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OBSERVATIONS ON THE DUCTILE DEFORMATION PATH OF THE PARAGNEISSES OF THE KTB PILOT HOLE

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OBSERVATIONS ON THE DUCTILE DEFORMATION PATH OF THE PARAGNEISSES OF THE KTB PILOT HOLE

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Zusammenfassung: Korn- und Reaktionsgefüge der Paragneise der KTB-Vorbohrung lassen auf einen retrograden Deformationspfad im Deckenkomplex der Zone von Erbendorf-Vohenstrauß (ZEV) schließen, der sich in 3 ductile Deformationsstadien gliedern läßt. Die ältesten Gefüge (Stage 1) sind HT-Mylonite, die durch sekundäre Quarzrekristallisation und feinkörnige (primäre) Feldspatrekristallisation unter trockenen, amphibolitfaziellen Metamorphosebedingungen entstanden. Es folgt ein metablastisches Deformationsstadium (Stage 2), das durch Kornvergröberung im Quarz-Feldspatgefüge und durch syntektonische Neubildung von Muscovit I und Biotit II sowie lokale Migmatisierung gekennzeichnet ist. Im anschließenden diaphthoritischen Stadium (Stage 3) zeigt Quarz primäre Rekristallisation, während Feldspat kataklastische verformt wird. Diaphthoritische Mineralneubildungen sind Muscovit II, der schwach bis ungeregelt ist und häufig Fibrolith einschließt, sowie Serizit, Chlorit, Ilmenit und Quarz.
Die Interpretation dieses Pfades erfolgt auf der Basis eines Deckenkonzepts. Danach können die Edukte der Paragneise als unterdevonische Flyschsedimente einem variszischen aktiven Kontinentalrand des Bohemikums zugeordnet werden. Im Verlauf der Subduktion und der mit ihr verbundenen druckbetonten Metamorphose wurden sie mit mafischen Gesteinen verschuppt. Als intrakrustaler Deckenkomplex wurde dieser Gesteinsverband weitgehend isothermal unter HT-mylonitischer Verformung in höhere Krustenstockwerke transportiert. Zunehmende Infiltration wässeriger Fluide führte zu metablastischer bis migmatischer Überprägung. Die Inkorperation und Obduktion von Inselbogengesteinen (Erbendorfer Grünschiefer) und von Sedimenten eines passiven Kontinentalrandes (Wetzldorf-Folge) führte im Verlaufe des Kollisionstadiums und des suprakrustalen Deckentransportes zur Infiltration großer Mengen hoch gespannter Fliude und zu kräftiger Diaphthorese, verbunden mit hydraulischer Bruchbildung. Alle duktilen Gefüge entstanden vor und während dieses SW-polaren Deckentransportes.

Abstract: Grain and reaction fabrics in the paragneisses of the nappe complex of the Zone of Erbendorf-Vohenstrauß (ZEV), exposed in the KTB pilot hole, document a ductile, retrograde metamorphic deformation path, which can be subdivided into three stages. Fabrics representing the early stage are HT-mylonitic (stage 1), and are characterized by primary recrystallization of feldspar and secondary recrystallization of quartz. The fabrics formed in dry amphibolite facies metamorphic conditions. Stage 1 is followed by the metablastic deformation stage (stage 2) which is characterized by grain growth of quartz and feldspar and the syntectonic formation of muscovite I und biotite II. During the diaphthoritic stage (stage 3) quartz shows primary recrystallization whereas feldspar is cataclastically deformed. Common diaphthoritic minerals are muscovite II, sericite, chlorite, ilmenite and quartz. Muscovite II has a weak preferred or random orientation and frequently contains inclusions of fibrolite.
These deformation stages are interpreted on the basis of the nappe concept of the ZEV. The protoliths of the paragneisses can be interpreted as Lower Devonian flysch sediments, deposited at an early Variscan active continental margin of the Bohemian terrane. In the course of subduction and HP-metamorphism they were tectonically intercalated with mafic rocks. Subsequently, they were displaced more or less isothermally as an intracrustal nappe complex into higher crustal levels. In the course of this deformation HT-mylonitization took place under dry amphibolite facies conditions, followed by metablastic grain growth and local migmatization due to infiltration of hydrous fluids. The incorporation and obduction of island arc rocks (Erbendorf greenschists) and sediments of a passive continental margin (Wetzldorf Formation) indicate the collisional stage and supracrustal nappe displacement. The emplacement of the crystalline rocks onto oceanic sediments abounding in water led to immigration of large amounts of overpressured hydrous fluids and to strong diaphthoritic mineral reactions, accompanied by hydraulic fracturing. All ductile fabrics were formed before and during the SW-directed nappe transport.

1. Introduction

The Variscan basement around the Continental Deep Drilling Site (KTB) Oberpfalz on the western margin of the Bohemian Massif is composed of three polyphasely deformed tectonometamorphic units (Fig. 17): the Saxothuringian, the Moldanubian and the Bohemian unit. The Saxothuringian of the Fichtelgebirge represents a former passive continental margin. The boundary of the Saxothuringian and Moldanubian is interpreted as a cryptic suture and is represented by the northwestern rim of the HT-mylonitic belt of the Zone of Tirschenreuth-Mähring (ZTM). This zone forms part of a formerly active continental margin. Dextral shearing played an important role in the ZTM during the advanced stage of collision, i.e. during the indentation stage (Weber & Vollbrecht, 1989). The klippen of the ZEV and the Münchberg Massif (MM) form part of a previously coherent nappe complex which was connected with the Zone of Tepla-Taus (ZTT) at the western margin of the Bohemian terrane.
The following investigations of rocks from the KTB pilot hole aims at a preliminarycharacterization of the microscopic deformation and reaction fabric of the paragneisses of the ZEV. The investigations deal with rocks from as deep as 4000 m. The data are interpreted on the basis of the nappe concept, developed for the Zone of Erbendorf-Vohenstrauß (ZEV) in the course of the pre-site studies (KTB, 1986) and succeeding investigations (Weber and Vollbrecht, 1989). Several stages of the deformation path can be distinguished in the paragneisses. The younger stages, which represent retrograde metamorphic stages of the strain path, are much better preserved than older prograde metamorphic stages. Their reconstruction will be subjected to further investigation, particularly of mafic rock, where the early stages in the deformation path seem to be better preserved.

