomerate (Figs. 4, 7).



**Figure 7:** Low-angle normal shear zone with ecc-fabrics, point 2348m (47°15'58,56"N; 13°37'52,11").

The trail from Akarscharte to Oberhütte (47°16'49,9"N; 13°35'45,5"E) exposes the complete, inverted section of Ladinian to possibly Norian rocks. Massive Ladinian? dolomite, in rare places interleaved by Carnian? slate is underlain by banded dolomite and limestone. The entire, inverted section of domain 2 with Norian? dolomite at the base, tectonically overlays Anisian quartzite of domain 3 near Oberhüttensattel (1866m) (47°16'36,1"N; 13°35'48,9"E). Unfortunately the tectonic boundary is not exposed. We draw attention to the fact that the structural style changes at this boundary. The dominant Swvergent extensional structure that dominate much of domain 1 is replaced by N-S compressional structures best seen in tight folding of basement and cover sequences in domain 3.

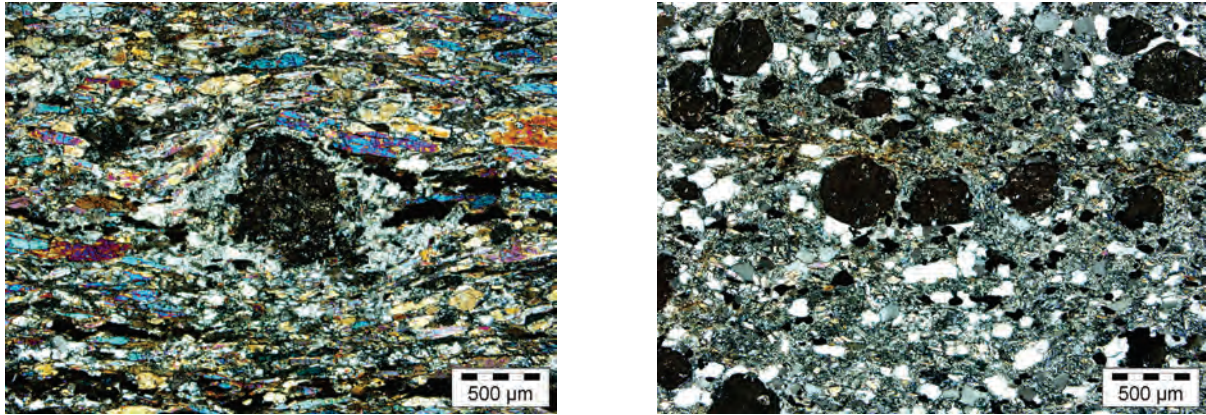
## Day 2

Cross section from Oberhütte (1845m) (47°16'49,00"N; 13°35'59,89") to point 2056m (47°16'36,30"; 13°35'25,25") and lake at 47°16'24,00"; 13°35'13,20".

This cross section provides an overview of the structure of the lower nappe within the Golling complex. This unit is build up of a pre-Alpine basement showing pre-Alpine amphibolite facies metamorphic overprint, and a Permian to Triassic cover. The contact between the basement and the cover units is marked by a clear angular unconformity (Fig. 8). The basement is characterised by a well developed, pre-Alpine penetrative foliation with subhorizontal to slightly W-dipping layering (Fig. 8). In the field trip area, this basement mainly comprises highly variable paragneisses (quartz, plagioclase, muscovite, partly garnet, biotite), orthogneisses (quartz, K-feldspar, plagioclase, muscovite), and amphibolites (hornblende, plagioclase, quartz) that partly contain garnet. The garnets within these amphibolites usually show rims of chlorite and epidote (Fig. 9), indicating an Alpine metamorphic overprint at greenschist metamorphic conditions. The degree of retrogression during Alpine metamorphism increases towards the basement – cover contact. Close to this contact the amphibolites are strongly retrogressed as well, indicated by the formation of very fine grained symplectite (Fig. 9).



