THE VARISCAN BLACK FOREST[1]

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ABSTRACT

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In the Black Forest three large gneiss regions, consisting of paragneiss with several intercalations of other rocks, are present. Low-grade metamorphics have probably an Early Palaeozoic sedimentary age.

Dated Upper Devonian and Carboniferous up to Westphalian is strongly folded. Stephanian and Permian occur as an unconformable cover.

Two different structural regions can be distinguished, a northern one with NE trending folds, and a southern one with basin structures and more variable fold trends. Four major faults occur: the northern two underthrust towards the south; the other two in the south have a reverse movement direction.

In the two structural regions there are indications for a different metamorphic evolution.

INTRODUCTION

The Variscan Black Forest is composed of three large gneiss areas: a northernmost one is distinguished from the central one on the basis of structural differences, whilst the latter is physically separated from the southernmost one by the Badenweiler-Lenzkirch zone of Palaeozoics. Low-grade metamorphic sediments of probably Early Palaeozoic age are found at the northernmost and southernmost margins of the gneiss zone of Baden-Baden-Gaggenau and Schlächtenhaus as well as between the central and southern gneiss areas (Badenweiler-Lenzkirch). Late Variscan granitic plutonism is important, but does not show any special areal preference. Stephanian and Permian sediments show a remarkable thickness and a basin-like arrangement in the northernmost regions (with a NE-trend) and in the southernmost regions (with an E-W trend). Between these two areas there are only scattered occurrences of little extension, assigned to irregular erosional or fault-generated depressions.

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GNEISS AREAS

Knowledge about the northern and central gneiss areas is relatively good, while that of southern gneiss area is very incomplete. Consequently the data presented here will mainly concern the first two areas.

There is a lack of proven lithostratigraphic division in the gneiss areas, but first attempts are being made by WIMMENAUER (1977) and his collaborators. The most widely developed rock complexes consist of thick *uniform paragneisses* with a quartz-plagioclase-biotite mineralogy, frequently containing cordierite, sillimanite and sometimes garnet. There are also intercalations of amphibolites and calc-silicate rocks. The amphibolites (pyroxene-, garnet- and biotite-amphibolites) are mostly supposed to be of volcanic origin (tuffs, tuffites, lavas and occasional dykes). Present information does not allow a distinction to be made of these various types on the map.

Besides these uniform paragneisses several other rocktypes occur as intercalations like leucocratic rocks, blastites, orthogneisses, and mafic to ultramafic rocks.

The leucocratic sequences are commonly composed of the following lithologic members:

(1) Massive 'aplite-like' or/and quartzitic rocks. The 'aplite-like' rocks are of granitic composition. Schistosity is less

developed than in normal gneisses because of a relatively low biotite content. It is supposed that they were originally arkoses and rhyolitic tuffs, because of their interlayering with paragneisses, amphibolites etc. They are also often accompanied by quartzites. They can, as has already happened, be easily confused with orthogneisses or real aplite granites.
(2) Garnetiferous and granulitic rocks. This member comprises paragneisses especially rich in garnet. Characteristic is the presence of well oriented disc- or lense-like quartz (ribbon quartz) with a length to thickness ratio of more than 10:1. These quartzes are embedded in a mosaic of quartz and feldspar with some parallel-arranged biotite. Therefore they are called granulites (in many cases identical with 'leptynites'). A common component is kyanite, which is frequently altered to cordierite and sericite. Frequently the rocks are very finely striped; this appearance being produced by the rapid alternation of biotite-rich and quartz-feldspar bands.

Typical for the leucocratic sequences seems to be a larger component of amphibolites and lime-silicate rocks. Detailed mapping and investigation of these sequences is still in a preliminary stage, so that the actual map gives only a rough idea of their distribution and trend. At present we can distinguish four leucocratic zones:
(1) Zone of St. Blasien (with predominantly garnetiferous gneisses).
(2) Zone of Staufen-Furtwangen (with predominantly aplite-like rocks and a dense concentration of amphibolites, leptynites and lime-silicate rocks; not indicated on existing maps).
(3) Zone of Freiburg-Waldkirch (with a remarkable participation of granulitic rocks and a marked concentration of amphibolites and lime-silicate rocks).
(4) Zone of the Haslach region (with more quartzitic rocks and an exceptional abundance of graphite schists).

