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KINEMATICS OF VARISCAN DEFORMATION IN THE MOLDANUBIAN ZONE, SOUTHERN BOHEMIAN MASSIF: PRELIMINARY RESULTS FROM THE DANUBE SECTION

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Zusammenfassung

Die strukturelle Entwicklung der moldanubischen Zone in der südlichsten Böhmischen Masse begann mit Versenkung und krustaler Imbrikation während frühvariszischer Zeit. Vier Decken können unterschieden werden. Eine kryptische Sutur könnte unterhalb der Granulitdecke vorhanden sein, in welche Mantelgesteine während der Versenkung inkorporiert wurden. Die Stapelung krustaler Gesteine ist die Folge dextraler Transpression gegen den brunovistulischen Mikrokontinent. Die Decken wurden zuerst in einem tiefkrustalen Niveau gegen NNE transportiert, später gegen E bis ESE. Schließlich führte die Platznahme des südböhmischen Plutons zur Aufdomung des Deckenstapels durch ostgerichtete Kompression. Wenn man die strukturellen Daten mit solchen zur Metamorphose und geochronologischen Daten kombiniert, so muß die Deckenstapelung und anschließende Intrusion des südböhmischen Plutons innerhalb einer kurzen Zeitspanne des späten Devons und Unterkarbons stattgefunden haben.

Späte koachsiale und vorwiegend SE-abschiebende, nonkoachsiale Dehnungsstrukturen sind Ausdruck des gravitativen Kollaps der vorher verdickten Kruste. Die duktilen Dehnungsstrukturen wurden vorwiegend unter amphibolitfaziellen und grünschieferfaziellen Bedingungen während des ausgehenden Unterkarbons gebildet.

Abstract

The structural evolution of the Moldanubian Zone in the southernmost Bohemian Massif started with burial and crustal stacking of continental lithotectonic units during Variscan times. Four units are distinguishable. The base of the granulite unit, the uppermost one, may represent a cryptic suture into which mantle slices were incorporated. Early crustal stacking occurred during dextral transpression against the Brunovistulic microcontinent, and is related to top-to-the-NNE shear within the Moldanubian zone in a deep crustal level. Subsequent top-to- the-ESE shear led to further stacking of continental slices. Finally, the emplacement of the large South Bohemian pluton caused updoming and push by the upwelling pluton. Structural, petrological, and geochronological data suggest that crustal stacking and intrusion occurred within a short time of late Devonian to early Carboniferous.

Coaxial, and noncoaxial SE-directed extensional structures are interpreted as the consequence of gravitational collapse of the previously thickened crust. Extension was operating within amphibolite to greenschist facies conditions mainly during early Carboniferous.

1. INTRODUCTION

The kinematics of the southeastern Bohemian massif bear some unsolved problems concerning the structure, subdivision of lithotectonic units, and direction and age of crustal stacking by thrusting. E.g., some controversial models were proposed during the last fifteen years to explain the fact that granulites occur on the top of other not dehydrated lithotectonic units (Fuchs 1976; Fuchs und Matura 1976; Matura 1976; Thiele 1976). The last interpretation favours a large-scale, top-to-the-ESE-directed thrusting of granulites onto the top of other units (Tollmann 1982; Matte et al. 1985).

This paper briefly describes preliminary results of a kinematic study which is being carried out along a well-exposed section mainly along the Danube river and its confluents between Krems and Grein (Fig. 1). The study is based on extensive field work about structures within and along boundaries of major lithotectonic units, and some preliminary results of microstructures and textures of rock-

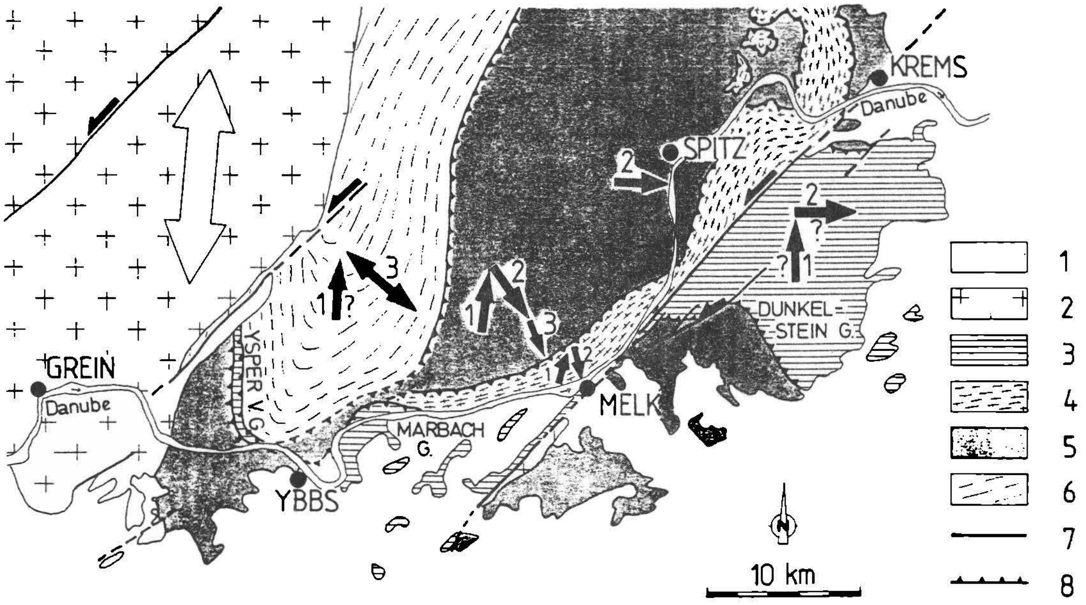


Fig. 1: Simplified structural map of the southeastern Moldanubian zone in the Bohemian massif (after Fuchs und Matura (1976) and Matte et al. (1985), modified). Local overturning of thrusts is omitted because clarity. Basic displacement paths of each unit is shown. Legend: 1 - Cenozoic sediments; 2 - Weinsberg granite; 3 - Dunkelstein and Marbach granulite; 4 - Gföhl unit; 5 - Variegated unit; 6 - Monotonous unit; 7 - fault; 8 - thrust and/or ductile low angle normal fault.

forming minerals. Of major interest is the influence of partial melts in migmatites on large-scale deformation, and the influence of large plutons on the kinematics and architecture of an orogen. The own structural data are discussed in relation to P-T conditions published by Carlswell (1989), Högelsberger (1989), Petrakakis (1986a, b), and Zaydan and Scharbert (1983) as well as to geochronological arguments for timing of metamorphic and deformational events (see chapter discussion).