**Figure 8** (previous page): Exposure at 47°16'24,00"N; 13°35'13,20"E, showing the angular discordance between the pre-Alpine basement (right) and the Permian to Triassic cover (left). The basement at this site mainly comprises various paragneisses with distinct layers of amphibolite. The cover at the contact comprises quartzite and quartz phyllite. Due to the angular disconformity the penetrative foliation within the basement is assumed to be of pre-Alpine origin. This pre-Alpine foliation is subhorizontally layered in the area of exposure; the foliation within the cover is dipping towards southeast.



**Figure 9:** Microfabric and texture of retrogressed garnet amphibolite; garnets show rims of chlorite and epidote (left); retrogression of hornblende to fine-grained symplectite (right).

The Permian to Mesozoic cover, from base to top, consists of chlorite phyllites, partly with quartz pebbles (Fig. 11), meta-conglomerates, quartzites, cornule, dark schists to phyllites, and banded dark calcite marbles as well as dolomite marbles. The cornules, dark schists and marbles are assumed to be of Anisian stratigraphic age. In general, these sequences show low-grade Alpine metamorphic overprint and are incorporated into large-scale folding at a scale of several meters to kilometers. This results in a succession of gentle to tight antiforms and synforms, characterized by a sub-horizontal to slightly ESE-dipping fold axis (Fig. 10).

**Figure 10:** Equal area projections of penetrative foliation orientation data from pre-Alpine basement (right) and Permian to Triassic cover (left) at site 47°16'24,00"N; 13°35'13,20"E. The poles to the foliation data within the cover units are distributed along a girdle, indicating folding of the foliation around a ESE- plunging fold axis.



Strikingly the trend of the Alpine penetrative foliation as well as the trend of stretching lineations and fold axes is orthogonal or highly oblique between the higher (domain 2) and the lower unit of domain 3 (east-west in the lower unit, north-south in the higher unit). Hence, beside the angular unconformity within the lower unit around the Obersee, there is an additional structural discontinuity between the two nappes within the Golling Complex.

The basement – cover contact along the angular unconformity is tectonically overprinted by penetrative shearing. Pebble-bearing, micaceous quartzites and quartz phyllites were transformed to phyllonites with a very prominent penetrative foliation, and a well developed, E-plunging stretching lineation. The penetrative foliation is moderately to steeply dipping towards southeast. As these phyllonitic shear zones are overprinting the Alpine foliation and subsequent folding, this localized shearing is assumed to be related to post-stacking, E-W extension.



**Figure 11:** Quartzphyllite with quartz pebbles (Permian?) close to the angular conformity at the basement cover contact.

On the way back to Ursprungalm we cross again the unexposed boundary between domains 2 and 3 southwest of Brotrinnl (2088m) (47°17'9,56"N; 13°36'4,7"E) and proceed within the sedimentary cover suite (phyllite, quartzite) of the Schladming basement.

## Summary of the tectonic evolution

- 1) Arguably the inverted metasedimentary suite exposed at Steirische and Lungauer Kalkspitze transgressively overlays basement rocks of the Silvretta-Schladming-Seckau Nappe system and thus are considered as part of a coherent nappe system.
- 2) The structural inventory and geometric relations suggest existence of two distinct nappes. The upper nappe of the Golling Complex in this area constitutes domains 1 and 2 that were assembled during an early phase of Eo-Alpine deformation. West-to northwest directed folding is considered to be responsible for the inverted stratigraphic succession of domain 2.
- 3) Stacking structures were overprinted by SE- vergent extensional structures that likely evolved during late Eo-Alpine (Gosauic) extension. During this phase previously buried rocks of domain 2 were exhumed along SE- dipping normal faults.
- 4) Rocks of domain 3 represent a deeper nappe of the Golling Complex, tectonically below domains 1 and 2. This unit preserves an angular unconformity between the Schladming basement and its cover. Variscan metamorphism and deformation is recorded within the basement. Tight folding of basement and cover units is related to Eo-Alpine shortening followed by late Eo-Alpine strike-slip shearing.