From the apparent differences between these sequences it seems reasonable to think that the leucocratic zones are at least partly of different age and not simply tectonic repetitions of the same lithostratigraphic units. In particular we regard the sequence of the Haslach region as a distinct one.

Another characteristic rock type in the paragneisses is *potassium feldspar blastites*. Several interpretations have been suggested for their origin.

A first occurrence is southeast of Badenweiler. Here these rocks are supposed to be formed during anatexis.

A second complex of blastites follows to a large extent the leucocratic zone of Staufen-Furtwangen. Recent investigations (ALTHERR, 1975; LÄMMLIN, 1977) have shown that the potassium-feldspar and plagioclase blastesis is closely related to and developed simultaneously in different rock types. Potassium-feldspar blasts formed both pre- and synkinematically (the earlier blasts being broken and cemented by new minerals; the latter blasts grew with a lense-like shape and are surrounded by biotites). The idiomorphic aspect of potassium feldspars cannot be seen in thin section and the grains instead reveal amoebic outlines. This zone has been the subject of various interpretations, two of which are still being discussed today. One of them requires rocks with an originally high potassium-content, while the other prefers introduction of potassium in connection with faulting activity.

A third zone of blastites, locally called durbachites, occurs near Offenburg at the southeastern border of the Oberkirch granite. The rocks are foliated with large potassium feldspars oriented more or less parallel to the foliation. The potassium-feldspar content is very high, but the blastite is similar to the ones mentioned above. Discussion still continues as to the explanation: magmatic intrusion, introduction of potassium in contact with the Oberkirch granite (perhaps along tectonized zones), or an originally high potassium content of the paragneisses. It should be mentioned that these blastites occur only along the SE border of the Oberkirch granite, and therefore they seem unrelated. Another type of blastites are *kinzigite-gneisses* (also called 'Körnelgneiss' but not to be confused with kinzigites s.s.). These are arranged in a broad NE-trending area between Waldkirch and Wolfach-Schiltach. They have a granular texture with rounded plagioclase and potassium-feldspar grains, separated from one another by micas. Some types have a uniform distribution of their blasts, giving the rock a more massive character and others occur which are parallel banded with bands that express the predominance of feldspar or mica. The majority of plagioclase blasts are posttectonic, but some which are deformed, are related to diaphtoresis and cataclasis. Garnet and graphite are also frequent components. All kinds of transitions exist to the neighbouring gneisses.

A fourth group of blastites are syenites, which consists of a very heterogeneous group of rocks, which vary with regard to composition as well as fabric. Different opinions exist about their genesis. We refer to the ideas of LANGERFELDT (1961), which are based on investigations of NE-trending syenite bodies in the region of Elzach and Wolfach (northern gneiss area). He supposes that all syenites are anatectic products derived from paragneisses, intruded to different levels of the crust and sometimes becoming so anatectic that they appear granitic. An independent potassium supply is assumed, and this supply could have happened especially in the areas of 'maximum tectonic movement during intrusion', during a complex sequence of movement and crystallization. Afterwards the different types of syenites could have been brought to the same level. The description of these rocks reminds of those in which a syntectonic introduction of potassium occurred, as its content increases to the SE in the direction of the Triberg granite. Nevertheless Langerfeldt doubts a substantial potassium exchange caused by this granite, as supposed previously by many authors. Finally there are potassium-feldspar blastites in the southern gneiss area which are called 'syenites' and 'diatexites of Wehra-Wiesetal'; they can be found between Schönau and Wehr. These rocks, very similar to those of the central area, are currently being investigated and we prefer to wait for new results before drawing conclusions about them.

Orthogneisses commonly form little irregular bodies with a definite tendency to be oriented parallel to the metamorphic layering. Most of them are of granodioritic composition with a typical lensoid texture. Less important are granitic orogneisses with parallelly arranged biotites. Possibly some of the assumed orthogneisses are derived from volcanic or sedimentary rocks. In the region north of Elzach the existing maps do not clarify this point and on the map in this paper orthogneisses are only schematically represented.

