NORMAL FAULTING IN A RIGID AND ANISOTROPIC BASIN BOUNDARY BLOCK - FIELD EVIDENCE FROM THE KORALM COMPLEX (EASTERN ALPS)

This research work is supported by:

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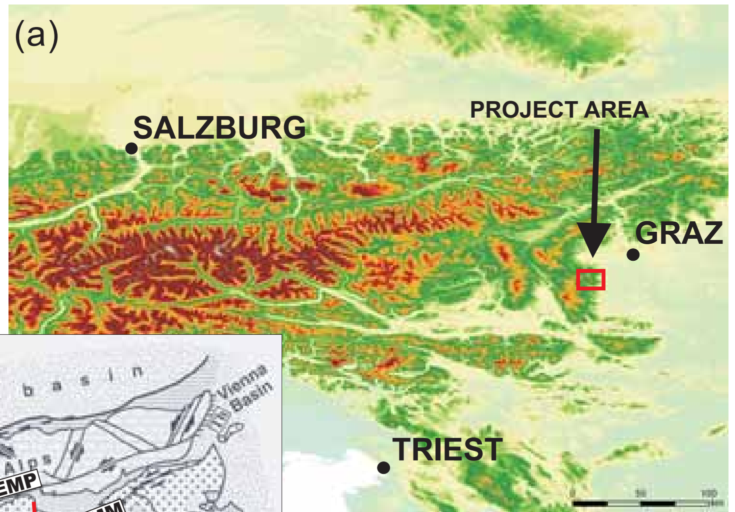
INTRODUCTION

Miocene lateral extrusion of the Eastern Alps resulted in the development of a prominent fault pattern which strongly mould the present-day morphology of the Eastern Alps (**Figure 1a and 1b,** Frisch et al., 2000; Ratschbacher et al., 1991). Bordered by the Lavant and the Styrian basin the polycrystalline Koralm complex together with the adjacent Saualpe form relative brittle and rigid blocks in this extrusion corridor and have experienced major tilting during this period (Genser and Neubauer, 1989). The tectonic imprint of continental escape and the consecutive events on this block has only sparsely been worked on in geological research (e.g. Kieslinger, 1928; Tollmann, 1976; Riedmüller and Schwaighofer, 1978; Brosch, 1983; Buchroithner, 1984; Peresson and Decker, 1998; Brosch et al., 2001; Vanek et al., 2001).

In our contribution we want to present outcrop evidence for pronounced normal faulting within this block from the eastern realm of the Koralpe adjacent to Stainz (Styria). This work is part of the FWF sponsored project P17697 "Structural evolution of faults and fault rocks: Tectonic and geotechnical consequences".

Figure 1a (right): Digital elevation model (90 m SRTM DEM) of the Eastern Alps to show the pronounced impact of the fault zones active during lateral extrusion (see Figure 1b) on the present morphology of the Alps.



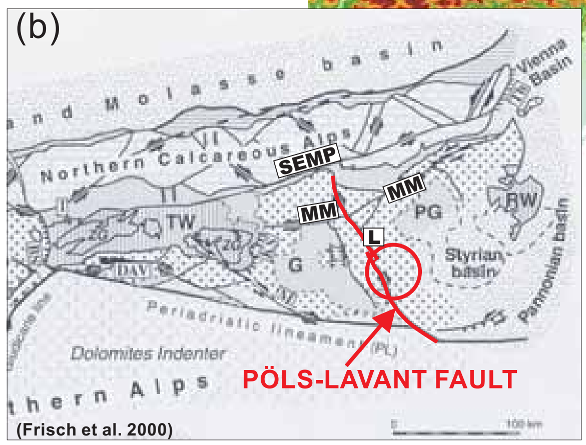


Figure 1b (left): Tectonic map of the Eastern alps, showing the major fault zones active during lateral extrusion of the Eastern Alps (taken from Frisch et al. 2000)

L.........Pöls-Lavant fault
MM.....Mur-Mürz fault
SEMP..Salzach fault

GEOLOGICAL AND GEOMORPHOLOGICAL OVERVIEW

At the western margin of the Koralm the major bordering fault zone, the Pöls-Lavanttal fault zone (**Figure 1**), is regarded as still active with a dextral sense of shear derived from focal plane solutions (Reinecker, 2000; Reinecker and Lenhardt, 1999).

