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Variscan crustal evolution in the Vosges Mountains and in the Schwarzwald: Guide to the excursion of the Swiss Geological Society and the Swiss Society of Mineralogy and Petrology (3–5 October, 1992)

by *Helmut P. Echtler*[1] and *Rainer Altherr*[2]

Abstract

The geology of the Vosges Mountains and the Schwarzwald (Black Forest) was studied during a three-day field excursion, which was held after the 1992 meeting of the Swiss Geological Society and the Swiss Society of Mineralogy and Petrology. Recent results of field work as well as petrologic and radiometric investigations concerning the Variscan crustal evolution of a central segment of the European Variscan belt on both sides of the Rhine Graben were presented and discussed. The Variscan tectono-metamorphism is characterized by a polyphase evolution, which develops from crustal collisional shortening until the latest Early Carboniferous to crustal extension at the Lower/Upper Carboniferous boundary. Stephano-Permian intramountain basins indicate the end of Late Paleozoic uplift.

Keywords: Vosges Mountains, Schwarzwald, Black Forest, crustal evolution, Variscan, radiometric dating, field guide.

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General geology

The European Variscan belt resulted from Devono-Carboniferous convergence between Laurasia and Gondwana (e.g. MATTE, 1983, 1986; WEBER, 1984; BEHR et al., 1984; FRANKE, 1986). Within this belt the massifs of the *Vosges* and *Schwarzwald* take a linking position between the larger outcorps of the Massif Central and the Bohemian Massif (Fig. 1a).

The exposure of the Vosges Mts. and the Schwarzwald on the shoulders of the southern Rheingraben is due to extensive uplift associated with continental rifting during the Neogene. Both massifs are characterized by the widespread occurrence of high-grade polymetamorphic gneisses, relics of high-pressure metamorphics (peridotites, eclogites, granulites), several generations of granites, and polyphase deformational structures. Based on field mapping and seismic reflection profiling, crustal fabrics have been interpreted as a result of bivergent thrusting during crustal shortening (Lower Carboniferous) and subsequent late orogenic extension of the thickened crust during Late Carboniferous and Early Permian time (KROHE and EISBACHER, 1988; EISBACHER et al., 1989; ECHTLER and CHAUVET, 1991, 1992). Extensive areas of deeper crustal rocks within the crystalline thrust sheets (KLEIN and WIMMENAUER, 1984; FLÖTTMANN, 1988; STENGER et al., 1989; WIMMENAUER and STENGER, 1989) have been interpreted to originate from pre-Variscan events. Lower Paleozoic Rb–Sr whole-rock ages and U–Pb ages on zircons from low-pressure anatectic gneisses have been interpreted to document igneous or tectono-metamorphic events (STEIGER et al., 1973; TODT and BÜSCH, 1981; LIPPOLT et al., 1986). However, as elsewhere in the internal Variscan belt, these radiometric data may reflect protolith ages of metasedimentary or meta-igneous gneisses (PIN and VIELZEUF, 1983) or may be geologically meaningless. The predominantly lower Carboniferous age of the polyphase tectono-metamorphism associated with the Variscan orogeny in the Schwarzwald is closely constrained by recent petrologic and radiometric data (WERCHAU et al., 1989 a, b; KALT et al., 1990 a, b; GRAUERT et al., 1990; KALT, 1991).

Vosges Mountains and Schwarzwald contain two major ENE-trending crustal discontinuities (Fig. 1b): (i) the Lalaye-Lubine-Baden-Baden fault zone in the north (WICKERT and EISBACHER, 1988; WICKERT et al., 1990) defining the Moldanubian-Saxothuringian boundary, and (ii) the Todtnau (or Badenweiler-Lenzkirch) fault zone in the south, which may continue into the "Ligne de klippes" fault zone of the Southern Vosges (KROHE and EISBACHER, 1988). Both fault zones are characterized by a polyphase evolution during oblique dextral convergence. Furthermore, they show opposite thrust directions: to the northwest (Lalaye-Lubine-Baden-Baden) and to the southeast (Todtnau, Ligne de klippes), thus defining a bivergent geometry (Fig. 2; WICKERT and EISBACHER, 1988; EISBACHER et al., 1989).

Based on tectono-stratigraphic evolution and lithology four terranes amalgamated during the early Carboniferous may be recognized from north to south (Fig. 1b):

(1) The Saxothuringian domain located to the north of the Lalaye-Lubine-Baden-Baden fault zone comprises lower Carboniferous pelagic sediments (cherts, flysch, olistostromes with blocks of Middle and Upper Devonian neritic carbonates), lower Carboniferous calc-alkaline volcanics (VOLKER and ALTHERR, 1987) as well as low- to medium-grade metasediments (in part with Lower Paleozoic protolith ages) and lower Carboniferous I-type granitoids (HOLL and ALTHERR, 1987; WICKERT et al., 1990).

(2) The Central Gneiss Complex (CGC) is characterized by high-grade, partly anatectic, metapsammitic and meta-igneous gneisses (WIMMENAUER, 1984; WIMMENAUER and STENGER, 1989; STENGER et al., 1989). Numerous relics of garnet and spinel peridotites, garnet pyroxenites, eclogites, and granulites point to a polymetamorphic nature of at least parts of these gneisses (KLEIN and WIMMENAUER, 1984; BAATZ, 1988; STENGER et al., 1989; WERLING and ALTHERR, 1991). According to recent radiometric data (Sm–Nd garnet-whole rock and garnet internal isochrons), the eclogites were formed in the lowermost Carboniferous (355–335 Ma ago) whereas low-pressure/high-temperature metamorphism (and anatexis?) occurred between 335 and 325 Ma B.P. (U–Pb data on monazites; Rb–Sr whole-rock method on thin slabs of migmatitic gneisses; WERCHAU et al., 1989 a, b; KALT et al., 1990 a,b; GRAUERT et al., 1990; KALT, 1991). Such an evolution corresponds to that of other parts of the Moldanubian zone. During the late Lower Carboniferous and the Upper Carboniferous, I-type and S-type granitoids intruded into the metamorphic rocks of the CGC (EMMERMANN, 1977; WICKERT and EISBACHER, 1988; WICKERT et al., 1990).

(3) The Badenweiler-Lenzkirch zone (BLZ) in the Schwarzwald (Figs 1b and 4) contains slices of high-grade to non-metamorphic sequences forming an inverse metamorphic profile with the metamorphic grade decreasing towards the south (ALTHERR and MAASS, 1977; WERLING, 1986; WERLING and ALTHERR, 1987; KROHE and