Published data about the *eclogitic* and *ultramafic rocks* (mostly serpentinites) are too scarce to indicate clear relationships. Only south of St. Blasien do ultramafics show a zone-like extension. Current investigations, however, seem to reveal several lime-silicate rocks as diaphtoritic products of eclogites (pers. comm. Baatz).

Metatexites and diatexites have been mapped only in the central and southern gneiss area (as far as Waldkirch-Elzach), while in the northern gneiss area anatexis is an unimportant phenomenon.

According to HOFMANN & KÖHLER (1973) the maximum age of mantle derivation for the Black Forest gneisses is (with Rb-Sr whole-rock analysis) 900 Ma, but TODT (1978), investigating detrital zircons in the same rocks (with U-Pb), obtained ages of 2000 Ma. Rb-Sr determinations for the strong anatexis in the central (and southern) gneiss area yielded 475 Ma (HOFMANN & KÖHLER, 1973). This result is supported by U-Pb measurements on zircon, giving an age of 480 Ma (STEIGER ET AL., 1973). The anatexis seems to be somewhat younger than the intrusion of many orthogneisses (especially of the northern area), because Todt has found intrusion ages between 500 and 550 Ma. Further 470 and 430 Ma ages have been obtained for meta-aplitic granulites from the northern gneiss area (HOFMANN & KÖHLER, 1973) which according to the present author are probably mixed ages. Ages of 510 and 410 Ma have been found from gneisses in the northern Vosges (BONHOMME & FLUCK, 1974). Taking these age data into account it seems reasonable to suggest a difference in the metamorphic evolution between the northern Black Forest and Vosges, and the central (and possibly southern) Black Forest.

MYLONITE ZONE BETWEEN GNEISS AND LOW-GRADE ROCKS (INTERMEDIATE UNIT)

The mylonite zone (the Spiesshorn series of ALTHERR & MAASS, 1977) has few outcrops at the southern border of the central gneiss area (north of Bernau, WNW and WSW of Lenzkirch). It is composed of fine-grained cleaved metagreywackes and metapelites with leptynites, amphibolites, some lime-silicate rocks and various cleaved aplites, grading into gneiss. Thin sections from new outcrops, discovered and studied by WIMMENAUER (1977), reveal gneissose rocks deformed by intense mylonitization. Sometimes these rocks apparently include tectonic lenses of metamorphic units and show retrogression. Comparable rocks are found at the northern gneiss border with small outcrops near Gaggenau. Often they are referred to as mica-schists. Such extremely mylonitized and retrogressed mica-schists also follow the northern border of the Vosgean gneisses in fault-contact with low-grade sediments. From the Vosgean example an age determination indicates 620 Ma (CLAUER & BONHOMME, 1970) for the original metamorphism of the gneiss.

LOW-GRADE METAMORPHIC UNITS (> 500 m)

These units suffered a more or less intense greenschist-facies metamorphism (biotite and chlorite zones mostly). They are lying against gneisses and are restricted essentially to two zones.

(1) Zone of Badenweiler-Lenzkirch. This consists of two metamorphic belts bordering the central and southern gneiss areas respectively, being separated from one another by non-metamorphic Palaeozoic rocks. The northern belt consists of metapelites with interbedded metagreywackes. One particcular thick horizon of metagreywackes north of Schönau contains rhyolitic bands (perhaps former tuffs or ignimbrites) and pebbles of quartz and rhyolite. These rocks with scattered pebbles were described by EMMERMAN & SITTIG (1975) as transgressive conglomerates, forming the base of the Palaeozoic above the gneiss complex (in an overturned position). However, the conglomerates never overlie directly the gneisses. These are always in contact with pelitic rocks or the contact is faulted. Hence, the conglomerates occur within the pelitic sequence. In the southern belt the metagreywackes and metapelites are intercalated with feldspar-bearing quartzites and some actinolitic rocks (probably former basic volcanics: BAATZ, 1976). Some metamorphic rocks of chlorite grade near Schlächtenhaus do not reveal any particular characteristics and are of minimal extension.