The eastern boundary of the range is assumed to be characterized by sets of normal faults which for the major part are hidden below Neogene sediments and are only partly reflected in the regional geological maps (Beck-Mannagetta, 1991, **Figure 3**). The boundary between the crystalline and the tertiary rocks generally trends approx. NNE to SSW, tracing the given morphology of the crystalline basement.

The investigated area is predominately situated in a mylonitic shear-zone ("Plattengneis") of Cretaceous age (Krohe, 1987; Kurz et al., 2002; Putz et al., 2006). The foliation strikes generally WNW-ESE, flatly dipping towards north. The "Plattengneis" is characterized by a pronounced, approx. N-S trending, lineation and a distinct mechanical anisotropy (Blümel et al., 1999) related to the metamorphic foliation fabric.

The eastern realm of the Koralpe near Stainz is characterized by generally W-E to WNW-ESE trending ridges and main creeks (Stainzbach, Gamsbach, Wildbach). The slope aspect distribution shows two maxima, one with slopes dipping towards NNE to ENE and one from SSE to SW. Slope angles (**Figure 4**) are most times larger than 24° along the gorge like creeks, indicating high relief energy. Between these, slope angles are mostly between 5° and 24°, with the mean at 14° probably reflecting the Neogene relief.

METHODOLGY

- Outcrop mapping of brittle tectonic indicators on fault planes and in fault rocks (Doblas, 1998; Meschede, 1994)
- Calculation of the extension resp. compression axis with the P/T method (Turner, 1953). The calculations were performed with the TECTONICS FP software package (http://www.tectonicsfp.com/).
- Lineament identification by visual inspection of a 10 DEM and its derivates (hillshade, contour lines, drainage pattern, slope angle and aspect) with the ARCGIS 9.1 desktop GIS.

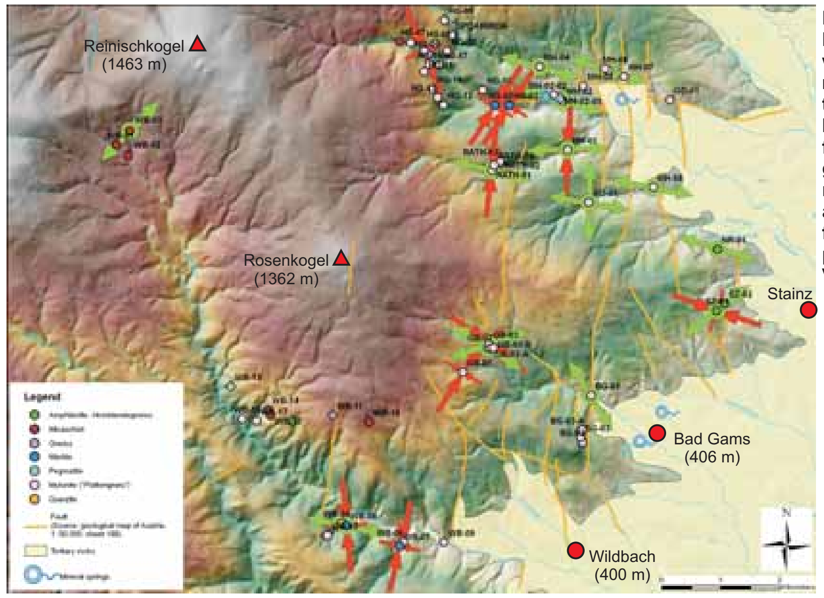


Figure 2 (left): Map of the project area with location of the mapped outcrops and the orientation of the kinematic axis derived from P/T analysis, green arrows indicate normal faulting, red arrows strike-slip faulting (10m DEM provided by BEV - Vienna).