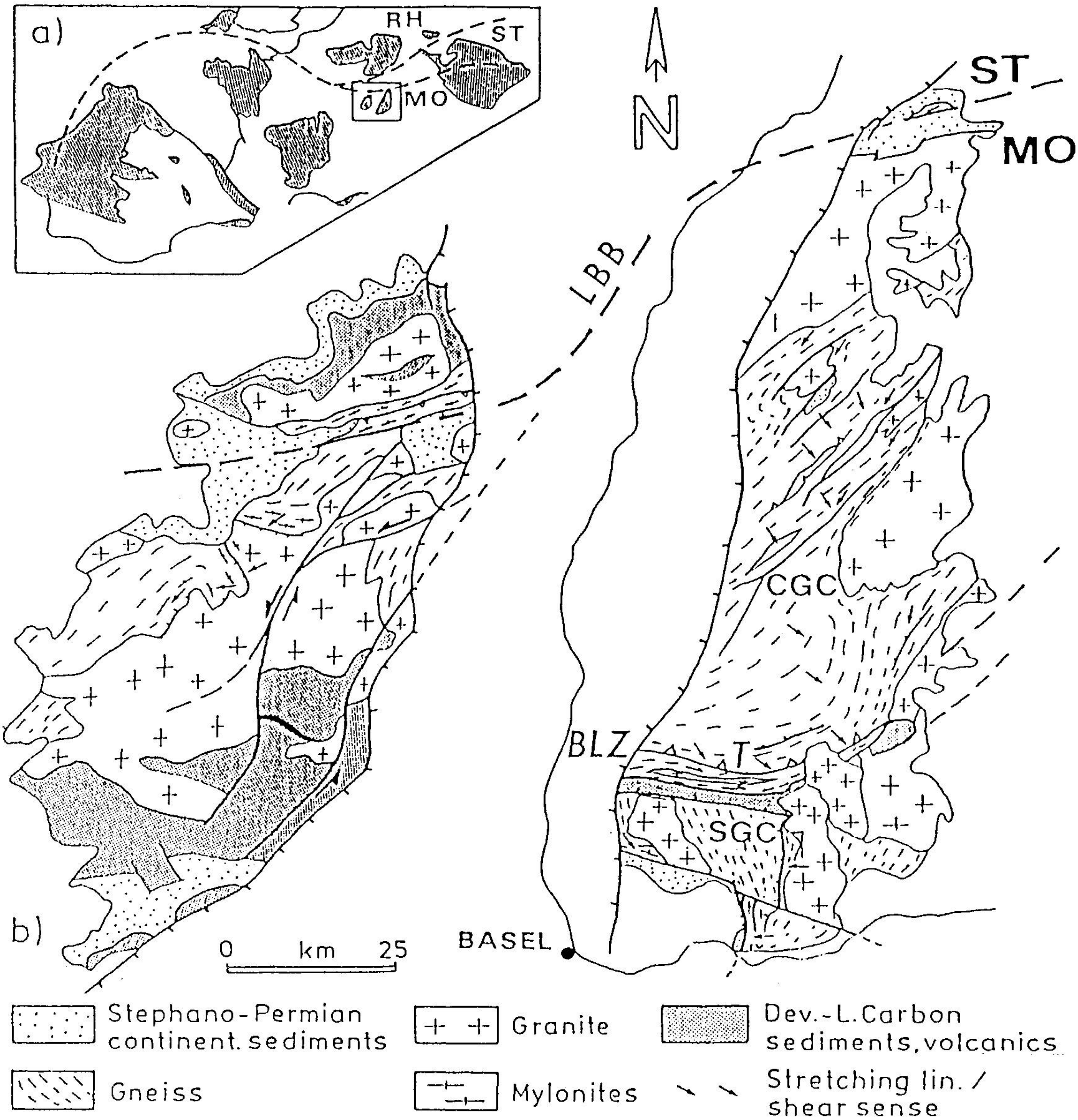

Fig. 1 a) Generalized zonation of the European Variscan belt (after KOSSMAT, 1927): MO = Moldanubian domain, ST = Saxo-Thuringian domain, RH = Rheno-Hercynian domain; b) Generalized geological map of the Schwarzwald and Vosges Massifs; LBB = Lubine-Lalaye-Baden-Baden zone; CGC = central gneiss complex; T = Todtnau thrust; BLZ = Badenweiler-Lenzkirch zone; SGC = southern gneiss complex. Structural data compiled from KROHE and EISBACHER, 1988; FLÖTTMANN, 1988; WICKERT and EISBACHER, 1988; REY et al., 1991; ECHTLER and CHAUVET, 1992.

EISBACHER, 1988). The non-metamorphic southern unit (Fig. 4) consists of Upper Devonian to Lower Carboniferous (Visean) fossiliferous sediments and volcanics (SITTIG, 1981; MAASS et al., 1990) that may represent a Lower Carboniferous syn-orogenic flysch basin with olistostromes of arc-relics and Devonian neritic sediments, as well as orogenic volcanics. Stratigraphic and lithologic analogies relate this unit to the Southern Vosges domain (Fig. 1b; WICKERT and EISBACHER, 1988).

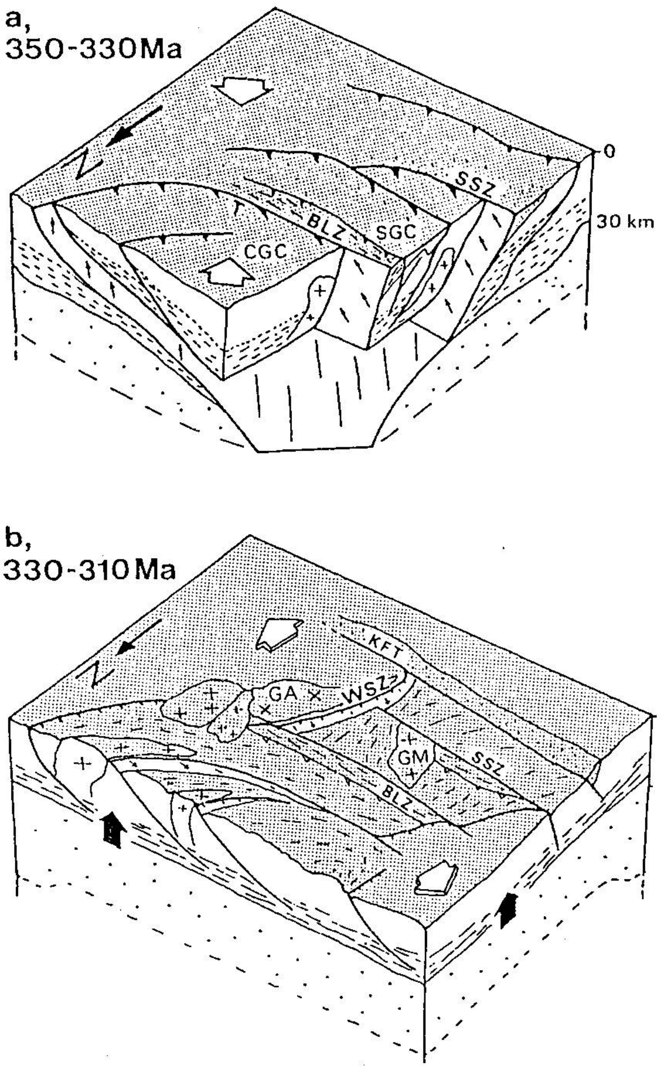

Fig. 2 Three-dimensional illustration of the kinematics and main stages of Variscan orogenic crustal evolution in the central and southern Schwarzwald. Abbreviations see figure 1. No vertical exageration. (a) Lower Carboniferous convergence associated with SE thrusting. (b) Middle to Late Carboniferous crustal thinning of the thickened crust, uplift and extension associated with granite intrusions and crustal melting. KFT = Konstanz–Frick trough, Stephano-Permian half-graben.

Intense polyphase deformation with syn- to post-metamorphic displacements along this crustal-scale discontinuity is associated with the major late Lower Carboniferous convergence (WERLING and ALTHERR, 1987; KROHE and EISBACHER, 1988; EISBACHER et al., 1989). To the south, the BLZ is bounded by a major normal fault juxtaposing non-metamorphic terrestrial sediments (late Lower Carboniferous to Namurian) onto deep crustal rocks of the southern Schwarzwald.

(4) The Southern Gneiss Complex (SGC) consists of widespread granitoids (EMMERMANN, 1977) intruded into a heterogeneous assemblage of medium-grade to anatectic gneisses and metagabbroic rocks (METZ and REIN, 1958; WIMMENAUER, 1984; SEBERT and WIMMENAUER, 1989). The virtual absence of relics of high-pressure metamorphics (garnet or spinel peridotite, eclogites, granulites) in the SGC represents a major difference to the CGC and suggests a different crustal evolution of both terranes. Major high-grade metamorphism (KALT, 1991) and the transition from compressional to extensional tectonics (ECHTLER and CHAUVET, 1992) occurred during the late Lower Carboniferous.

The Variscan polyphase tectono-metamorphic evolution in the central and southern Schwarzwald and Vosges is characterized by a fundamental change in the tectonic regime from collisional shortening to crustal extension (EISBACHER et al., 1989). This change coincides with the paroxysm of crustal melting and intrusion of large volumes of granitic magmas under high-grade (HT/LP) to retrograde metamorphic conditions.

Major crustal shortening until the latest Early Carboniferous is indicated by convergent shear zones. These shear zones are consistent with southeastward directed crustal-scale thrusting and have to be attributed to intracontinental orogenic shortening (Fig. 2a; ECHTLER and CHAUVET, 1992; KROHE and EISBACHER, 1988; FLÖTTMANN, 1988). Recent structural and chronological data from the Southern Schwarzwald (ECHTLER and CHAUVET, 1992) constrain a model of late orogenic (i.e. late Lower Carboniferous to Upper Carboniferous) thinning of previously thickened crust (Fig. 2b).