2. Stages of the deformation path

2.1 Stage 0: Prograde metamorphic deformation

This stage refers to all possible earlier deformation stages which preceded the HT-mylonitic stage and which possibly form part of the prograde metamorphic deformation path.

2.2 Stage 1: HT-mylonitic deformation

The HT-mylonitization stage is characterized by dynamic primary recrystallization of Fsp. The minimum temperature of Fsp recrystallization is 500°C (White, 1978; Voll, 1980). The acid Plg of the paragneisses form a fine-grained, equigranular fabric with well equilibrated grain boundaries (Fig.1). Partly recrystallized Plg-clasts can be preserved (Fig.2). Together with coarsely grained ribbon quartz (see below) they evidence a coarsely grained metamorphic protolith of the HT-mylonites. No Kfsp-clasts have been observed. Plg-Qz symplectites (myrmekite) are found around clasts of chessboard albite that could have developed from Kfsp.

Bio I is fine-grained, homogeneous in grain size, and shows a strong preferred orientation which tends to be oblique to the metamorphic foliation or compositional layering, as observed in sections parallel to the mineral lineation. Bio I has grown syntectonically only outside Qz grains and recrystallized Fsp grains, preferably in stretching shadows (Fig.3). The sense of shear derived from this oblique orientation fabric is identical with that of delta- and sigma-clasts. The syncrystalline strain seems to be high, but cannot be determined quantitatively. However, pervasive microboudinage in the recrystallized Fsp-Bio I matrix indicates high strain in sections parallel to the mineral lineation (Fig.4). Indications of high strain are also given by strongly stretched corona structures of Ga+Qz surrounding Hbl-Qz symplectites after Cpx in a completely recrystallized anorthositic gneiss. The corona structures reveal a pronounced prolate strain with X:Y:Z approx. 50:3:1.
Qz grains are mostly larger than Fsp. Unlike Fsp, Qz shows highly unequilibrated grain boundaries and no primary recrystallization (Fig.5). The coarse grain size and the highly lobate grain boundaries of Qz can be interpreted as resulting from secondary dynamic recrystallization. Due to high dislocation mobility at temperatures above 500°C (the minimum temperature of Fsp recrystalliza-

tion), migration recrystallization dominates recrystallization by subgrain rotation. Mortar textures due to primary recrystallization develop at lower temperatures in the course of the diaphthoritic strain path (see below).

The HT-mylonitic part of the deformation path is characterized by the formation of ribbon quartz (Fig.6). These document high strain and show the abovementioned characteristics of secondary dynamic recrystallization and indications of low viscosity, enabling them to protrude (intrusion in the solid state) along grain boundaries of the recrystallized Fsp fabric (Fig.2 and 7). In several cases single quartz grains may coalesce into larger grains of ribbon quartz in the course of the strain-induced protrusion process.

During the HT-mylonitic stage small-scale internal folds developed contemporaneously with the s_1-foliation. These F_1-folds can occur as sheath folds (Weber, 1988). Their pronounced asymmetry refers to a SW-directed sense of shear in accordance with the abovementioned rotational and oblique orientation fabrics. In sections perpendicular to the stretching lineation rotational fabrics have formed with changing vorticity around the stretching lineation.

HT-mylonitic fabrics of the paragneisses are preserved predominantly in those high-grade gneisses that were primarily free of Ksp. Gneisses bearing Ksp possibly were transformed into Ms bearing gneisses and micaschists during the metablastic deformation stage.

2.3 Stage 2: Metablastic deformation

Metablastic grain coarsening, particularly in the Fsp fabric (Fig.8), took place with the occurrence of Ms I and Bio II under amphibolite facies metamorphic conditions (675°±50°C, 7±1 kbar, Reinhardt and Kleemann, 1989). Locally, concordant and discordant migmatic mobilisates are present. Ms I has grown syntectonically parallel to the s_1-foliation (Fig.9). It is (unlike Ms II) free of Sil (Fibrolite)-inclusions. The amount of Ms I varies. Bio II is intergrown with Sill (Fibrolite). It formed during the metablastic deformation stage from:

$$\text{Ga + Kfsp (or } K^+\text{-bearing hydrous fluids)} \;\text{-->}\; \text{Bio II + Sill + Qz}$$

In contrast to Bio I, the Bio II-fibrolite-aggregates are more coarsely grained (Fig. 10) and do not occur in pressure shadows around recrystallized Fsp grains. In addition, fibrolith has been formed from prismatic Sil.

Metablastic Plg (Oligoclase) does not show recrystallization. Quartz and ribbon quartz have instable (lobate) grain and phase boundaries and show, like the entire Qz-Fsp fabric, increasing grain size. Inside larger Qz grains there is an internal development of lobate grain boundaries and lobate to plane subgrain boundaries (Fig.8) There is still no primary recrystallization. The degree of oblique preferred orientation of Bio I decreases with increasing metablastic grain growth. At the same time metamorphic differentiation continues, in the course of which the s_1-foliation is intensified by enrichment of Ms I and Bio II.

During the metablastic deformation stage no new penetrative foliation developed in those F_2-folds that refold the metablastic and migmatic fabrics. Together with the lack of Fsp-recrystallization, this can be regarded as an indication of low effective stress due to high P_{H2O} during F_2-folding (see chapter "Interpretation"). In the observed cases the F_2-fold axes are parallel to the F_1-axes, evidencing largely homoaxial folding. Surface exposures in the ZEV support this assumption.

2.4 Stage 3: Diaphthoritic deformation

With decreasing temperature more and more mineral phases sink below their metamorphic conditions of stability. Retrograde retrograd metamorphic mineral reactions therefore becoming increasingly dominant and affecting the rock fabric.

In the Qz-Fsp fabric the beginning of stage 3 is indicated by primary recrystallization of Qz (Fig. 11 and 12) and cataclastic deformation of Fsp (Fig.13). The recrystallized Qz grains are undulous (Fig.12) and there are all transitions to subgrain fabrics and continuous undulosity, particularly inside larger Qz grains. Strongly strained layers of diaphthoritic gneisses show some characteristics of LT-mylonites.