2. LITHOTECTONIC UNITS AND STRUCTURE

In the area of investigation, following lithotectonic units occur from bottom to the top (Fig. 1), although boundaries may be overturned locally (not shown in Fig. 1):

(1) The Monotonous unit, which is composed of migmatitic paragneisses mainly,
(2) the "Variegated unit", containing migmatitic micaschists, paragneisses, quartzites, marbles, amphibolites, and also including the Dobra gneiss at the base and the Rehberg amphibolite near the hangingwall boundary,
(3) the Gföhl unit, an orthogneiss,
(4) and the granulites of the Dunkelsteiner Wald and Marbach.

The lithologic composition of all units mentioned above is described in Fuchs und Matura (1976), Matura (1984), and Franke (1989).
Granulites form the hangingwall tectonic unit, but thin lenses and slices of granulites also occur along the interface between the Monotonous and Variegated unit (Fuchs und Scharbert 1979). The Ysper valley granulite has a comparable tectonic position between the Monotonous and Variegated units although there are some uncertainities about relationships (Fig. 1). Here granulites are accompagnied by frequent ultramafic rocks. Similar ultramafic rocks also follow the base of the Gföhl unit. The presence of ultramafic rocks which bear seldom hT-hP mineral parageneses underline the tectonic subdivision presented above.

In the area north of the Danube near Ybbs (Fig. 1), the Monotonous unit forms a large dome ("Ostrong dome"). According to published maps of the Geological Survey of Austria (Fuchs und Matura, Thiele, respectively compilation of Fuchs und Matura 1976), the boundaries of some units are cut by the large South Bohemian pluton in the western area (Fig.1). Some postmetamorphic, NNE-SSW trending, left-lateral strike-slip faults crosscut different units as well as the South Bohemian pluton.

3. STRUCTURES OF THE MONOTONOUS UNIT

The rocks of the Monotonous unit have a dominant E-dipping foliation which contains a rather weak stretching lineation. The lineation is dipping to the SE (Fig. 2). Near the hangingwall boundary, a weak NNE-SSW trending lineation is recognizable which is older than the SE-plunging lineation because overprint relationships. Stromatitic banding of migmatites is parallel to the foliation which may be formed

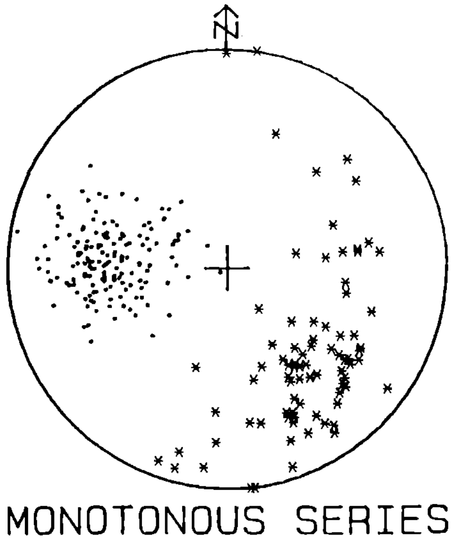


Fig. 2: Poles of the penetrative foliation (•) and lineation (·) of the Monotonous unit in the Lambert projection, lower hemisphere.

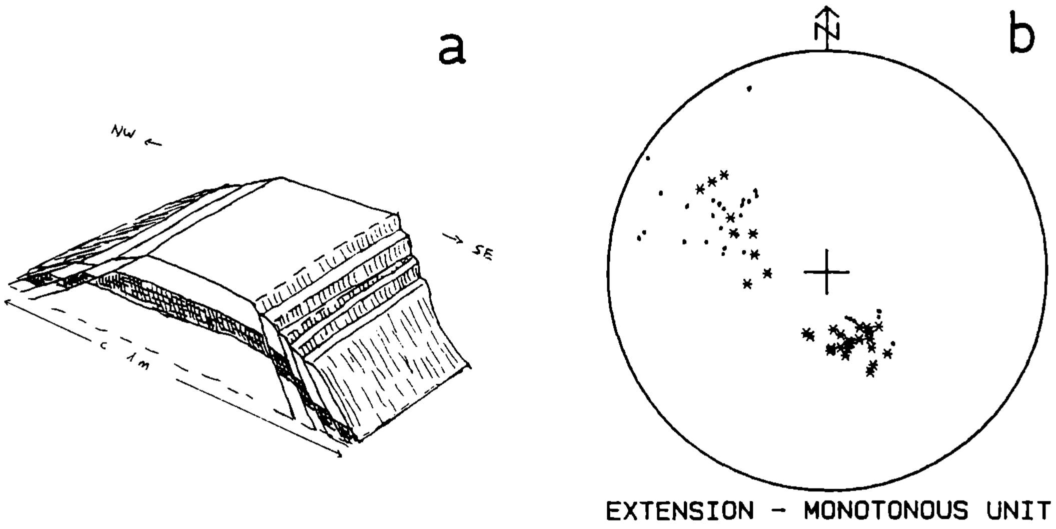


Fig. 3: Conjugate muscovite-bearing extensional faults of the Monotonous unit: a - Schematic sketch (Höllental); b - foliation pole (•) and lineation (·) in the Lambert projection, lower hemisphere.

during partial melting of metapelites. However, most structures like boudins which are surrounded by leocosomes suggest a coaxial deformation regime.

A third set of structures form distinct conjugate normal faults (Fig. 3). As a rule, white mica on such fault surfaces is indicating a metamorphic retrogression by formation of secondary white mica in migmatites otherwise free of muscovite. Also cordierite is related to such structures because it is concentrated on such foliation surfaces and in necks between boudins. These ductile conjugate fault sets indicate ENE-WSW- directed stretching of rocks and non-coaxial rock flow.