The large scale of the extensional shear zones and the relatively rapid exhumation of deep-seated high-grade rocks imply crustal-scale processes. Structures from other segments of the Schwarzwald (KROHE and EISBACHER, 1988; WICKERT et al., 1990) and particularly equivalent patterns in the Vosges (REY et al., 1989, 1991) corroborate a model of regionally important extensional tectonism and crustal thinning (Fig. 2b). The close structural and chronological relationship between high-grade metamorphic and plutonic complexes and their exhumation attests to a very short time interval between preceeding thickening and subsequent late orogenic crustal extension at the Lower/Upper Carboniferous boundary.

Stephano-Permian intramountain basins (Fig. 1b) with non-metamorphic continental sediments unconformably overlying the exhumed high-grade crystalline structures document a late- to post-orogenic phase of continental extension. Abundant rhyolite and granite porphyry dikes as well as Permian rhyolitic extrusives suggest a thermal event with extensive lower-crustal melting. This suggests that late-orogenic formation of a "normal" crustal thickness of about 30 km was mainly achieved by tectonic denudation during Upper Carboniferous time as previously proposed for the Massif Central (MALAVIEILLE et al., 1990; ECHTLER and MALAVIEILLE, 1990).

Itinerary

SATURDAY, 3 OCTOBER 1992 – NORTHERN VOSGES MOUNTAINS

Route

Châtenois (N 59, D 424) – Villé (D 39) – Fouchy – Urbeis – Château de Bilstein – Col d'Urbeis (D 214) – Col de Steige (D 424) – Steige – St. Martin – Villé – Triembach au Val (D 203, D 253) –

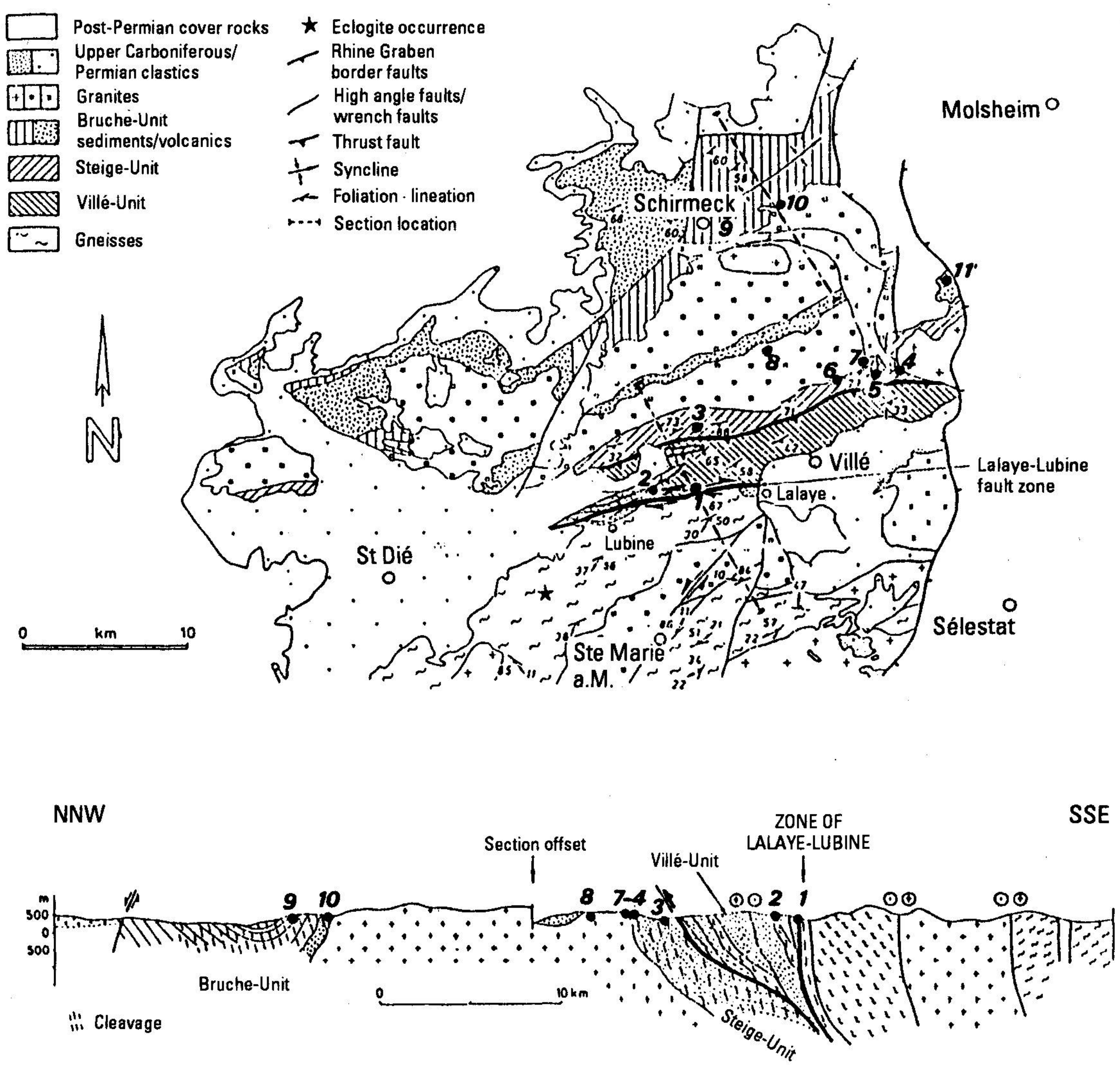

Fig. 3 Geological sketch map and cross-section of the northern Vosges and stops (modified after WICKERT and EISBACHER, 1988).

Andlau (D 425) – Le Hohwald (D 426) – Welschbruch (D 130) – La Rothlach – Rothau (N 420) – Schirmeck – Hersbach – Wisches – Schwartzbach (D 204) – Grendelbruch – Klingenthal (D 426) – Ottrott (D 109) – St. Nabor – Châtenois (Fig. 3).

Topographic maps

1 : 50,000 Feuille XXXVII-16 Molsheim
Feuille XXXVII-17 Sélestat
Feuille XXXVI-17 Saint-Dié
1 : 25,000 Feuille XXXVII-16 Molsheim 5–6, 7–8
Feuille XXXVII-17 Sélestat 1–2, 3–4, 5–6, 7–8
Feuille XXXVI-17 Saint-Dié 3–4, 7–8

Geological maps

Carte géologique de la France, 1/50,000, Sélestat (1972), + notice, ed. BRGM
Carte géologique de la France, 1/50,000, St-Dié (1975), + notice, ed. BRGM
Carte géologique de la France, 1/50,000, Molsheim (1975), + notice, ed. BRGM
VON ELLER, J.P., BLANALT, J.G., HAMEURT, J. and HOLLINGER, J. (1970): Carte géologique du socle vosgien, septentrionale. Bull. Serv. Carte géol. Alsace Lorraine 23: 5–28.
VON ELLER, J.P., FLUCK, P., HAMEURT, J. and HOLLINGER, J. (1970): Carte géologique des Vosges moyennes, partie centrale et partie orientale. Bull. Serv. Carte géol. Alsace Lorraine 23: 29–50.

Stop 1

Ruins of the Château de Bilstein (Topographic map 1:50,000 Feuille XXXVII-17 Sélestat, coordinates 96125 / 8155).

Follow the road from Urbeis to Steige for approximately two kilometers, take a small forestry road leading to the right (uphill), follow this road for another 2 km; at a small parking lot a foot path leads to the ruins of the Château de Bilstein, located about 500 m to the north of Urbeis in the southernmost parts of the Lalaye-Lubine shearzone. The porphyroclastic "gneisses of Urbeis" (kalifeldspar + plagioclase + biotite + quartz) belong to the CGC terrane. Shearing occurred during oblique dextral convergence between the CGC and the Saxothuringian domain.

Stops 2a and 2b

Road D 39, W of Urbeis, about 1 km ENE of Col d'Urbeis between the intersections with road to Le Climont and an unpaved forestry road to the right (Topographic map 1:50,000 Feuille XXXVI-17 St-Dié, coordinates 95988 / 8180).