During stage 3 a new Qz generation appears, represented by millimeter to centimeter thick veins parallel to the s_1-foliation (Fig.14) that are polyphasely mineralized. Individual Qz-mineralizations within a vein are separated by thin, more or less continuous films of wall-rock minerals, which indicates incremental dilation and mineralization ("crack-seal"). These crack-seal veins are formed by syntectonic hydraulic fracturing and indicate an abnormally high fluid pressure during this diaphthoritic deformation stage. The volume of crack-seal quartz reaches 30% of the total rock volume in the 300 m deep borehole "Püllersreuth" (Heidelbach 1989) approx. 2 km SW of the KTB pilot hole. The source of these large volumes of hydrous fluids for solution and precipitation of Qz is unknown (see "Interpretation"). The Sr-isotopes of the Quartz veins, however, are significantly different from those in the country rocks (Albat et al.1989, Grauert, pers. comm.).

The crack-seal veins predate the cataclastic deformation. The intensity of ductile strain varies in different veins and is generally much higher in the KTB pilot hole than in the Püllersreuth drillhole, where most veins are weakly deformed (Fig.15). In such veins the Qz-crystals are oriented with their rhombohedral planes preferably parallel to the vein boundary (Heidelbach et al 1988). These growth fabrics are transformed by ductile deformation and recrystallization into cross-girdle and oblique-girdle fabrics (Heidelbach et al. 1988, Heidelbach, 1989).

Ms II occurs in different form during stage 3. It shows all transitions between a preferred orientation parallel to s_1 and a random orientation. The varyring degrees of preferred orientation of Ms II presumably do not reflect an age sequence, but represent a spatially and temporarily inhomogeneous strain.

Ms II frequently has inclusions of fibrolite and sometimes of prismatic Sil. Very often Ms II adopts the fibrous and curly texture of fibrolithic Sil and forms aggregates of flaky to fibrous sericite. Sericite is also formed in ductile shear zones by dynamic recrystallization of Ms I and Ms II. Coarsely grained random Ms II is locally developed as poikiloblasts, or as symplectites by intergrowth with Qz. It cannot be proven with certainty whether Ksp was involved in the formation of Ms II. Usually the following reaction is observed (Fig. 16):

$$\text{Bio} + \text{Sil} \longrightarrow \text{Ms II} + \text{Ilmenite} + \text{Qz}$$

Chloritization of Bio takes place contemporaneously with the formation of Ms II, but it continues into the cataclastic stage. At the end of stage 3 the ductile deformation path terminates and stage 4, the cataclastic deformation begins, which will not be described here.

Also in the course of stage 3 the s_1-foliation remains active and represents the dominant penetrative foliation. Extensional cleavage, SC-fabrics (Fig. 16) and delta- or sigma-clasts can occur between s_1- foliation planes, particularly during the diaphthoritic deformation stages. Some F_2-folds show a very weakly developed intersection cleavage.

3. Interpretation

The Ga, Ky-Sil, Bio paragneisses, interpreted as high-temperature mylonites, are characterized by ribbon quartz and Plg-recrystallization. Rare Plg-clasts show core and mantle structures and indicate a coarsely grained precursor. These rocks, free of Ms at the end of the prograde metamorphic strain path, developed their HT-mylonitic fabric at high deviatoric stress and low water activity, i. e. under dry amphibolite facies conditions. Therefore, almost no Ms has been formed during amphibolite facies HT-mylonitization.

Supply of hydrous fluids under amphibolite facies conditions induced metablastic processes and locally partial melting. Ms I appeared as a new mineral phase. HT-mylonites are relics in metablastic gneisses.

During the diaphthoritic stage substantial amounts of overpressured hydrous fluids invaded the rocks contemporaneously with uplift, cooling and reduction of effective stress. Strain, accordingly, became increasingly inhomogeneous.

The source of the fluids is not known. Since the crack-seal Qz-veins are isotopically different from their host rocks, the source of the fluids was possibly outside the gneisses of the ZEV nappe complex. The post-tectonic granites cannot be regarded as their source because the crack-seal veins of the pilot hole are strongly strained and therefore older than the granites. Nonmetamorphic or very low-grade metamorphic rocks are a possible source, provided they were tectonically drained under the load of the crystalline nappes, and have released water from prograde metamorphic mineral reactions. In fact, the Erbendorf greenschists and their associated greenschist-facies phyllonitic to quartz-phyllonitic Wetzldorf sequence constitute the basal units of the ZEV-nappe complex at the present outcrop level. They represent a possible source of fluids in the course of the nappe transport. Younger fluids entered the rocks after the emplacement of the nappe complex in the course of late diaphthoresis and brittle faulting. Outside the cataclastic faults proper the formation of retrograde metamorphic minerals (e.g. Biotite --> Chlorite) took place under static conditions in all three types of paragneisses described.

The maintenance of unstable grain boundaries and subgrain boundaries in Qz from HT-mylonitic, metablastic and diaphthoritic gneisses shows that no post-tectonic annealing took place. In this respect the Qz-grain and Qz-subgrain boundaries of the ZEV differ from those of the LP-HT metamorphic Moldanubian and Saxothuringian.

The post-tectonic granites did not influence the rock fabric of the drilling site. In spite of the short distance to the post-tectonic Falkenberg granite the KTB pilot hole is situated outside its thermal contact area. However, the ZEV at the Waldnaab fault zone has been downthrown about 3000 m (Stettner, pers. comm.), so at the time of granite intrusion the rocks of the drilling site could have been at another position relative to the granite body than they are now.

There are continuous transitions between the different deformation stages described. The older fabrics are relics inside rocks overprinted during younger deformation stages of variable intensity. HT-mylonites e.g., can be strongly overprinted diaphthoritically without substantial metablastic grain growth or can be altered during the brittle deformation stage.

The following tectonic interpretation can be derived from the described ductile deformation path: According to the character of metamorphism, the MP- to HP- metamorphism must be related to the subduction stage, whereas the LP-metamorphism took place in the course of the complex collision of the Bohemian, Moldanubian and Saxothuringian terranes (Weber & Vollbrecht, 1987). The nappe complexes of Münchberg and the ZEV escaped the younger LP-metamorphism by obduction and supracrustal displacement.