4. STRUCTURES OF THE VARIEGATED UNIT

Rocks of the Variegated unit contain a foliation and stretching lineations of different orientations, mainly preserved in different lithologies. Two clusters of lineations are recognized, a flat-lying SW-plunging lineation, and a SE-plunging one. Amphibolites and orthogneisses exhibit a NE-SW trending lineation (Fig. 4). In some outcrops, there is a clearly preferred NNE-SSW orientation of amphiboles in amphibolites. Coarse-grained plagioclase amphibolites are well-recrystallized showing preferred orientation of amphiboles and stretched white aggregates which are composed exclusively of well-recrystallized plagioclase. The plagioclase aggregates may be derived from decomposition of single plagioclase grains which are recrystallized during deformation. Measurements of strain indicate con-

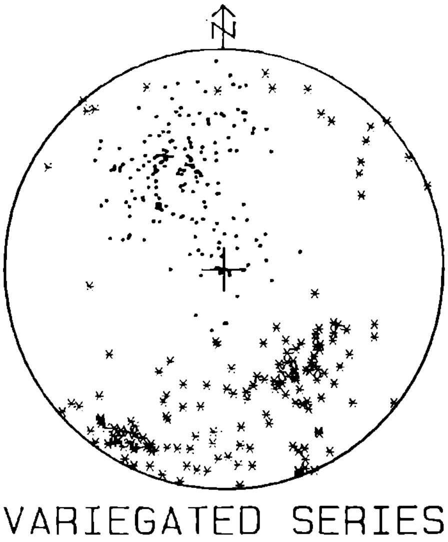


Fig. 4: Poles of the foliation (•) and lineation (·) of the Variegated unit in the Lambert projection, lower hemisphere.

strictional strain (Fig. 5). All mineral phases (plagioclase, brown amphibole, clinopyroxene) show no internal optical zoning, and well-established, coexisting boundaries between different mineral phases. Thus, the deformation occurred during maximum P-T conditions or grains have been overgrown mimetically during maximum P-T conditions. The maximum P-T conditions and those before the maximum P-T has been reached therefore are those of the stretching in NNE-SSW-direction. Zaydan and Scharbert (1984), Petrakakis (1986a, b), and Högelsberger (1989) propose maximum P-T conditions of approximately 670 - 770 °C, and a pressure of 7(5) - 9 kbar of rocks of the Variegated unit.

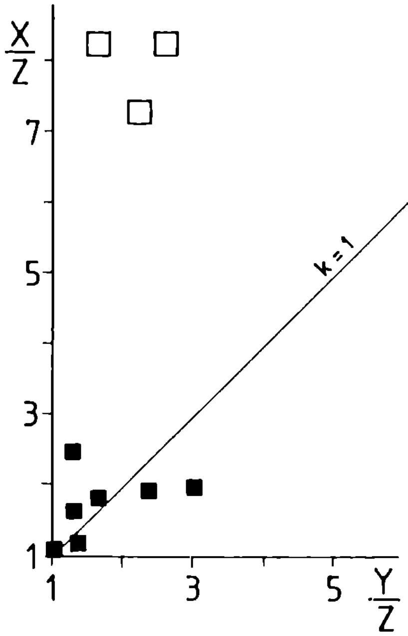


Fig. 5: FLINN-plot of strain data: open squares - recrystallized plagioclase aggregates of plagioclase amphibolite, Weiten valley; filled squares - strain derived from the distribution of K- feldspar megacrysts (line intercept method) and of elongated diorite schollen in the South Bohemian pluton.

The Spitz granodioritic gneiss is interlayered roughly parallel to the lithological boundaries of paragneisses and micaschists etc. although discordant contacts are well-known on the map-scale. The Spitz granodiorite is deformed in a similar way with a stretching lineation in the same orientation like in amphibolites. Amphibolite boudins embedded in the Spitz gneiss bear differently orientated sets of undeformed granitic veins. The veins are perpendicular or acute to foliation and lineation (Fig. 6a, b). Thus the stretching of the amphibolite boudins exhibits the same geometry as the gneissic country rocks. The opening of the veins acute to the foliation as marker of the extension plane reflects a simple shear regime and a top-to-the- NNE shear (compare Simpson and Schmid 1983).

Another type of deformation is present in migmatitic paragneisses and micaschists. In some areas, the rocks are composed of melanosome boudins and interconnected leucosomes, e.g., in the diorite gneiss of St. Michael (Scharbert und Fuchs 1981). The long axes of the boudins are parallel to a weak lineation. In the X-Z sections, boudins are separated by oblique veins which indicate a top to the SE shearing (Fig. 6c, d).