(a) Very low-grade metamorphic schists of the Villé unit (Saxothuringian domain) showing ENE–WSW trending, steeply dipping cleavage and NE–SW oriented dextral shear bands related with two distinct deformational events during terrane accretion: (i) NW-vergent folding and thrusting and (ii) subsequent cataclastic transcurrent strike-slip movements. The Villé unit (Cambrian to Ordovician protoliths; Ross, 1963) comprises phyllites, meta-sandstones and meta-conglomerates.

(b) Walk from (a) for about 200 m to the S-SE towards Col d'Urbeis along road:

Tectonic sliver of cataclastic gneisses of Urbeis (CGC) within the Villé unit. NE–SW trending, steeply SE dipping foliation and subhorizontal stretching lineation. Superimposed cataclastic shear bands.

Stop 3

Road from Climont to Steige, after Col du Steige, 500 m NW of Steige (Topographic map 1:50,000 Feuille XXXVII-17 Sélestat, coordinates 96230 / 8530).

Roadcuts on both sides of the road expose phyllites of the Steige unit (Saxothuringian domain). The very low-grade Steige unit (Ordovician to Silurian protoliths) consists of metapelitic slates and phyllites and rare intercalations of meta-sandstones (ROSS, 1963; CLAUER, 1970). Relatively open, E–W to NE–SW trending folding and crenulation with prominent axial planar cleavage (WICKERT and EISBACHER, 1988).

Stop 4

Roadcut along road D 425 from Andlau to Le Howald, 2 km WNW of Andlau and 500 m NW of Einungkopf (Topographic map 1:50,000 Feuille XXXVII-17 Sélestat, coordinates 97355 / 8955).

On the right side of the road the intrusive contact of the Andlau granite with the Steige unit is exposed. The Andlau granite is a biotite granite with minor hornblende and contains mafic enclaves of hornblende-biotite granodioritic to dioritic compositions. This pluton belongs to the younger (330–325 Ma B.P.) group of I-type granitoids in the Northern Vosges Mountains. Contact metamorphism has caused intense recrystallization in the metapelites of the Steige unit. Near to the contact, hornfelses contain the parageneses quartz + muscovite + biotite + plagioclase + magnetite + cordierite + andalusite. Along the northern contact, quartz-free hornfelses with corundum occur.

Stop 5

Roadcuts along road D 425 from Andlau to Le Howald, about 3 km W of Andlau, between Heiligenbaum and Eftermatten.

Gray-coloured knotted slates with porphyroblasts of cordierite surrounded by a matrix composed of quartz, muscovite, biotite, plagioclase, and magnetite. Cordierite is mostly transformed to pinite (= chlorite + muscovite). It is assumed that cordierite was originally formed by contact metamorphism related to the intrusion of the Hohwald granodiorite and later became instable during contact metamorphism related to the intrusion of the Andlau granite (VON ELLER et al., 1971).

Stop 6

Auberge de Lilsbach at road D 425 from Andlau to Le Howald (1:50,000 Feuille XXXVII-17 Sélestat, coordinates 97115 / 8875).

From the auberge (former maison forestière), walk across road D 425 and follow the unpaved forestry road for about 20 meters, then turn left and take the foot path to Sperberbaechel along the northern bank of the Andlau creek. On the right side of the foot path small outcrops with hornfelses of the Steige unit containing the parageneses quartz + muscovite + biotite + plagioclase + magnetite + cordierite + andalusite. After about 100 m you cross the intrusive contact of the Hohwald granodiorite with the Steige unit. The hornblende granodiorite of Hohwald contains mafic enclaves (dioritic compositions) and belongs to the older (335–330 Ma) group of I-type granitoids of the Northern Vosges Mountains.

Stop 7

Maison forestière d'Eftermatten, located just south of road D 425, about 4 km W of Andlau (1:50,000 Feuille XXXVII-17 Sélestat, coordinates 97130 / 8878).

From Auberge de Lilsbach turn back on road D 425 towards Andlau; after about 200 m turn right to Maison forestière d'Eftermatten. At the junction turn to the left and proceed over a small bridge across the creek to a small (inofficial) parking lot on the eastern side of the creek called Hasselbach. At the parking lot, schists of the Steige unit cut by a late Carboniferous lamprophyric dike are exposed.

Walk back across the creek and follow the small forestry road on the western bank of the small creek (Hasselbach). After a few meters, reddish-coloured Permian rhyolites are visible to the right. From this point, a 2 kilometers walk from Eftermatten to the south shows a profile through the Steige and Villé units. With decreasing metamorphic grade, gray (magnetite) knotted slates with porphyroblasts of cordierite are followed by gray slates without cordierite and andalusite, red (hematite) slates, and still further to the south, by slates and metasandstones of the Villé unit.

Stop 8

Neuntelstein, about 1.2 km ESE of La Rothlach (Topographic map 1:50,000 Feuille XXXVII-16 Molsheim, coordinates 96965 / 9190).

From La Rothlach, a short walk (1.2 km) leads to Neuntelstein (vantage point). The hornblende-biotite diorite of Neuntelstein belongs to the older group of I-tpye granitoids in the Northern Vosges Mountains (HOLL and ALTHERR, 1987).

Stop 9

Quarry between Schirmeck and Hersbach on the northern side of road N 420 (Topographic map 1:50,000 Feuille XXXVII-16 Molsheim, coordinates 96125/9955).

The Bruche unit (Saxothuringian domain) documents a strong facies differentiation into middle Devonian reef limestones, an upper Devonian sequence of dark shales with mixed assemblages of marine fauna to marine-terrestrial flora, arkoses, slates, and chert, followed by olistostromes and Visean shales, turbiditic graywackes, and conglomerates (WICKERT and EISBACHER, 1988, and references therein). In the quarry, sandstones and shales are exposed.

Stop 10

Abandonned quarry "Socavo" near Schwartzbach (Topographic map 1:50,000 Feuille XXXVII-16 Molsheim, coordinates 96480 / 10040).

Extrusive and intrusive orogenic volcanics (andesites, dacites) of the Saxothuringian domain. At the southern end of the quarry, the contact between volcanics and Visean sediments is exposed. The volcanics may locally show hydrothermal-metamorphic overprint (prehnite, pumpellyite, epidote, hematite, rare grossularite and diopside).

All volcanics of the Northern Vosges Mountains belong to the medium-K to high-K series and display negative Nb–Ta anomalies in primordial mantle-normalized element concentration plots. Compositions of magmatic clinopyroxenes and amphiboles are similar to those of recent arc volcanics (VOLKER and ALTHERR, 1987).

Stop 11

Quarries to the west of St. Nabor (Topographic map 1:50,000 Feuille XXXVII-16 Molsheim, coordinates 97565 / 9600).

From Hersbach, follow road N 420 to Wisches, turn left to Schwarzbach, Grendelbruch, turn right to Klingenthal, Ottrott and St. Nabor. The large quarries to the west of St. Nabor expose calc-alkaline volcanics (Lower Carboniferous) of the Saxothuringian domain (VOLKER and ALTHERR, 1987). Andesitic to dacitic pyroclastics are the most abundant rock types.

The participants spent the night at Châtenois.

SUNDAY, 4 OCTOBER 1992 – SCHWARZWALD, CENTRAL GNEISS COMPLEX AND BADENWEILER-LENZKIRCH ZONE

Route

Châtenois (N 59) – Sélestat (D 424) – Marckolsheim – Endingen – Riegel (A 5) – Freiburg – Schauinsland – Notschrei – Todtnau – Geschwend – Bernau – Geschwend (B 317) – Schönau (Fig. 4).

Topographic maps

1 : 25,000 Blatt 8013 Freiburg SO
Blatt 8113 Todtnau
Blatt 8114 Feldberg (Schwarzwald)

Geological maps

METZ, R. and REIN, G. (1958): Geologisch-petrographische Übersichtskarte des Südschwarzwaldes, 1:50,000, mit Erläuterungen. Moritz Schauenberg Verlag, Lahr (1958).

WIMMENAUER, W. (1981): Geologische Karte von Baden-Württemberg 1:25,000, Blatt 8114 Feldberg (Schwarzwald). Geol. Landesamt Baden-Württemberg.