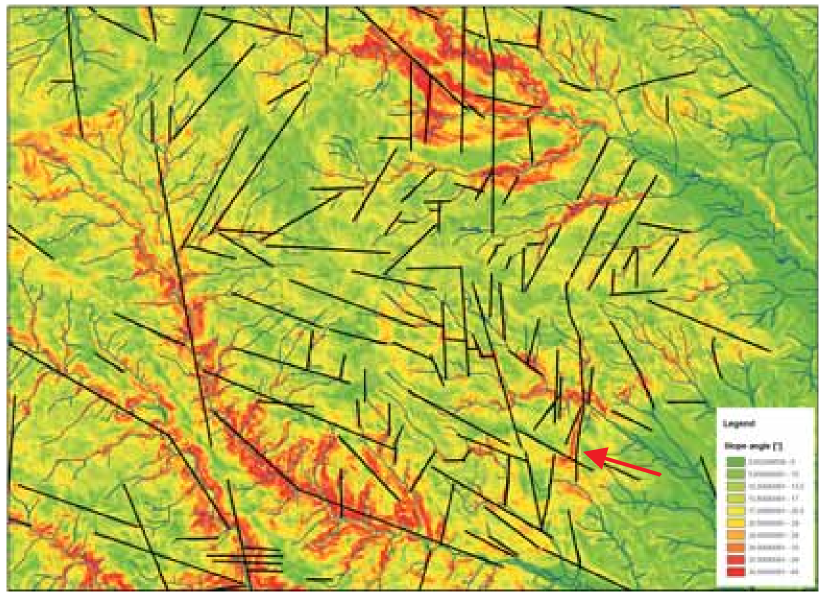


Figure 3 (left): Slope angle distribution in the project area (classified by natural breaks). Note the N-S trending steep slope W of Bad Gams (red arrow) representing a fault scarp of the Greimkogel fault. Similar, but smaller scarps are found further north. Drainage pattern was calculated from the DEM data.

Quarry Ungerlipp (MH-08)

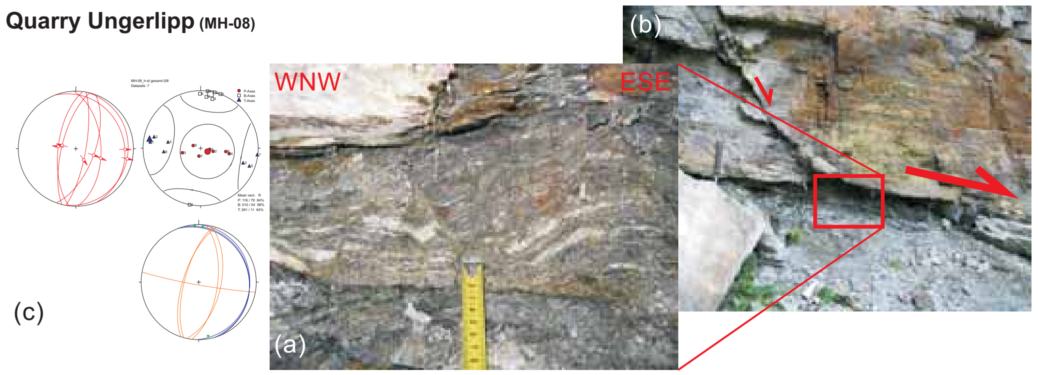


Figure 4: Quarry Ungerlipp (Marhof).
(a) A major normal fault parallel to the foliation cuts through the quarry, again cataclastic sheared Plattengneis forms the fault core. Note tilting towards W of the foliation in the shear zone.
(b) Listric normal fault terminates in foliation parallel shear zone, note synthetic splays and tensile fractures in the hanging wall. (blue great circle = foliation, green cross = stretching lineation, orange great circle = discontinuity with unclear genesis)

RESULTS

- The mapped outcrops reveal a pronounced influence of WNW-ESE directed extensional tectonics which represents the most distinct faulting event in this area. It resulted in the formation of cataclastic E- to SE-dipping shear zones and slickensides, often with listric geometry. The P/T analysis of these fault-slip data yield approx. WNW-ESE directed extension axes **(Figures 4 and 5).**
- The metamorphic foliation was activated by this extensional event and foliation parallel shear zones are abundantly exposed. Observed fault rock thickness in these foliation parallel shear zones reaches up to approx. 50 cm with exposed fault lengths larger than the outcrop size.