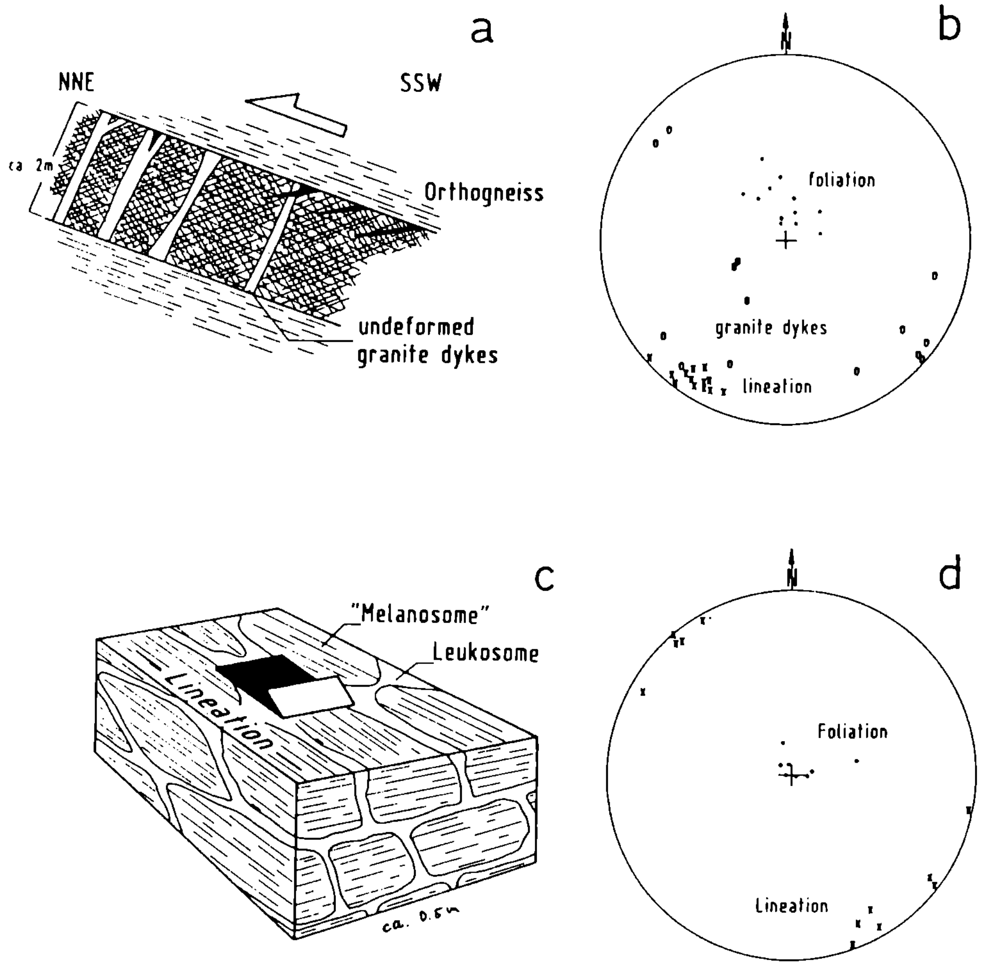


Fig. 6: Amphibolite boudins within the Spitz granodiorite (a, b), and migmatitic diorite gneiss of St. Michael (c, d). a, b: Roadcut S of Eitental, Weiten valley; c, d: southwestern exit of St. Michael, Wachau.

A further type of deformation is related to metamorphic retrogression, mainly along the hangingwall boundary of the Variegated unit. A cm-spaced, SE-dipping foliation and accompanying SSE-plunging lineation overprint the penetrative foliation (Fig. 7). White micas have been formed by alteration of garnets in pressure shadows around garnets during this deformation. All shear criteria indicate dip-slip, normal fault movement of the hangingwall Gföhl unit. These structures are interpreted, therefore, as a major low angle normal fault which overprints the previous thrust zone.

In contrast, a fourth, relatively younger deformation is widespread in the more southern area. Conjugate shear zones deform granitic veins (Fig. 8) as already known since the paper of Matura (1984). This type of deformation is the result of subhorizontal noncoaxial shortening and extension along a steep axis.

A major unresolved problem is the presence of map-scale tight to isoclinal folds with a flat-lying axial surface. Such folds are common in the interior of the Variegated unit. Fuchs (1986) argued for west-directed transport due to the west-directed vergence.

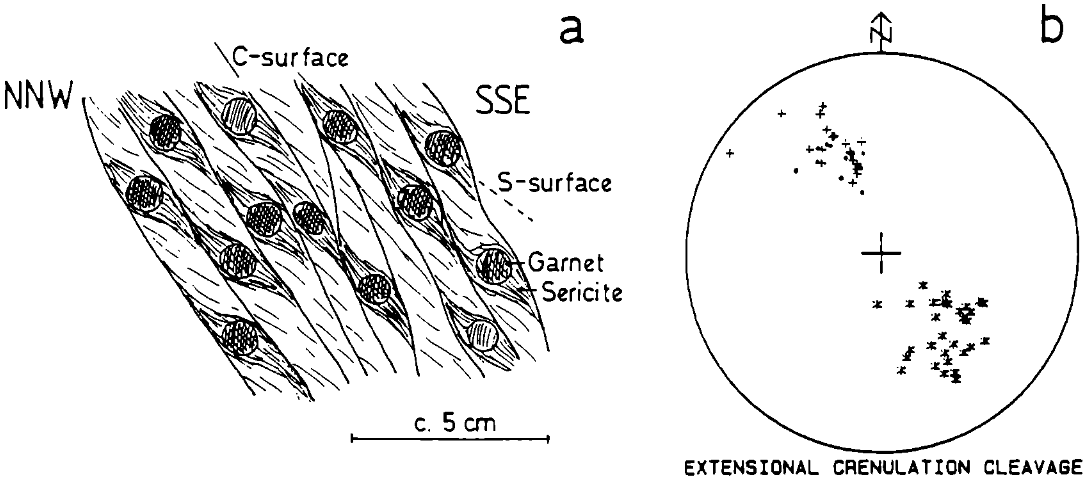


Fig. 7: Extensional structures of the Variegated unit in the footwall of the Gföhl unit (locality Grießbrücke, Weiten valley). a - Schematic sketch; b - poles of S-foliation (•), poles of C-shear planes (+), and lineation (·) in the Lambert projection, lower hemisphere.

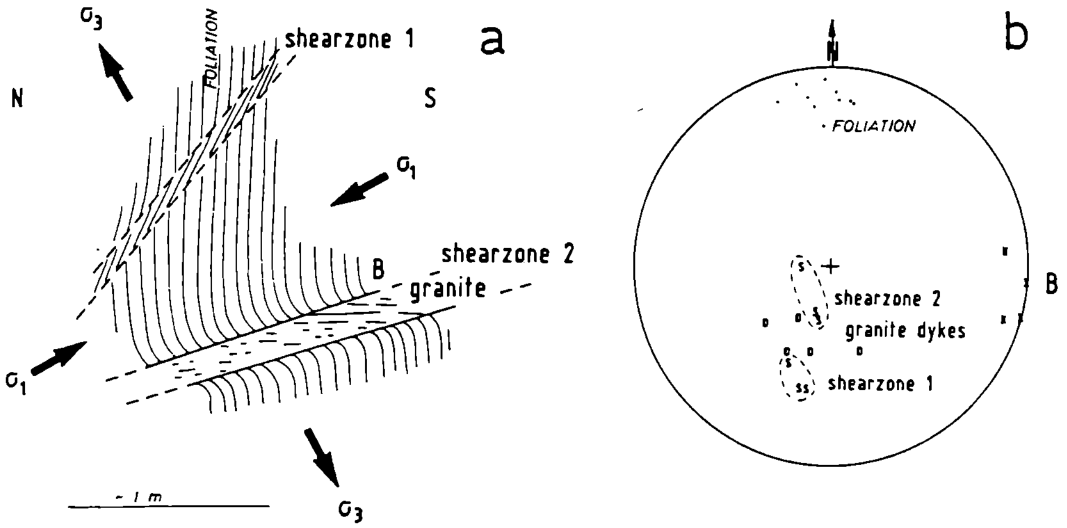


Fig. 8: Conjugate shear zones which deform granitic veins in paragneiss. a: Schematic sketch; b: orientation data in the Lambert projection, lower hemisphere. Roadcut between Marbach and Maria Taferl.