WIMMENAUER, W. and HÜTTNER, R. (1968): Geologische Karte von Baden-Württemberg 1:25,000, Blatt 8013 Freiburg SE. Geol. Landesamt Baden-Württemberg.

ISLER, A., PASQUIER, F. and HUBER, M. (1984): Geologische Karte der zentralen Nordschweiz, 1:100,000, mit Erläuterungen, ed. NAGRA.

Stop 1

Outcrops along the road from Freiburg to Schauinsland (Topographic map 1.25,000 Blatt 8013 Freiburg SO, coordinates: r341578 / h531025).

Migmatitic gneisses of the CGC. The porphyroclastic gneisses show a pronounced layering with leucocratic (plagioclase-quartz-rich) and melanocratic (biotite-rich) layers. The critical paragenesis cordierite + sillimanite + biotite + plagioclase + quartz ± kalifeldspar points to pressures around 0.3 GPa and temperatures in the range of 620–700 °C. Discussion focused on the problem of anatexis. Locally, discordant leucosomes are visible.

Stop 2

Outcrop along the road from Notschrei to Todtnauberg (Topographic map 1:25,000 Blatt 8113 Todtnau, coordinates: r342013 / h530130).

Anatectic gneisses of the CGC with heterogeneous penetrative deformation. Ductile and cataclastic, mainly south-vergent shearzones. Discordant leucosomes with mm-sized amphiboles.

Stop 3

Quarry at Feldberg-Bärental (Topographic map 1:25,000 Blatt 8114 Feldberg, coordinates: r343355 / h530437).

Boudins of relic eclogites within anatectic gneisses. Sm–Nd dating (mineral-mineral and inter-mineral isochrons) on several eclogitic relics within the CGC yielded lower Carboniferous model ages which are interpreted as crystallization ages (KALT, 1991).

Stop 4

Various outcrops along the road from Feldberg to Fahl (Topographic map 1:25,000 Blatt 8114 Feldberg, coordinates r342660 / h530268)

Anatectic gneisses of the CGC.

Stop 5

Southern limit of the town of Todtnau, roadcuts along road B 317 to Geschwend (Topographic map 1:25,000 Blatt 8113 Todtnau, coordinates r342087 / h529925).

Migmatitic gneisses (biotite + plagioclase + quartz + kalifeldspar) at the southern limit of the CGC.

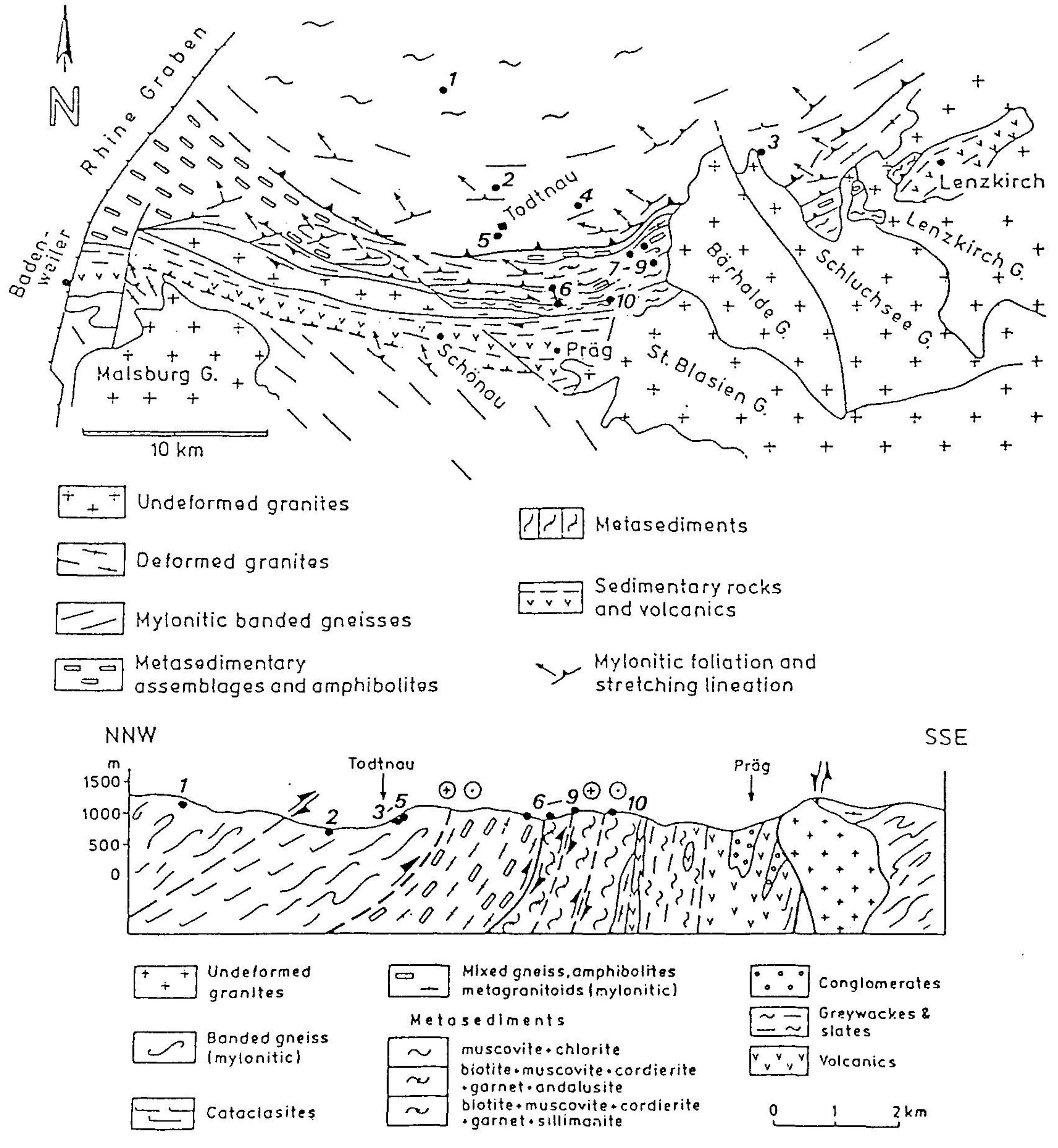

Fig. 4 Geological sketch map and cross-section through the oblique thrust and metamorphic gradients between the southern CGC and the Badenweiler-Lenzkirch Zone and stops (modified after KROHE and EISBACHER, 1988).

Stop 6

Various outcrops along a small forestry road ("Unterer Brenntfelsenweg"), about 2 km SE of Todtnau (Topographic map 1:25,000 Blatt 8113 Todtnau, coordinates: r342288 / h529825).

Porphyroclastic migmatitic gneisses (CGC) in the northern part of the Badenweiler-Lenzkirch fault zone. This fault zone shows ductile deformation in the northern parts but cataclastic deformation in the south. The cataclastic zone contains sediments and calc-alkaline volcanics of upper