(2) Zone of Baden-Gaggenau (according to SITTIG, 1965, 1966). Metamorphism increases here from N to S (towards the gneiss). The lower, less-metamorphosed beds begin with a coloured series of slates and quartzites (locally conglomeratic) interbedded with actinolitic rocks. In the upper part banded slates and phyllites with crystalline limestones and dolomites occur.

There are neither fossils nor radiometric age determinations in the metamorphic units of the Black Forest. On the other hand, in the northern Vosges phyllites and slates occupying the same tectonic position (at the gneiss contact) have furnished ages of 425 Ma (for diagenesis) and 360 Ma (for the metamorphism) (BONHOMME & DUNOYER, 1962; CLAUER & BONHOMME, 1970). Ordovician and Silurian ages are also indicated by fossils (DOUBINGER & VON ELLER, 1963; ROSS, 1964). Despite a lack of more detailed correlations, a similar age is supposed for units of the Black Forest.

NON-METAMORPHIC UNITS

Upper Devonian (> 150 m)

Whilst non-metamorphic Middle Devonian is known in the northern Vosges, in the Black Forest only Late Devonian sediments have been found (around Schönau: WEYER, 1962). The latter are composed of greywackes, predominantly green siliceous siltstones and pelites with thin bands of red slates.

Tournaisian and lower Visean (> 300 m)

The contact between the Devonian and the Carboniferous is somewhat arbitrary, because of their similar facies. The Tournaisian and the Lower Visean consist of greywackes, dark and green siltstones or pelites with some conglomeratic breccias and intercalated cherts at the base. Less distinct are slumps, and spilitic, kerathophyric and diabasic volcanics, which are very numerous in the southern Vosges where the succession reaches more than 100 m. Both stages are proven by fossils. The sequence is restricted to the zone of Badenweiler-Lenzkirch.

Upper Visean (> 250 m)

In reality this term denotes here the lower Visean up to the uppermost Visean. The formation is only to be found in the zone of Badenweiler-Lenzkirch. The sequence is dominated by volcanics (andesite and rhyolitic effusives or tuffs) and coarse-grained sediments (arkoses, breccias and conglomerates). The sudden change between 'lower' and 'upper' Visean from marine to predominantly terrestrial conditions (indicated by *Asterocalamites* in life position) is remarkable. Fossils near Lenzkirch point to ages of uppermost Visean. There are so far no indications of Late Carboniferous rocks in this region. The same situation exists in the southern Vosges, where the sequence exceeds 1000 m.

Namurian-Westphalian (> 100 m)

There is only one isolated occurrence of Namurian and Westphalian (near Offenburg), which lies amidst granitic and gneissic rocks. It consists of terrestrial conglomerates, arkoses, and some shales with poor coal seams. So the facies changed only with respect to volcanic activity, which ceased almost completely at this time.

Stephanian-Permian (0-300 m)

Stephanian and Permian are found notably near Baden-Baden and Schlächtenhaus, but also as small outcrops throughout the Black Forest. The sediments of both time units are dominated by terrestrial breccias (fan conglomerates), arkoses with conglomeratic horizons or scattered pebbles and some coal measures. The Stephanian and the lower part of the Permian are pale-coloured and contain pebbles derived from the underlying gneiss (mainly quartz) or from the underlying sediments. The middle and upper part of the Permian sediments are generally red-coloured and often intercalated with lavas and tuffs (porphyrite and ignimbrite). Volcanic material reaches a considerable proportion in the conglomerates.

GRANITES

Excluding orthogneisses, several groups of granites can be distinguished:
(1) Foliated granites: ages point mostly to 365-330 Ma, but the ages show a considerable scatter. The gneissose Klemmbach-granite gave ages of 440 Ma and the Lenzkirch-Steina-granite furnished 400 Ma (LEUTWEIN & SONET, 1974). This latter date was revised by LIPPOLT ET AL. (1978) to 340 Ma.
(2) Biotite-granites: with ages between 330-305 Ma.
(3) Two mica-granites: with ages between 315-285 Ma.