The chemical composition of the described paragneisses corresponds to greywackes, clayey greywackes and shales (Röhr et al., this vol.). Findings of acritarchs point to a Lower Devonian age of these sediments (Pflug & Prössl, 1989). Therefore, they can be interpreted as flysch deposits at a Hercynian active continental margin of the Bohemian terrane. During subduction they underwent progressive metamorphism at about 390 Ma. In the course of the HT-mylonitic part of the deformation path, the presumably MP-granulite facies rocks were transported together with slices of mafic and ultramafic HP-metamorphic rocks as an intracrustal nappe from deep into higher crustal levels. During the early stage of this transport the effective stress was high due to low water activity. In the course of advancing intracrustal transport, i.e. during the metablastic stage, a gradually inreasing infiltration of hydrous fluids took place possibly from underlying subducting and prograde metamorphosed rocks.

During the diaphthoritic stage the crystalline nappe has been emplaced as a supracrustal nappe onto oceanic sediments abounding in water. The island arc affinity of the Erbendorf greenschists

(Schüssler et al, 1989) as basal parts of the ZEV nappe complex indicates collision with a presumably late Proterozoic island arc. Silurian metacherts (Reitz et al. 1988, Pflug and Reitz 1987), associated with the Wetzldorf Formation along the eastern rim of the ZEV may idicate the incorporation of oceanic sediments in the nappe complex. The highly mature phyllitic-quartzitic sediments of the Wetzldorf Formation must have been deposited on a passive continental margin. They were incorporated into the nappe pile during the early collision stage. Equivalents of the Wetzldorf Formation are presumably preserved along the nordwestern margin of the Zone of Tepla-Taus (Stettner, pers. comm.) and in the Silurian rocks (Reitz & Pflug 1987) of the Kühnesche Gebirge.

Under the load of the crystalline rocks high pore fluid pressures were generated inside the basal nappe units abounding in water (Erbendorf greenschists and Wetzldorf beds), thus reducing effective stress and internal friction. The overpressured sediments acted as glide horizon during the diaphthoritic stage of nappe transport. Correspondingly, the deformation concentrated inside the basal nappe unit producing their mylonitic to phyllonitic fabric. Overpressured fluids migrated into the overlying crystalline rocks leading to diaphthoritic mineral reactions and producing hydraulic fractures and corresponding crack-seal Qz mineralizations, preferably along the foliation as planes of lower cohesion.

The temporal and spatial relationship between the Moldanubian LP-metamorphism at about 320 Ma (Teufel, 1987) and the obduction of the ZEV nappe, which were subjected to prograde metamorphism during Devonian subduction prior to 380 Ma, is still open to question. If the crack-seal Qz-veins were formed at about 360 Ma (Albat et al.,1989), the diaphthoritic stage of the nappe transport and the incorporation of the basal nappe unit must have taken place prior to the 320 Ma old LP-metamorphism of the Moldanubian. The Rb/Sr-mineral ages of 365 to 370 Ma of Bio and Ms from gneisses of the ZEV (Teufel, 1987) support this assumption. A correlation of the ZEV with the Münchberg nappe complex, the basal unit of which contains Lower Carboniferous wildflysch (Franke, 1984), shows that the nappe transport continued into late to post-Lower Carboniferous time. Overthrusting of the ZEV over the Moldanubian could then have taken place during the time of its LP-metamorphism as a supracrustal nappe, i.e. in a high structural level outside the area of the Moldanubian metamorphism, similarly to the Münchberg nappe complex. Stretching lineations and associated shear sence indicators evidence, that the polarity of the tectonic transport was in SW direction through all stages of the ductile deformation path.

LP-metamorphic overprint increases from the NW to the SE. There is no LP-metamorphic overprint in the MM and it has not yet been proven in the northern ZEV. It seems, that the Wetzldorf Formation suffered lower grade metamorphism in the NW than in the SE. Further to the SE, the LP-metamorphic overprinted eclogites of Winklarn (Blümel, 1986; O'Brien, 1989) could be interpreted as basal relics of the ZEV nappe complex on top of the Moldanubian, affected by the Moldanubian metamorphism (Fig. 17). The western rim of the ZTT has been overprinted by the Moldanubian metamorphism. Still open to question are the younger Hbl cooling ages east of, and in the roof of, the post-tectonic granites forming the eastern rim of the ZEV (Kreuzer at al.,1989). It can be assumed that these granites reset the Hbl cooling ages of the ZEV.