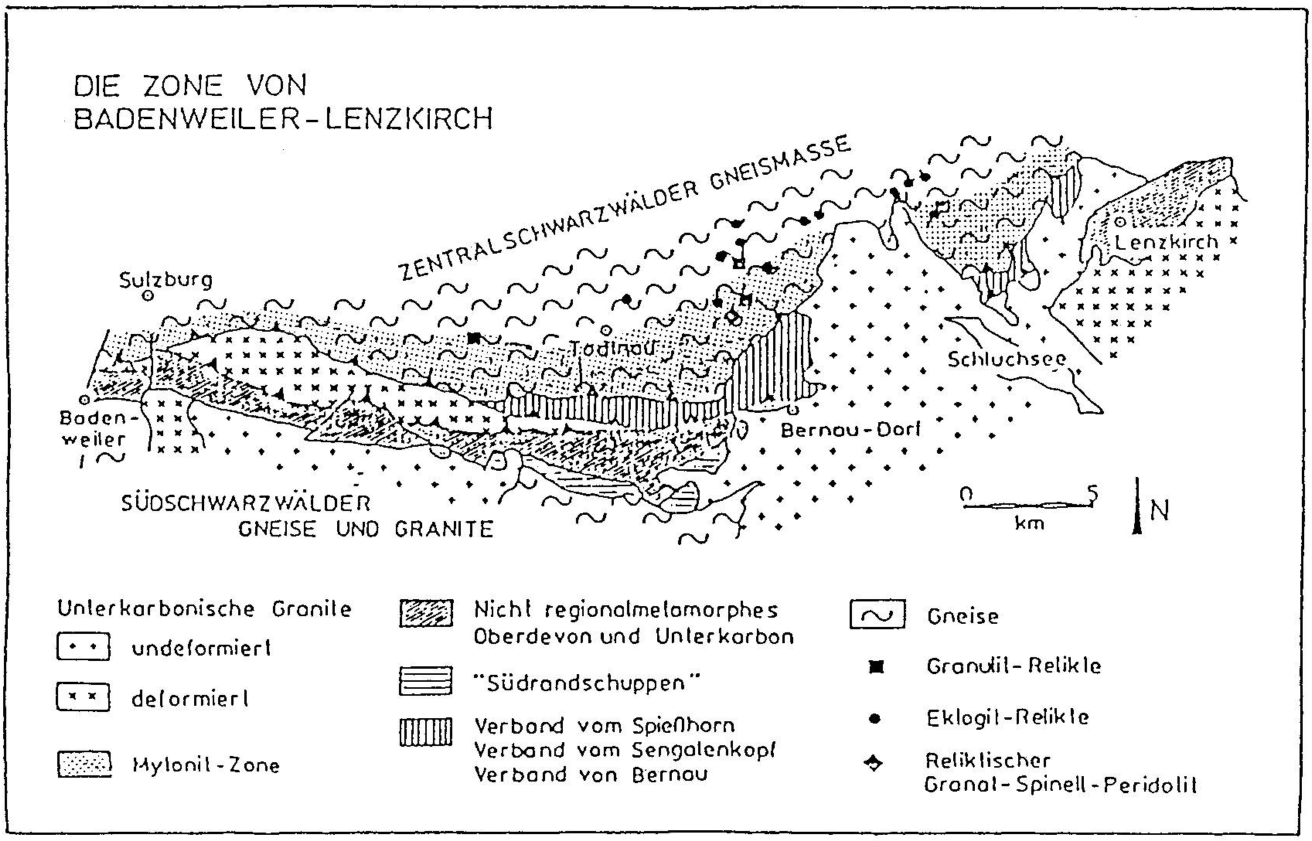

Fig. 5 Metamorphic setting of the southern CGC and the Badenweiler-Lenzkirch Zone (after WERLING, 1986).

Devonian to lower Carboniferous age. The mylonitic foliation generally dips to the NW, i.e. under the gneisses of the CGC. Stretching lineations dip to the W to NW. Different shear sense indicators show that the northern gneisses were thrust onto the Paleozoic rocks in a system of SE-vergent thrusts and dextral shear zones. Within the ductile zone, different thrust sheets can be distinguished on the basis of lithology and metamorphic grade. The metamorphic profile is inverse and discontinuous with respect to both the premylonitic (M_{pm}) and synmylonitic (M_{sm}) metamorphism as documented by the following parageneses (WERLING, 1986; WERLING and ALTHERR, 1987):

(a) Gneisses of the CGC and Spießhorn unit

M_{pm} + M_{sm}: sillimanite + cordierite + garnet + biotite + muscovite + quartz

(b) Sengalenkopf unit

M_{pm}: andalusite + cordierite + garnet + biotite + muscovite + quartz

M_{sm}: cordierite is unstable (→ chlorite + muscovite)

(c) Bernau-Wacht unit

M_{pm}: not detectable

M_{sm}: albite + chlorite + muscovite + quartz

Stop 7

Ecklewald, about 800 m SW of Bernau-Hof, small outcrops along unpaved forest road (Topographic map 1:25,000 Blatt 8114 Feldberg, coordinates r342600 / h529820).

Walk from Bernau-Hof. Fine-grained metapelitic and calc-silicate gneisses (ductile and late cataclastic deformation) of the Spießhorn unit.

Stop 8 (optional)

Small blocks at forest road about 1.2 km NW of Bernau-Hof (Topographic map 1:25,000 Blatt 8114 Feldberg, coordinates r342533 / h529940).

Walk from Bernau-Hof. Blocks of serpentinized pargasite-garnet-spinel peridotite with secondary tremolite and chlorite occur within variable gneisses of the CGC. Primary P-T conditions as recorded by homogeneous garnet, opx, cpx and Cr–Al spinel are estimated to about 15 kbar and 700 °C (garnet-opx pressures, 2-pyroxene and cpx-garnet temperatures; KALT, ALTHERR and HANEL, in prep.). Sm–Nd dating is in progress.

Stop 9

Schwemmbachfelsen, about 1 km NE of Bernau-Hof, outcrop along unpaved forest road (Topographic map 1:25,000 Blatt 8114 Feldberg, coordinates r342665 / h529942).

Walk from Bernau-Hof. Migmatitic gneisses (biotite + hornblende + plagioclase + kalifeldspar + sphene) showing penetrative deformation leading to porphyroclastic textures. The rocks belong to the southern margin of the CGC.

Stop 10

Quarry "Auf der Wacht", road from Geschwend to Bernau, about 2 km WSW of Bernau-Dorf (Topographic map 1:25,000 Blatt 8114 Feldberg, coordinates: r342550 / h529670).

Mylonitic and cataclastic schists, metasandstones and metaconglomerates of the Sengalenkopf and Bernau-Wacht units. E to NE trending, steeply north-dipping foliation.

Stop 11

Outcrops along a small forest road (walk) about 400 m to the W of stop 14 (Topographic map 1:25,000 Blatt 8114 Feldberg, coordinates: r342585 / h529658).

Sheared meta-conglomerates of the Sengalenkopf unit. Mylonitic deformation with E-NE trending foliation and moderately W-dipping stretching lineation. Boulders of calc-alkaline volcanics, low to medium grade metamorphics, and clastic sediments in a sandy to silty matrix. Grade of metamorphism is upper greenschist to lower amphibolite facies (almandine-rich garnet, cordierite).

The participants spent the night at Schönau.

MONDAY, 5 OCTOBER 1992 – SOUTHERN GNEISS COMPLEX (SGC)

Route

Schönau – Zell im Wiesetal (B 317) – Hausen – Wieslet – Weitenau – Hofen – back to Hausen – Raitbach – Sattelhof – Hasel – Wehr – Todtmoos-Au – Wehr – Bergalingen – Bad Säckingen – Basel (Fig. 6).

Topographic maps

1 : 25,000 Blatt 8213 Zell im Wiesental
Blatt 8312 Schopfheim
Blatt 8313 Wehr

Geological maps

METZ, R. and REIN, G. (1958): Geologisch-petrographische Übersichtskarte des Südschwarzwaldes, 1:50,000, mit Erläuterungen. Moritz Schauenberg Verlag, Lahr (1958).

ISLER, A., PASQUIER, F. and HUBER, M. (1984): Geologische Karte der zentralen Nordschweiz, 1:100,000, mit Erläuterungen, ed. NAGRA.

Stop 1

South of Schönau between Wembach and Mambach, road B 317 (Topographic map 1:25,000 Blatt 8213 Zell im Wiesental, coordinates: r341680 / h529165).

Anatectic gneisses, migmatites and granitic, granodioritic rocks of the Southern Gneiss Complex.

Stop 2

Quarry about 500 m NE of Hofen, road to Endenburg (Topographic map 1:25,000 Blatt 8312 Schopfheim, coordinates: r340570 / h528500).

In the western part of the SGC an oblique ductile thrust fault is situated between the large Blauen-Malsburg granite pluton and the high-angle brittle faults limiting the rifted Permo-Triassic Dinkelberg area (Figs 6 and 7). The Schlächtenhaus fault zone (ECHTLER and CHAUVET, 1992) represents a compressive ductile shear zone (Fig. 7) analogous to the major tectonic discontinuity along the southern edge of the Central Gneiss Complex and is probably part of the same crustal shortening event (i.e., late Lower Carboniferous time).

The mylonitic zone comprises orthogneisses superimposed onto lower-grade metamorphic (biotite) arenaceous pelitic formations which, in analogy with the Badenweiler-Lenzkirch terranes, are presumably Early Carboniferous in age.