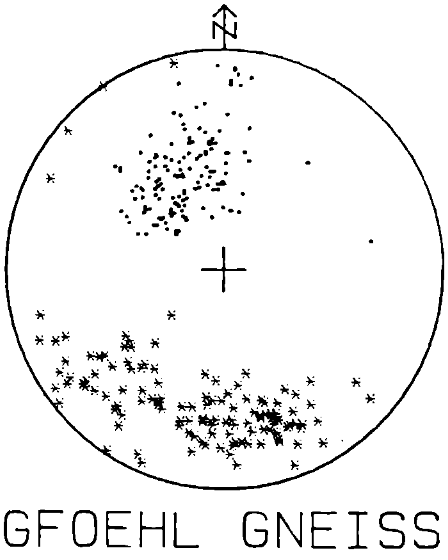


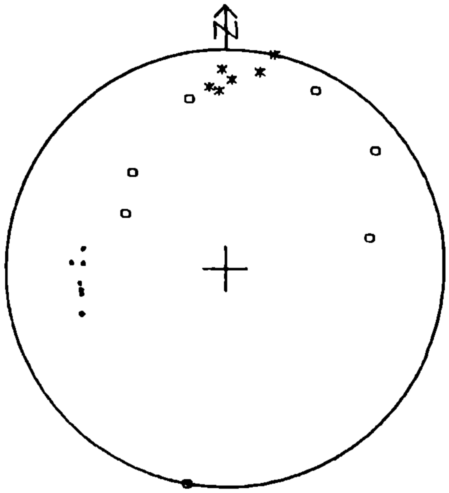
Fig. 9: Foliation poles (•) and lineations (·) of the Gföhl unit in the Lambert projection, lower hemisphere.

5. STRUCTURES OF THE GFÖHL UNIT

The foliation of the Gföhl gneisses plunges to the SSE (Fig. 9). Two clusters of lineations are recognizable. One cluster plunges to the S to SSE, another cluster to the SW. Like within deeper units, the SW plunging lineation seems to be the older one because the lineation is formed by rows of medium-sized feldspars which are overprinted by a foliation with fine-grained minerals. Numerous shear criteria like shear bands, and antithetic rotated boudins indicate mostly top-to-the-NE shear during earlier deformation.

6. STRUCTURES OF THE DUNKELSTEIN AND MARBACH GRANULITES

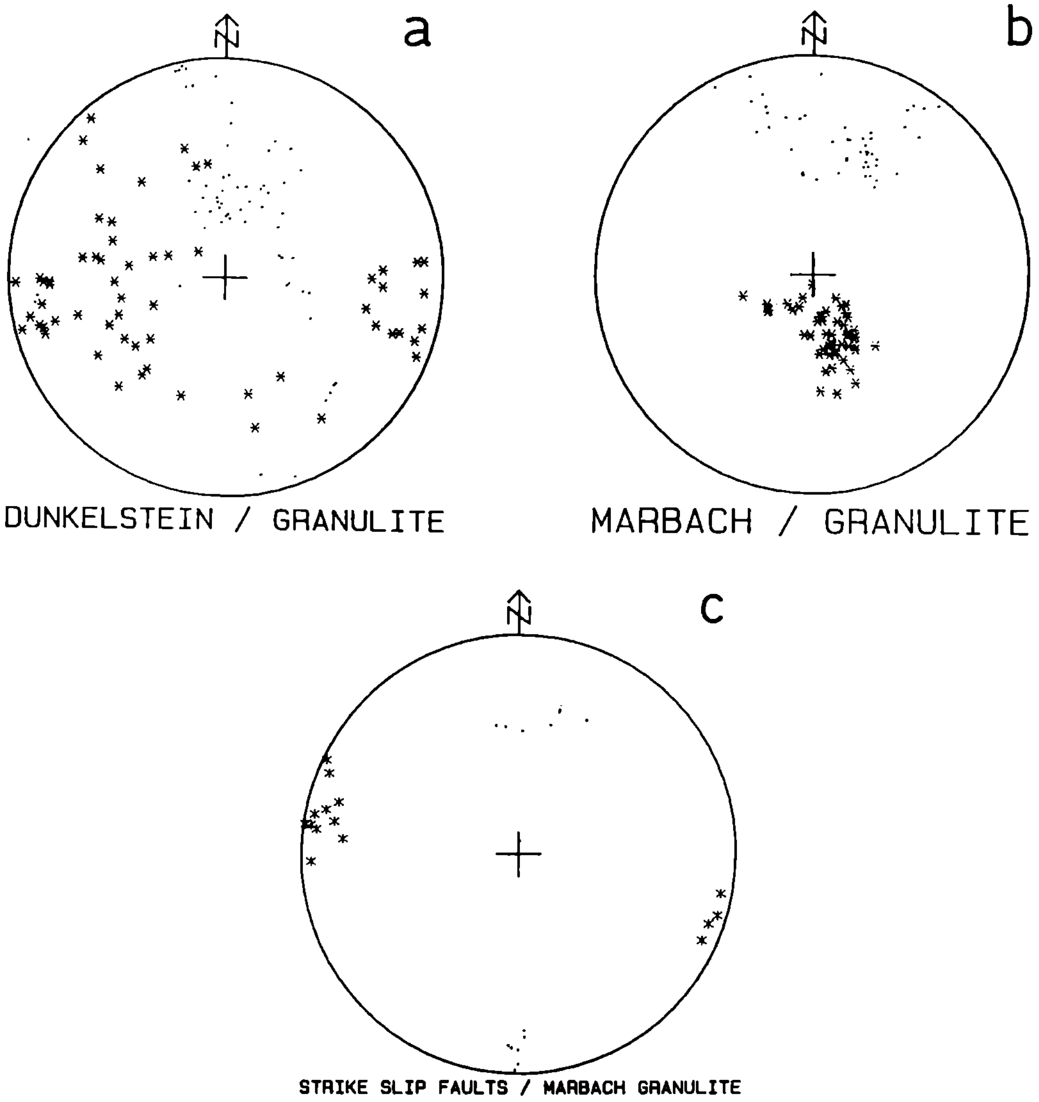
Granulites surround the southern dome of Moldanubian lithotectonic units (Fig. 1). The Dunkelstein granulite forms a tectonic klippe on the top of the Gföhl unit respectively of the Rehberg amphibolite. The Dunkelstein granulite contains lense-shaped bodies of ultramafic rocks, from which the largest one is exposed in the Meidling quarry. Most ultramafic rocks are strongly serpentinized, but some lenses often contain cores of unaltered garnet peridotites and pyroxenites. Ultramafic rocks are massive in the core of lenses, and strongly foliated along margins (e.g., Kappel 1967; Scharbert 1963). The foliation surface contains garnet porphyroclasts, pressure shadows around garnets forming a clearly visible lineation, and sometimes preferred orientated clinopyroxenes. According to the proof of a few



GARNET PERIDOTITE / LAUTERBACH

Fig. 10: Orientation data (• - pole of foliation; • - lineation) of a garnet-bearing ultramafic rock (Lauterbach, Dunkelstein granulite). Poles of conjugate serpentine veins (o) which intersect lineation and foliation indicate a second E-W stretching comparable to stretching in surrounding granulites.

outcrops, the lineation of ultramafic rocks is orientated in N - S direction. In Figure 10, the example of a single outcrop is given. Therefore the lineation of garnet peridotites is nearly perpendicular to the lineation of the surrounding granulites (Fig. 11a).