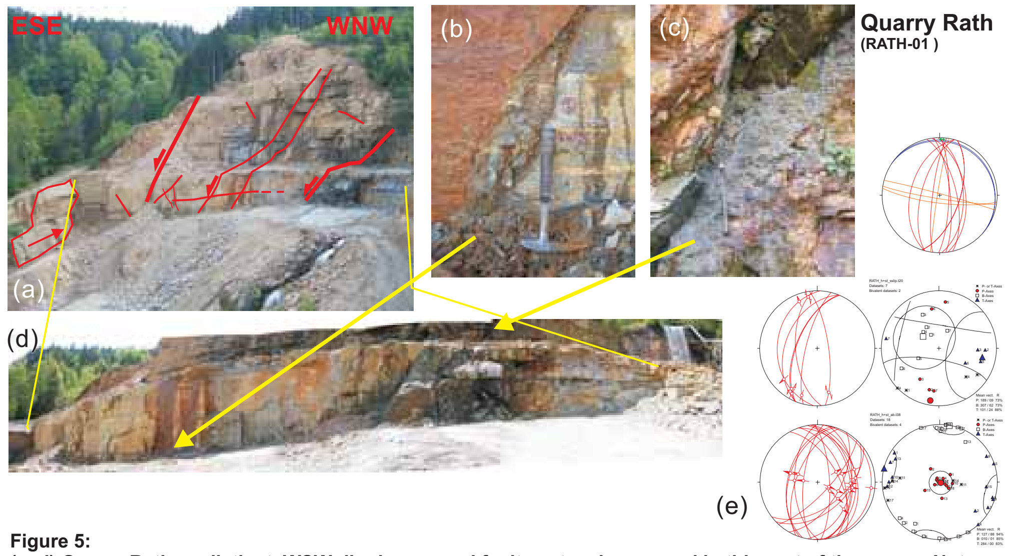


Figure 5:
(a, d) Quarry Rath, a distinct WSW dipping normal fault system is exposed in this part of the quarry. Note strike-slip fault with probable sinistral kinematic on the left side, which is reactivated by normal faulting.
(b) Releasing stepover with heavily fractured rock in the stepover lense.
(c) Fault core of a normal fault with fault gouge shear bands and cataclastic sheared Plattengneis.
(d) Fault-slip data (Angelier type plot of lower hemisphere) and results of the P/T analysis
(blue great circle = foliation, green cross = stretching lineation, orange great circle = discontinuity with unclear genesis, red = fault plane without striation)

- Normal faulting lead to the formation of N-S directed fault scarps (e.g. Greimkogel, **Figure 3**) and to a pronounced morphological structuring of the WNW-ESE trending ridges through saddles and peaks.
- A further brittle deformation event is clearly deducible from the mapped outcrops. This event is marked by strike-slip to oblique-slip on predominantly N-S striking slickensides. Fault rocks related to this event could not be documented. Paleostress analysis yields an approx NNW-SSE to NNE-SSW directed compression axis. The observed age relations indicate that the strike-slip event is older than the normal faulting event **(Figure 5)**.
- Field data additionally indicate two further kinematic events: WNW-ESE directed compression linked to strike-slip faulting and N-S orientated normal faulting. An age relation to the other deformation events could not yet be established.
- Detected lineament directions reflect clear the discontinuity and fault pattern observed in the outcrops.

CONCLUSIONS

- The foliation plays a crucial role in brittle faulting of such an anistropic rock mass.
- Fault density seems to be much higher than depicted in the regional geological maps.
- Intersection of listric and foliation parallel, flatly oriented shear zones with the morphology result in a complete different map representation fault than the current one.
- To allow a clearer distinction of the different tectonic events further investigations like radiometric dating and additional field mapping seem crucial.
- The distinct normal faulting is thought to be related to continental escape tectonics and Miocene subsidence of the Styrian Basin. Kinematic similarities exist to the Late Cretaceous Graden Normal fault adjacent to the Kainach Gosau (Rantitsch and Mali, 2006).

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