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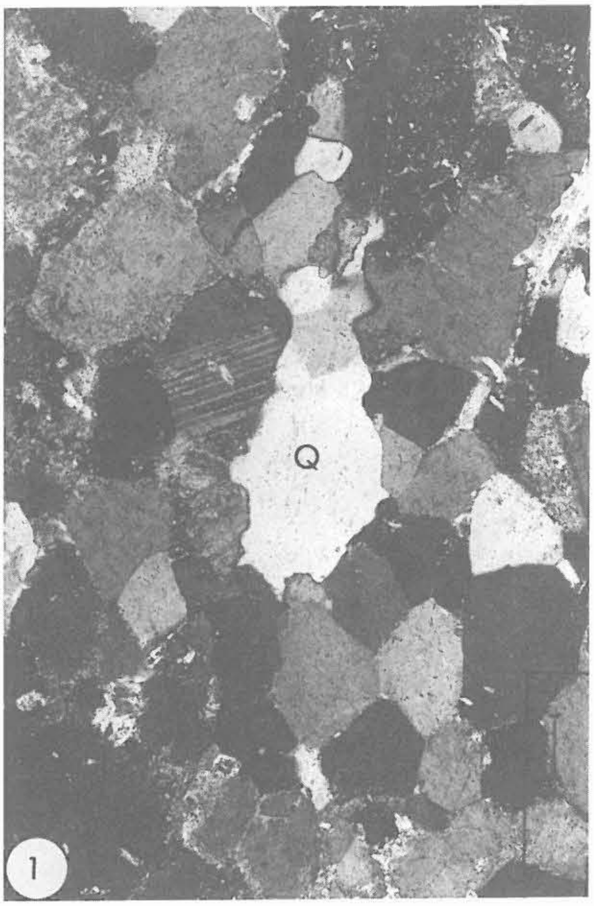
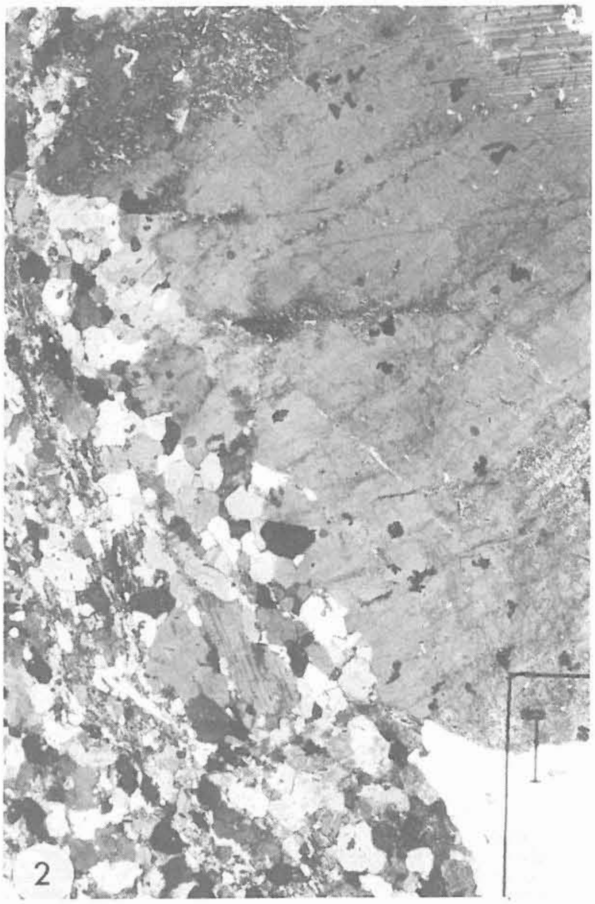
Fig. 1: Quartz (Q) grain surrounded by recrystallized plagioclas. Most of the Plg grains are untwinned. The Qz grain shows no primary recrystallization. Its acute offshoots are interpreted as resulting from ductile protrusion along grain boundaries of the recrystallized feldspar fabric. HT-mylonitic deformation stage. Sample VB 447 C2h, 1977,69 m, x pol., short picture length: 0,45 mm.

Fig. 2: Coarsely grained plagioclas relic showing subgrains and recrystallized grains along its rim. HT-mylonitic deformation stage. Sample VB 447 C2h, 1977,69 m, x pol., short picture length: 3,4 mm

Fig. 3: Biotite-rich HT-mylonite showing untwinned recrystallized Plg. Bio is oriented parallel to the finite stretching direction. Sample VB 449 B2e, 1983,39 m, oblique pol., short picture length: 1,2 mm.

Fig. 4: Microboudinage fabric inside a Bio-rich HT-mylonite. The orientation of Bio indicates the direction of finite elongation. Sample VB1a 500 B2h, 2170,81 m, one pol., short picture length 1,5 mm.


Q
1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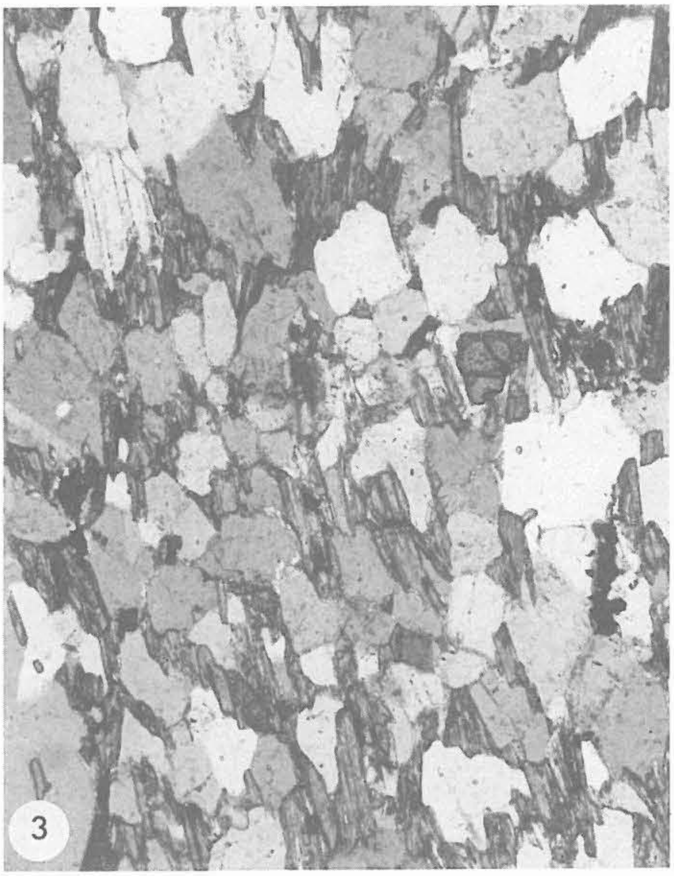
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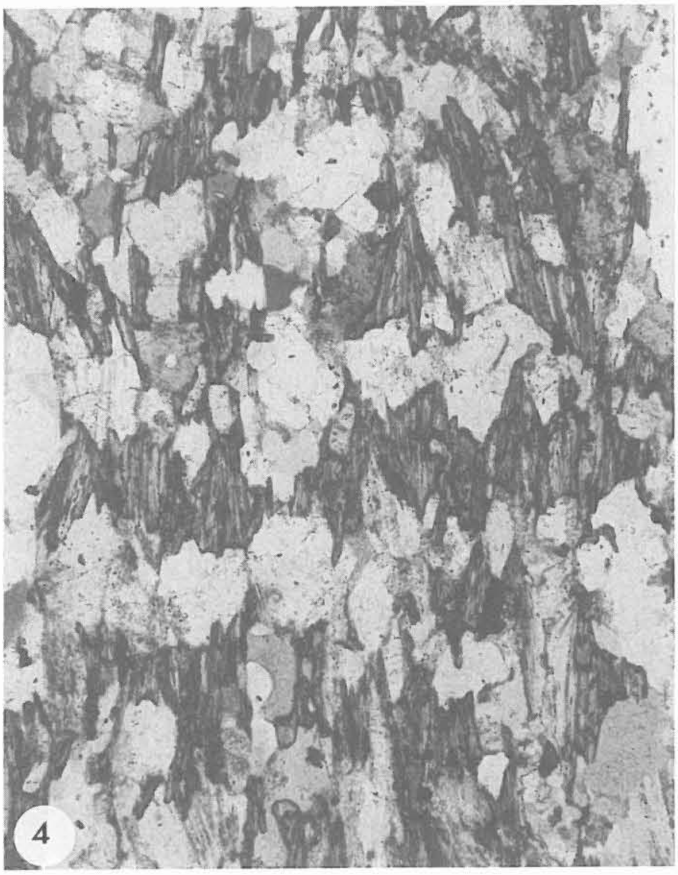