DUNKELSTEIN / GRANULITE

MARBACH / GRANULITE

STRIKE SLIP FAULTS / MARBACH GRANULITE

Fig. 11: Poles of the penetrative foliation (•) and lineation (·) of the Dunkelstein (a) and Marbach granulites (b) in the Lambert projection, lower hemisphere. Second, muscovite-bearing foliation (•) and related lineation (·) of the Marbach granulite (c).

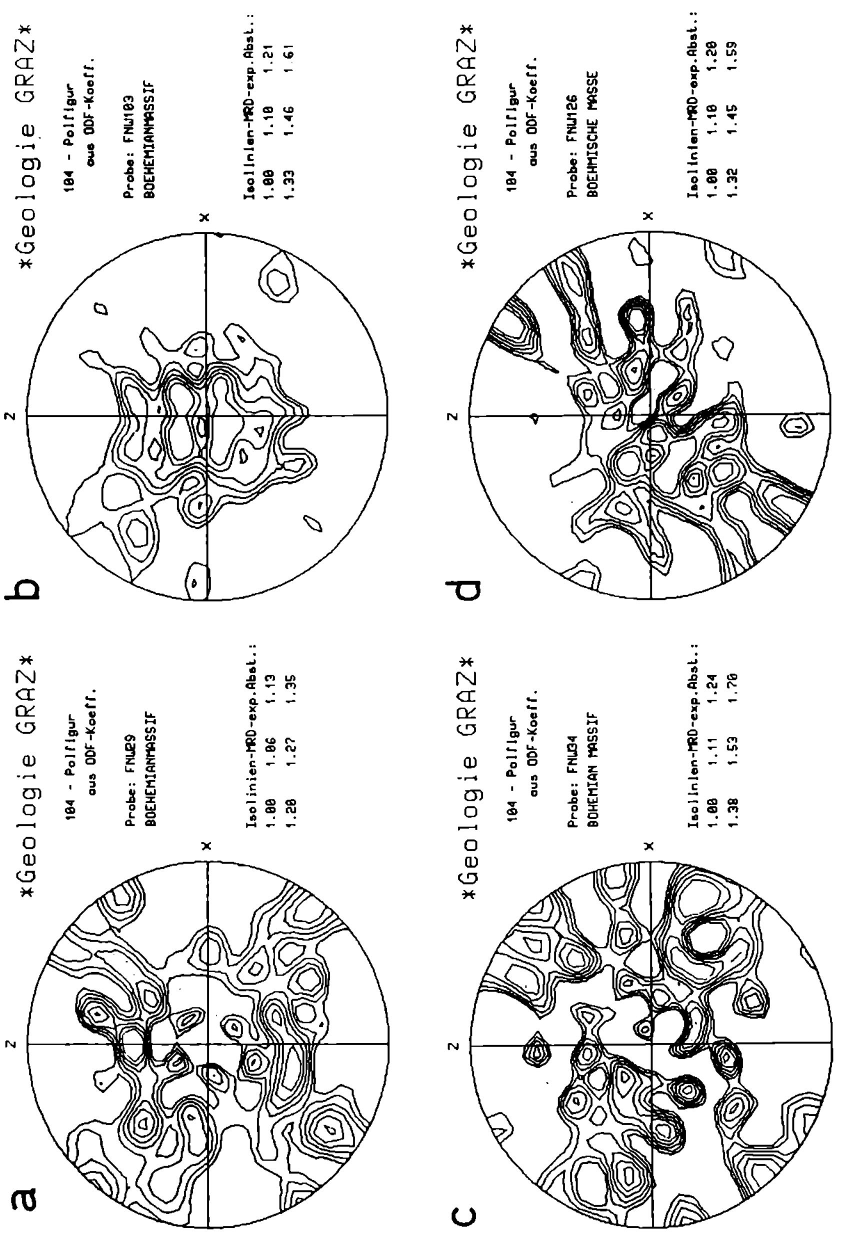


Fig. 12: Some representative X-ray textures of quartz in gneisses and granulites of the southern Moldanubian zone. The (104)-plane is used as representative for quartz c-axis (compare Schmid and Casey 1986). Horizontal line in each diagram indicate trace of foliation, X the lineation. a: Granulite from the interface between Monotonous and Variegated units; Mandlgupf SE Pöggstall, Weiten valley. b: Dobra gneiss at the base of the Variegated unit; junction of Mühlbach and Krottenbach W of the Weiten valley. c: Gföhl gneiss; roadcut north of Weitenegg, Weiten valley. d: Dunkelstein granulite from an abandoned quarry near Goldegg castle, Dunkelsteiner Wald.

Granulites at the base of the granulite nappe are strongly foliated although massive rocks are common within the Dunkelstein body. Within the Dunkelstein granulite, the lineation on flat S- surfaces is approximately E - W (Fig. 11a). The presence of biotite and rare chlorite in pressure shadows around garnet indicate stretching after peak metamorphic conditions during decompression. Quartz textures of approximately 40 samples which were measured by X-ray texture goniometer indicate strong flattening due to coaxial deformation and only a subordinate shear component (Fig. 12). Because of microfabrics which include HT-disk quartz fabrics as well as granulites with stretched pressure shadow fringes around garnet with LT-biotite/chlorite infillings, coaxial deformation occurred during different, decreasing temperature conditions.