Intensely deformed two-mica granite ("Schlächtenhaus granite"). Intense progressive shearing is indicated by pervasive S-C type mylonites. The mylonitic foliation (C-planes) shows a constant strike of N100°–N130°E and dip of 30°–50° to the NNE. Foliation is defined by alternating layers of mica and quartz-feldspar aggregates. The foliation plane contains a prominent

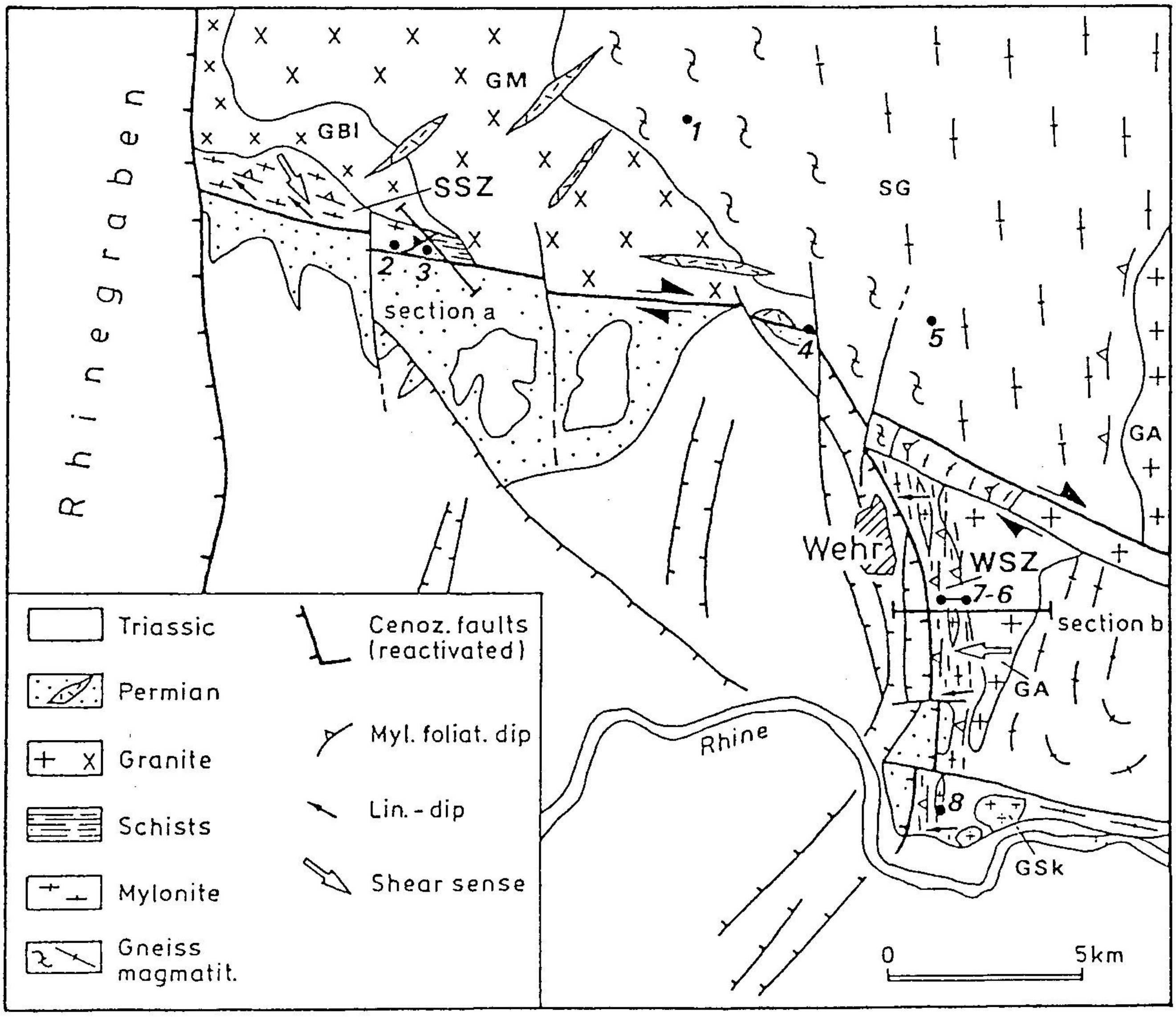

Fig. 6 Generalized geological sketch map of the southern Schwarzwald and stops. SSZ = Schlächtenhaus thrust zone; WSZ = Wehra normal shear zone. Variscan granites: GBl = Blauen granite; GM = Malsburg granite; GA = Albtal granite; GSk = Säckingen granite; see also table 1; SG = southern gneiss complex, in part migmatitic. Sections see figures 7 and 8 (after ECHTLER and CHAUVET, 1992).

stretching lineation, characterized by elongated quartz and aligned mica grains (310° to 320°; plunge 30° to 40° NW). Micro-structures (S-C fabrics) indicate southeastward directed thrusting.

Contact with undeformed intrusive Mahlsburg granite (Tab. 1) and cross-cutting rhyolitic dyke.

Stop 3a

Quarry about 500 m E-NE of Hofen at unpaved forestry road, at intersections hold to the right (Topographic map 1:25,000 Blatt 8312 Schopfheim, coordinates: r340680 / h528500).

Quartz-rich metasediments show a pervasive cleavage subparallel to transposed bedding. Shearing of these rocks is indicated by folded and boudinaged quartz veins parallel to the foliation. Foliation and pervasive schistosity, marked by biotite and chlorite, are parallel to the mylonitic foliation of the (stop 16) orthogneissic sequences (N100°–N130°E, dip 30°–50° to the NNE). The retrogressive stretching lineation is less prominent in the fine-grained and low-grade rocks but compares to the S-C structures seen at stop 16). Late brittle faults.

Stop 3b (optional)

500 m north of Farnbuck, along road to Lehnacker (Topographic map 1:25,000 Blatt 8312 Schopfheim, coordinates: r340720 / h528500).

Tab. 1 Radiometric data and characterization of different intrusive granitic suites of the southern Schwarzwald. Locations see figure (modified after HOEFS and EMMERMANN, 1983).

Granite intrusions	Radiometric ages	Characterization	Reference
Klemmbach-Schlächtenhaus-granite (GKS, Fig. 4a)	357 ± 10 Ma, Rb/Sr	leucogranitic, muscovite bearing	LEUTWEIN and SONET, 1974
Malsburg granite (GM)	328 ± 6 Ma, U/Pb	biotite granite to granodiorite	TODT, 1976
Albtal granite (GA)	326 ± 2 Ma, Rb/Sr	Porphyric biotite granite to granodiorite	SCHULER and STEIGER, 1978
Säckinger granite (GSk)	325 ± 5 Ma, Rb/Sr	two mica granite	v. DRACH, 1978

Intensely deformed metasediments with isoclinal folding (compare Stop 3a). Cataclastic contacts with "Blauen granite".

Stop 4

500 m E of Sattelhof, road Gersbach – Schopfheim, 1 km N of intersection with road to Hasel (Topographic map 1.25,000 Blatt 8313 Wehr, coordinates: r341700 / h528200).

Malsburg granite with cataclastic E–W trending strike-slip faults and tilted discordance of Lower Permian clastic sediments upon the granite.

Stop 5

About 4 km N-NE of Wehr, road to Todtmoos, Wehra-valley, Parking lot "Hirschfelsen" (Topographic map 1:25,000 Blatt 8313 Wehr, coordinates r342070 / h528270).