4

Fig. 5: Quartz grain (Q) showing strongly unequilibrated internal grain boundaries resulting from secondary recrystallization. Sample VB 1a 480 E1o, 2099,52 m, x pol., short picture length: 1,8 mm.

Fig. 6: Ribbon quartz inside a matrix of recrystallized plagioclase. The quartz grain shows no primary recrystallization, but small acute offshoots along grain boundaries of the recrystallized plagioclase, interpreted as in Fig. 1. HT-mylonitic deformation stage. Sample VB 447 C2h, 1977,69 m, x pol., short picture length: 1,8 mm.

Fig. 7: Detail from Fig. 6, short picture length: 0,45 mm

Fig. 8: Metablastic grain coarsening of the quartz (Q) - plagioclase (P) fabric together with newly formed muscovite I (MI) and biotite II (BII). biotite II is intergrown with fibrolite. Metablastic deformation stage. Sample VB 401, x pol., short picture length: 4,5 mm.


Q
5


6


7

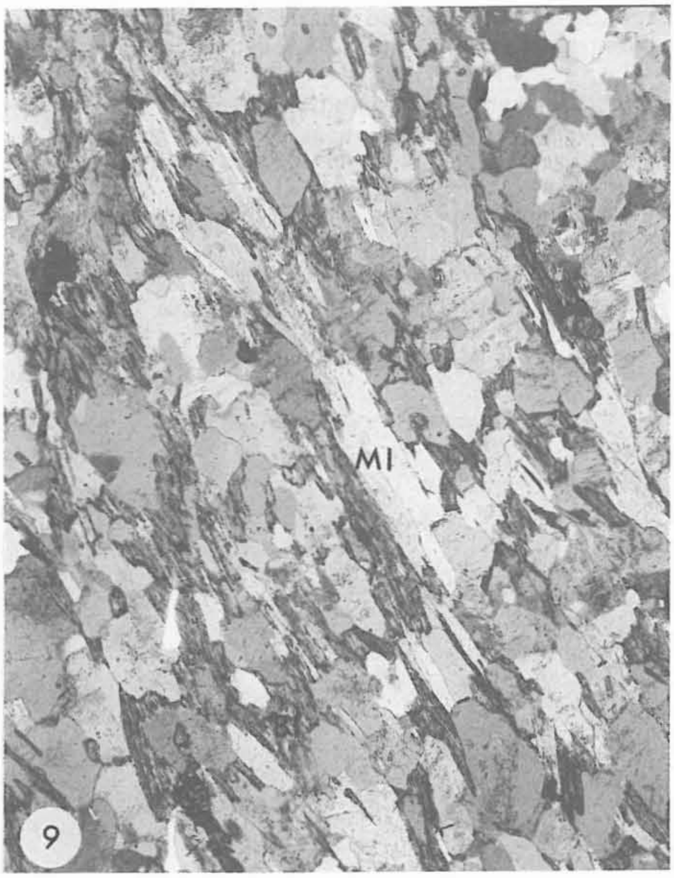

MI
Q
BII
P
8

Fig. 9: Muscovite I (MI), syntectonically grown parallel to the s1-foliation. Biotite I (BI) forms a relic of the HT-mylonitic defornmation stage and is, in contrast to the younger Ms I, located dominantly in pressure shadows of feldspar grains. Sample VB 465 E4b, 2040,32m, oblique pol., short picture length: 1,7 mm.

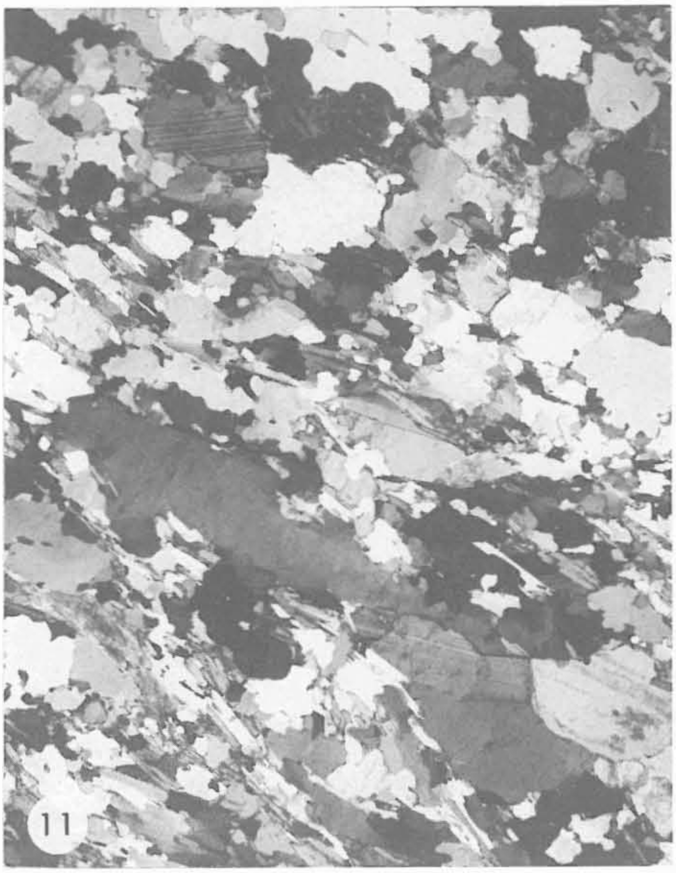
Fig. 10: Biotite II - fibrolite aggregates. They formed during the metablastic deformation stage. In contrast to biotite I, biotite II has not grown in pressure shadows, but only on the s1 foliation planes. Sample VB 422 D1l, 1869,60 m, one pol., short picture length: 1,7 mm.