The lineation in the Marbach granulite plunges steeply to the S respectively SE (Fig. 11b) due to the site on the southern closure of the dome. Near the basal contact, rather low-angle normal faults are more dominant than NNE-directed shear structures. However, a second, steep foliation is present near the footwall boundary of the Marbach granulite (Fig. 11c). The lineation on such surfaces is nearly horizontal and strikes WNW - ESE. Shear criteria favour a dextral strike-slip movement. This observation is supported by map-scale thinning of all units in the footwall of the Marbach granulite which may be the result of a shear zone which operated during uplift of Moldanubian rocks.

7. STRUCTURE OF THE SOUTH BOHEMIAN PLUTON

The South Bohemian pluton forms a large, elongated body in the west of the units described above. The exposed surface comprises approximately 4,200 km^2. The main rock type is the Weinsberg granite, a coarse-grained biotite granite with large K-feldspar megacrysts. The elongation of the body is approximately NNE - SSW. The internal structure is dominated by a rough magmatic foliation which is visible by the Shape Preferred Orientation (SPO) of K-feldspar megacrysts (Blumenfeld and Bouchez 1988; Paterson et al. 1989). The long axis of K-feldspar forms a magmatic lineation which is orientated approximately N-S due to data from a restricted number of outcrops. This is in accordance with the preferred orientation of the long axis of elongated diorite schollen (Fig. 13). A few three-dimensional strain data of elongated diorite schollen indicate flattening strain (Fig. 5). Plane strain data are derived from the line intercept method after Panozzo (1984) which is applied to the distribution of K- feldspar megacrysts (Fig. 5).

In general, the magmatic foliation is flat-lying, but a steep magmatic foliation also occurs locally, e.g., in the area east of Grein. The steep magmatic foliation is rather due to local convective flow cells in the crystallizing magma than the expression of later large-scale updoming with a steep foliation at the flanks of the pluton.

Local regularly orientated quartz veins near the eastern margin indicate post-emplacement WNW-ESE extension (Fig. 14a). This is in accordance with a local secondary solid-state foliation near the southern margin of the pluton, e.g. along the Danube east of Grein. Here, secondary muscovite is associated with a flat-lying foliation and a NW-SE orientated stretching lineation (Fig. 13).

The basic problem of the Weinsberg granite is how to emplace a melt with such a high amount of K-feldspar megacrysts. The Rheological Critical Melt Percentage (RCMP) of solid bodies within a melt is approximately 45 % (Arzi 1978) but it also depends strongly on the shape of the solid bodies. In the Weinsberg granite, the amount of K-feldspar megacrysts is within a wide range between 0 % and 50 %. Sometimes grain-supported K- feldspar megacryst fabrics indicate clearly that magmatic flow was not possible.

The tiling of megacrysts in X-Z sections (Den Tex 1969), it means their imbrication, may be used as a shear criterion (Blumenfeld and Bouchez 1988). The preliminary data suggest that imbrication of megacrysts is related mainly to steep magmatic foliation indicating up- or down-flow in local convective cells.

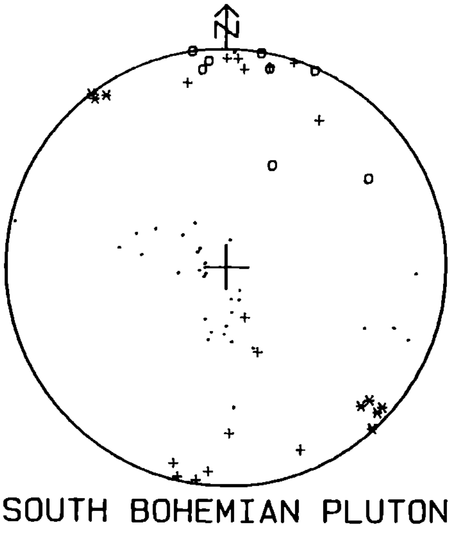


Fig. 13: Poles of the magmatic foliation (•) and magmatic lineation (+ - long axis of K-feldspar; o - long axis of diorite inclusion) and solid-state (·) lineations of the South Bohemian pluton in the Lambert projection, lower hemisphere.

Granite veins are widely distributed within the southernmost South Bohemian pluton and within country rocks east of the pluton. The distribution of veins is very regular. The veins are very steep within the granite and more flat in the area east of the pluton. As a rule, the veins are the more flat-lying the wider the distance from the pluton. The exception are numerous steep granitic veins in the north-eastern Gföhl unit and some in the Variegated unit.

All veins together show a very broad N-S girdle distribution in the Lambert projection (Fig. 14b). Granitic veins reflect the extension plane during the time of magma emplacement. The plane is perpendicular to the minimum normal stress axis, and includes the intermediate and maximum normal axes. The distribution is compatible with horizontal intermediate normal stress axis in E-W direction. The N-S girdle distribution suggests a regular change of the minimum stress axis perpendicular to the E-W intermediate axis.

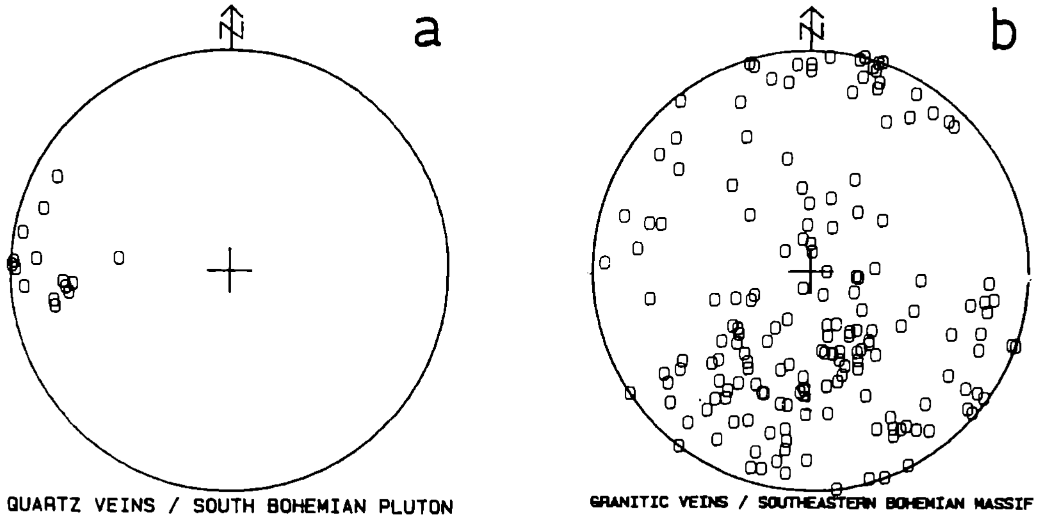


Fig. 14: Poles of quartz veins (a) of the eastern margin of the South Bohemian pluton, and poles of granitic veins (b) of the southern Moldanubian zone in the Lambert projection, lower hemisphere.