Mafic to intermediate gneisses (hornblende + biotite + plagioclase + sphene ± kalifeldspar ± quartz) of the Wehra-Wiesetal complex (SGC) with discrete mylonites. The Wehra-Wiesental complex represents a large body of mafic to granitic rocks (in part layered metagabbro: peridotite, pyroxenite, gabbro, anorthosite) metamorphosed during the lower Carboniferous under granulite to amphibolite facies conditions (SEBERT and

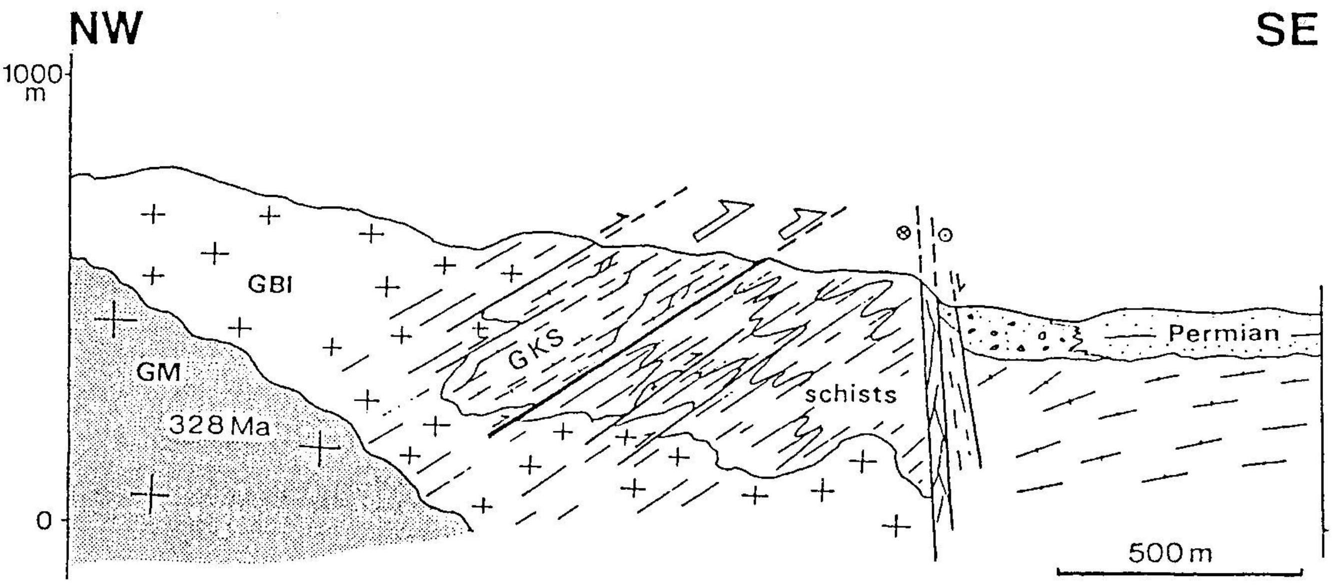

Fig. 7 Cross-section through the Variscan Schlächtenhaus shear zone and Cenozoic northern Dinkelberg border fault (after ECHTLER and CHAUVET, 1992).

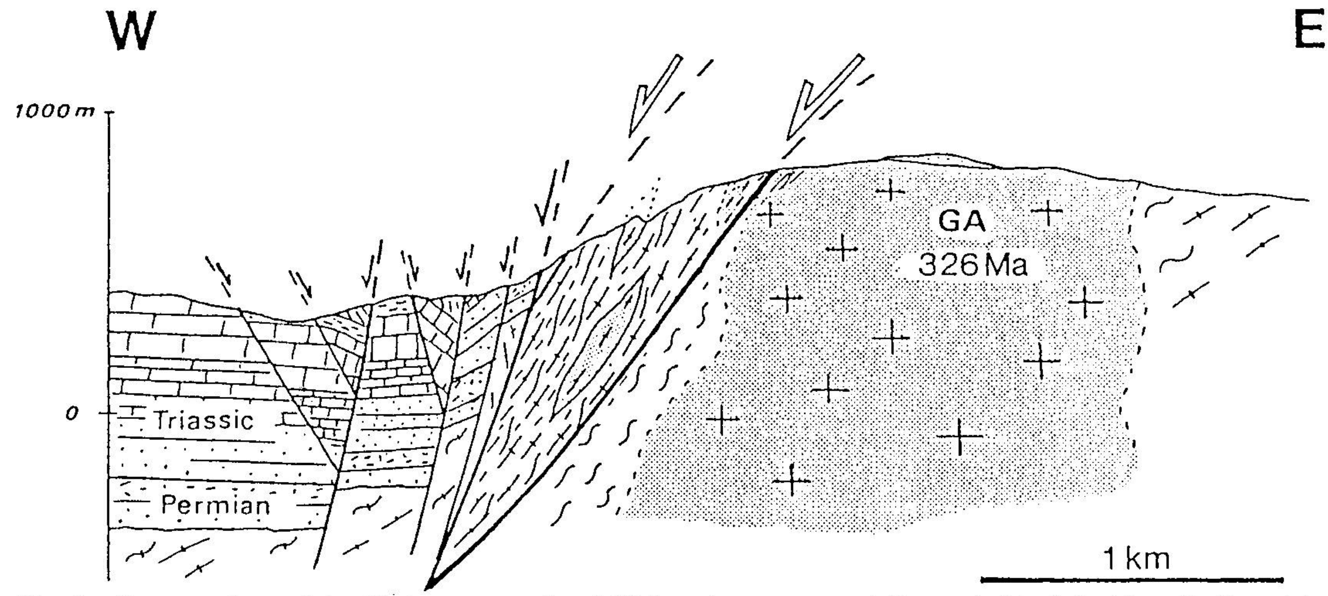

Fig. 8 Cross-sections of the Variscan extensional Wehra shear zone and Cenozoic block-faulting. Radiometric ages see table 1 (after ECHTLER and CHAUVET, 1992).

WIMMENAUER, 1989; KALT, 1991). The protolith ages are not known. Radiometric studies of igneous relics within the complex did not yield meaningful results (KALT, 1991). Late- to post-Variscan (Permian) rhyolitic dykes and late cataclastic faults.

Stop 6

Road Wehr – Bergalingen, about 1 km south of the junction to Hütten, small parking lot (Topographic map 1:25,000 Blatt 8313 Wehr, coordinates r342015 / h527585).

The eastern part of the Dinkelberg block displays an approximately 1 km wide N–S trending high-angle normal fault zone affecting both the Permo-Mesozoic sediments (LUTZ, 1964) and the crystalline basement (Fig. 8). This set of normal faults developed during Cenozoic rifting of the adjacent Upper Rhine Graben. However, the main characteristic of this structure is a Variscan syn-metamorphic (amphibolite to lower-greenschist facies conditions) mylonitic shear zone in high-grade gneisses. Structural analysis indicates a Variscan age of progressive shearing and mylonitization with intense non-coaxial deformation along a ductile extensional fault zone (ECHTLER and CHAUVET, 1992). The mylonites are located on the western flank of a N–S trending antiform of anatectic and migmatitic core-rocks intruded by "Albtal granite" (Fig. 6).

From the parking lot walk for about 400 m to the north on unpaved forestry road. Blocks and outcrops of undeformed biotite granite ("Albtal granite") with large phenocrysts of kalifeldspar. At the overhead power supply line intensely deformed "Albtal granite" with mylonitic foliation, oriented augen and shear bands is exposed. This corresponds to the base of the shear zone. To the east (uphill) anatectic gneisses of the SGC form the base of the deformed "Albtal granite".

Stop 7

Road Wehr – Bergalingen, about 1 km south of the junction to Hütten, below overhead power supply line (Topographic map 1:25,000 Blatt 8313 Wehr, coordinates r342000 / h527585).

Walk downhill, parallel to the overhead power supply line: heterogeneous, fine-grained mylonitic gneisses. Mylonitic foliation and shear planes are oriented consistently N–S (350° to 0°) and dip toward the west. Stretching lineations (partly defined by fibrolitic sillimanite) and late striations on shear planes and shear bands trend consistently 260° to 270° and plunge about 50° to 70° W.

Just before the overhead power supply line crosses the road Wehr – Bergalingen, a decametric boudinaged lense of porphyric ortho-mylonite (Albtal granite) within fine-grained mylonites is visible to the left. Intensely deformed granitic apophyses parallel to shear planes. Ultra-mylonitic textures. Discussion focused on the syn- to late-tectonic character of plutonism and the interaction of extension tectonics and magmatism. Shear sense criteria on the normal top-to-the-west detachment.

Stop 8 (optional)

Bergsee, 1 km N of Säckingen, small road to Günnenbach.

Mylonitic fabrics in the southern prolongation of the Wehra shear zone. Large scale boudinage of porphyric granite, microstructures and shear criteria.

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