Fig. 11: Incipient primary recrystallization of quartz, overprinting the metablastic fabric; beginning of the diaphthoritic deformation stage. Micas are biotite I and muscovite I. Sample VB 426 A1ekI, 1889,78 m, x pol., short picture length 4,5 mm.

Fig. 12: Primary recrystallized ribbon quartz, surrounded by a diaphthoritic host rocks. Oblique orientation of elongated recrystallized grains indicate sinistral sense of shear. Sample 206 B1B, layer A, x pol., short picture length: 3,2 mm.


MI
9


10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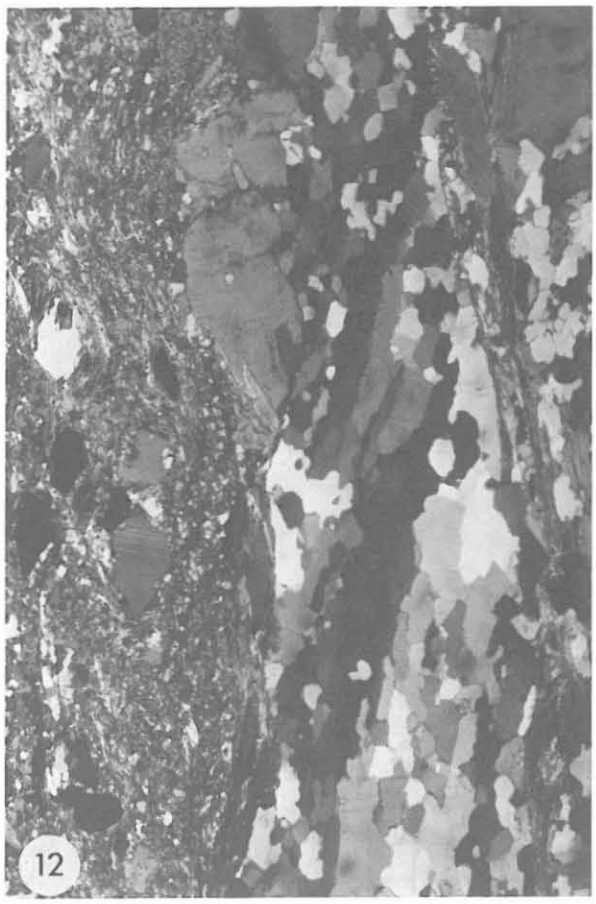

12

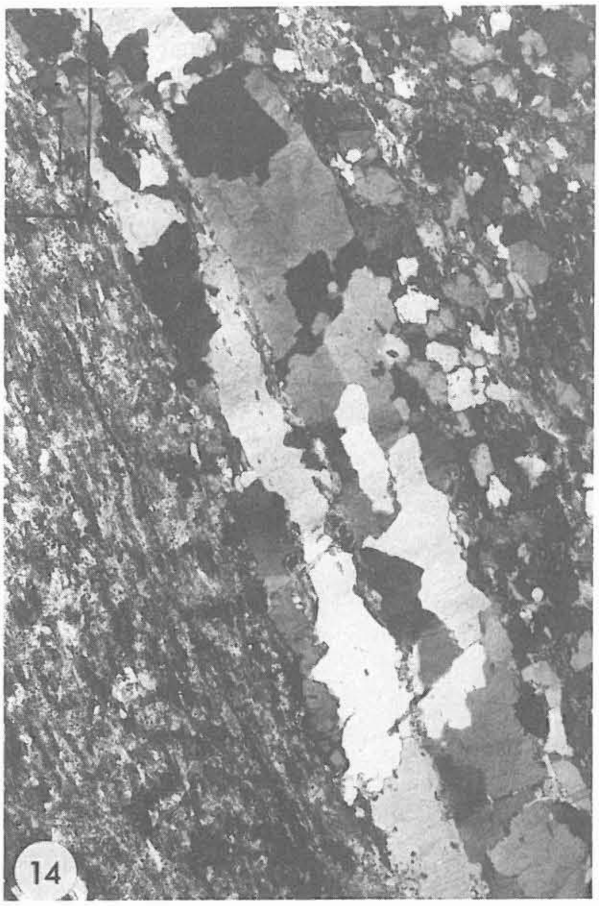
Fig. 13: Cataclastically deformed plagioclase, surrounded by recrystallized quartz. Diaphthoritic deformation stage. Sample 206 B1B, layer A, x pol., short picture length: 3,6 mm.

Fig. 14: Crack-seal quartz vein surrounded by diaphthoritic country rocks. Individual quartz mineralizations within the vein are separated by thin, more or less continuous films and lenses of wall-rock minerals. Sample VB 447 C2h, 1977,69 m, x pol., short picture length: 3,2 mm.

Fig. 15: Weakly deformed crack-seal quartz veins from the bore hole "Püllersreuth". Sample 193,1 m, x pol. short picture length: 24 mm.

Fig. 16: Diaphthoritic mica schist with SC-fabric indicating sinistral sense of shear. Sample 206 B1B, layer A, one pol., short picture length: 1,2 mm.