8. DISCUSSION

The preliminary structural data suggest some basic features of kinematics in the interior of the Moldanubian zone. The deformation path is much more complicated than suggested by previous work. However, some essential observations, e.g., the deformation regime and direction of motion of ultramafic rocks need further proof.

Stacking of lithotectonic units mentioned above is supposed to be of Variscan age. Basic arguments come from increasing geochronological evidence for metamorphic equilibration at maximum P-T conditions and penetrative deformation during Variscan times (Tab. 1, and additional data from Czechoslovakia: Breemen et al. 1982, and Kröner et al. 1988), particularly of garnet peridotite lenses within granulites (see Carlswell 1989). On the other hand, the presence of such garnet-bearing ultramafic rocks along interfaces of tectonic units suggests strongly the presence of a suture zone which separates different units.

No record of burial of tectonic units is found up to now. Early stacking occurred transpressionally to the boundary of the Moravian plate by top-to-the-NNE directed shear along boundaries of lithotectonic units (see also Fritz, this volume). Deformation of garnet peridotites occurred after static equilibration at c. 370 - 320 Ma (Sm-Nd mineral-whole rock data: Carlswell 1989, and pers. comm.). Deformation of probable synkinematic (?) granitoids, e.g., of the Spitz granodiorite, may play an important role to lower the overall shear resistance because magmatic liquids cannot support shear forces. Although it has to be noted that the age of magma formation and crystallization of the Spitz granodiorite gneiss is unknown up to now. It could be markedly older than subsequent deformation !

A second phase of deformation started during partial melting of metapelites and continued under decreasing P-T conditions, is directed to the E - ESE. The second phase is more penetrative in the high levels of the Variegated unit, the Gföhl unit, and in granulite klippens. Strain analysis and preferred crystallographic orientation of quartz indicate high flattening strain in the interior of all units. This is possibly combined with passive fold amplification in the interior of the Variegated unit. Both features may be related to vertical crustal thinning during uplift and exhumation of the Moldanubian zone. However, the ductile normal faults along boundaries of major lithotectonic units overprinted earlier ductile thrust surfaces.

The intrusion of the South Bohemian pluton sealed earlier ductile shear zones. However, a continuing top-to-the-E shearing in the more eastern area seems reasonable because the uprising pluton probable caused gravitational transport of hangingwall units from the top and flanks of the pluton.

The Rb/Sr age of the Weinsberg granite (349 ±4 Ma: S. Scharbert 1987) may be used as the lower bracket for time of thrusting. In contrast to the relative sequence of deformation events proposed above, there are some discrepancies between the more younger ages of granulite metamorphism and the more older ages of the

Tab. 1: Incomplete sequence of deformation events and supposed correlation to pressure, temperature, and time in the southeastern Moldanubian zone, southern Bohemian massif.

	P - T	Evidence of timing
(1) Shearing of garnet peridotites:	850 - 900°C, 20 kbar (Carlswell 1989)	370 - 340 Ma Sm-Nd garnet-WR (Carlswell 1989)
(2) Top NNE shearing and stacking of all units:	720 - 770°C, 7 - 9 kbar (Högelsberger 1989) (Petrakakis 1986 a, b)	341 ± 4 Ma U-Pb zircon (Breemen et al. 1982) 340 ± 1 Ma U-Pb monazite (Schenk und Todt 1983)
(3) Top E to ESE shearing:	Start at comparable conditions to (2), later decreasing P-T	Time: Before and during regional cooling
(4) Intrusion of the South Bohemian pluton (Weinsberg granite) and doming of the eastern Moldanubian zone:	??	Time: 349 ± 4 (Scharbert, 1987)
(5) Exhumation by SE-directed low angle faults:	Amphibolite (early) to greenschist facies (late) 630 - 530°C, 2 - 4 kbar (Petrakakis, 1986 b) (Högelsberger 1989)	323 ± 7 Ma $^{40}Ar/^{39}Ar$, biotite (Matte et al., 1985)
(6) Conjugate strike slip fault activity:	Greenschist facies conditions	Late Carboniferous(?) to early Permian basin Zöbing (Fuchs und Matura, 1976)

granite (see, Tab. 1). However, all data together indicate that stacking of continental slices, the subsequent uplift of the whole pile to shallow crustal levels as well as the intrusion of the South Bohemian pluton happened within a short timespan between 370 and 340 Ma. Especially, the Sm-Nd data of garnet peridotites, the protolith ages as well as of the metamorphic HP-HT history (370 - 340 Ma, cf. Carlswell 1989), suggest that the present metamorphic state of the Moldanubian zone is of Variscan age.

The large South Bohemian pluton forms a NNE trending, elongated body. The orientation of endogenic diorite xenoliths, and the orientation of granitic veins indicate a N-S stretching during intrusion. Grain-supported K-feldspar megacryst fabrics indicate high flattening strain due to ballooning and filter pressing. The updoming of the Moldanubian zone east of the pluton, the so-called "Ostrong structure" (North of Grein in Figure 1), may be caused by push of the intruding and ballooning pluton.

Predominantly the low Moldanubian units show evidence of retrogressive metamorphism during extensional deformation due to gravitational collapse of thickened crust. Typical features of the extensional deformation are conjugate, predominant ESE- and subordinate WNW-directed muscovite-bearing, low angle normal faults which are observable in all units and on all scales. Extensional faulting is related to regional cooling, exhumation and uplift. A singular $^{40}Ar/^{39}Ar$ biotite datum (323 ±7 Ma: Matte et al. 1985) suggests cooling below 300 °C and the end of early Carboniferous.

On the other hand, geometry of extensional faults may fit the kinematics of steep conjugate ductile shear zones which are widespread in the Bohemian massif (Fig. 1; see also Wallbrecher et al. this volume). Locally deviating orientations of extension direction may be explained by local accomodation and rotation of crustal blocks between major faults. Permian sediments and $^{40}Ar/^{39}Ar$ muscovite data of mylonites (Dallmeyer pers. comm.) favour a late Carboniferous to early Permian age of strike-slip activity.

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