13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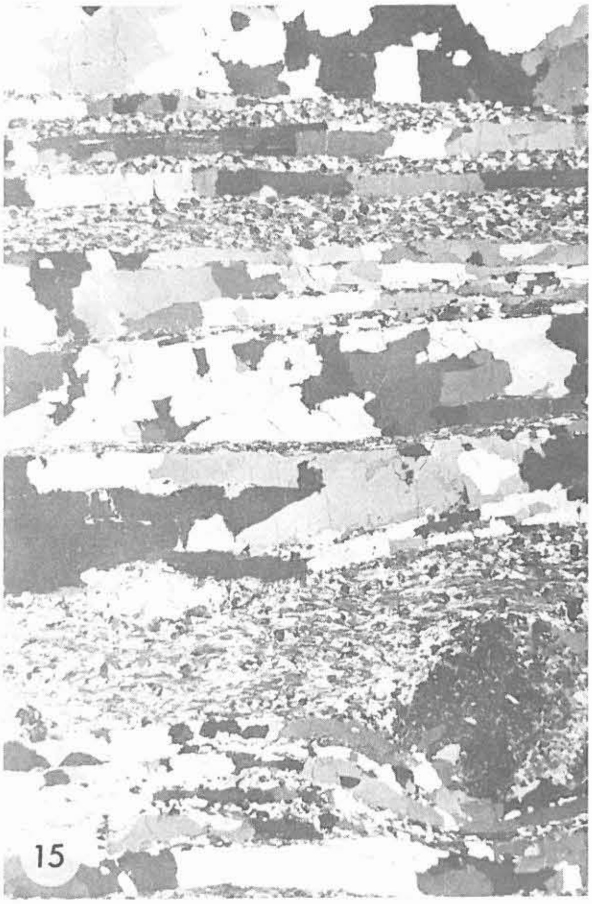
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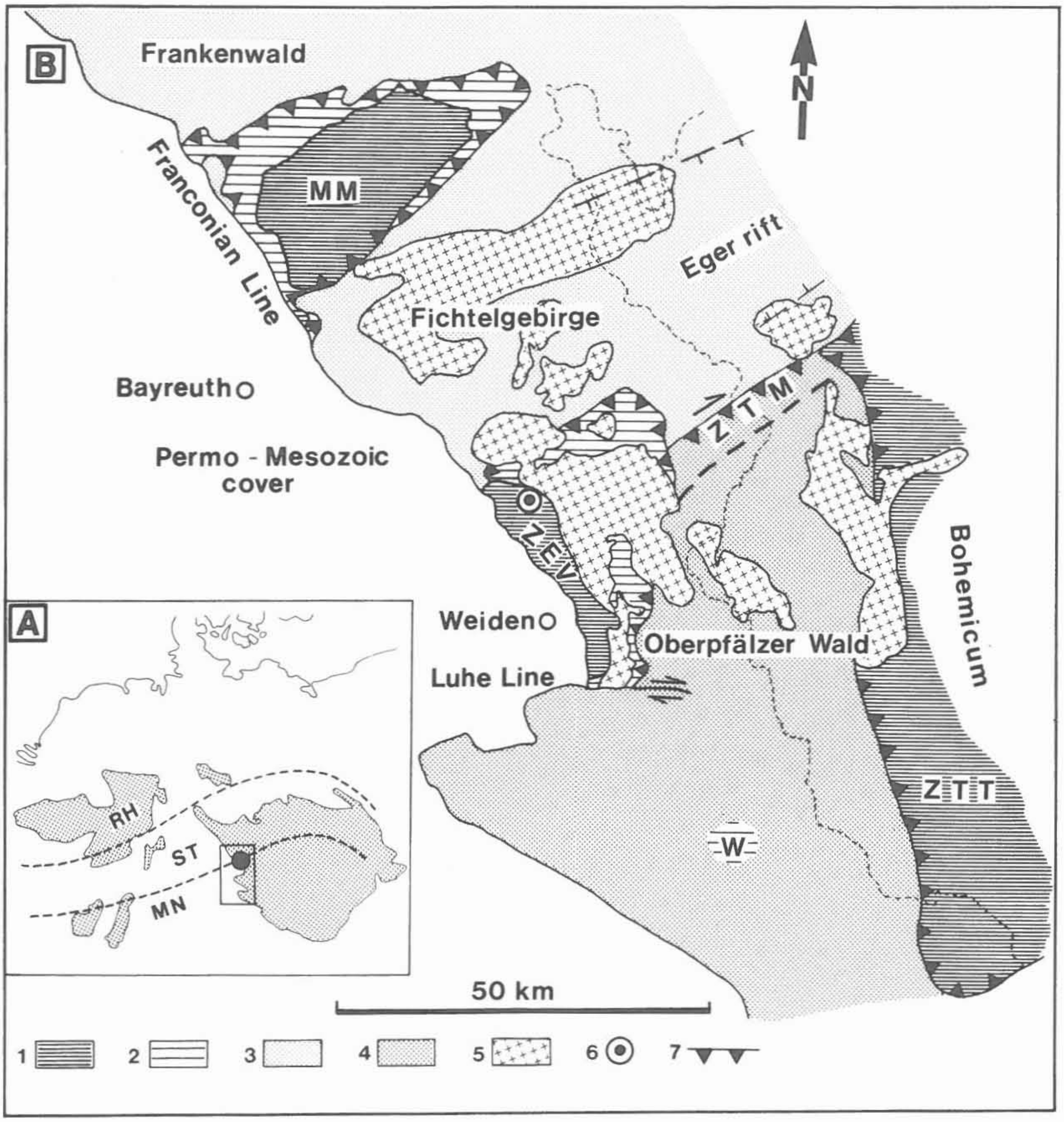
Fig. 17: Geological sketch map of the western rim of the Bohemian Massif in NE Bavaria. A: Variscan basement outcrops in Middle Europe with zones according to Kossmat (1927). RH: Rhenoherzynian Zone; ST: Saxothuringian Zone; MN: Moldanubian Region. B: Geological map with the tectonometamorphic units. 1: crystalline nappe complexes; 2: basal units of the nappe complexes; MM: Münchberg nappe complex; ZEV: nappe complex of the Zone of Erbendorf-Vohenstrauß; ZTT: Zone of Tepla-Taus, forming the western part of the Bohemian terrane (Bohemicum); 3: Saxothuringian; 4: Moldanubian of the Oberpfälzer Wald; 5: late- to post-tectonic granites; 6: KTB drilling site. 7: overthrust; ZTM: Zone of Tirschenreuth-Mähring; W: Winklarn.


B
Frankenwald
MM
Franconian Line
Fichtelgebirge
Eger rift
N
Bayreuth
Permo - Mesozoic cover
ZTM
ZEV
Weiden
Luhe Line
Oberpfälzer Wald
Bohemicum
ZTT
W
A
RH
ST
MN
50 km
1
2
3
4
5
6
7