It was approximately at the end of the anatectic and main metamorphic period that granite plutonism began. The foliated granites indicate probably a deeper intrusion-level than the other granites and are found in gneisses as well as in other metamorphic rocks (as more ore less concordant bodies). The other, unfoliated granites are always discordant to the country rock, and well differentiated.

STRUCTURES

In the northern and central gneiss areas the available data allow strike lines of the metamorphic layering to be drawn. The map only shows the large-scale pattern, and local details have been omitted.

There are clear differences between the structural configuration of the central and northern gneiss areas (compare also WAGER, 1935). North of Waldkirch-Schiltach/Triberg a NE (Variscan) trend of folds and dome-like structures dominates, while the southern region is occupied by a large basin-shaped structure with a few short WNE-trending folds in its northwestern part. There is no clear relationship between these folds and the large basin structure. The border zone of the two major structural districts is marked by a conspicuous concentration of supposed faults (giving discontinuities in trend lines). This zone is accompanied by a remarkable concentration of kinzigite gneisses and syenites (the former also present at the possible tectonic contact of the basin structure with the WNW-folds). Moreover the two districts are dissimilar not only with regard to structures but also with respect to the degree of anatexis. At the junction between the two areas near Waldkirch there are some relicts of strongly tectonized, but almost non-metamorphic, probably Palaeozoic sediments (GROSCHOPF, 1973). These circumstances could be explained perhaps by simple uplift of the central area (representing the deeper level) and/or by horizontal movements, for instance southward underthrusting of the northern gneiss area and uplift of the central gneiss. As far as data exist, the southern gneiss area appears to form an arcuate structure with varying trends: SE in the northwestern area and E-W in the southern and southeastern area. It exhibits therefore a structure similar to that of central gneiss, but situated more to the E. The structural differences between northern and central/southern areas of the Black Forest and Vosges described in this paper are clearly reflected by the magnetic and gravimetric anomalies (compare EDEL, 1978). The anatectic rocks do not occur in the cores of gneiss domes as seen in the profiles. The different kinds of anatectic and non-anatectic complexes occur as parallel and often interlayered units. Diatexites have sometimes direct contacts with non-anatectic paragneisses. The profiles do not show a definite interpretation. It concerns either differences in the composition of the original material, or there is a repetition due to recumbent folding. More work is needed to solve this question.

HEIZMANN (1965) presented orientation diagrams for layering, lineations and fold axes in the gneisses. According to his data the layering of the northern gneiss areas (Waldkirch, St. Peter, Elzach, Haslach) is very uniform and flat-lying (dips 10-30°). In the central gneiss area Freiburg, Höllsteig, Feldberg, Todtnau) the layering has a more complicated structure with a general steepening at the southern and southeastern margin. In contrast to the various orientations of the layering, the lineations and fold axes of the two gneiss areas show a broad scatter, but with a clear maximum in a NW direction. HEIZMANN (1965) presented 21 diagrams of quartz c-axes. Most quartz c-axes are oriented in the layering and normal to the lineation, and have a NE direction. Near the southern border of the area the maximum of the quartz c-axes is parallel to the intersection between a foliation and the metamorphic layering.

There is a great difference between the rounded open structures of the flat-lying gneiss, the tight, steep folds in the low-grade metamorphics, and the Devonian and Carboniferous sediments of Badenweiler-Lenzkirch. The stereograms (MAASS, 1974) indicate upright structures without a significant vergence, except in the neighbourhood of faults. Their axes are parallel to the margin of the central gneiss-block, namely E-W, but change orientation where the boundary turns to the NE. In the Palaeozoics of the southern Vosges the situation is more or less similar. In spite of the existence of various structural directions, E-W and NW-structures seem to predominate. This contrasts strongly with northern regions, where the structures in the Palaezoic as well as in the gneisses have the typical Variscan NE trend. Even the young 'post-orogenic' granites follow the same characteristic trends.

OROGENIC EVOLUTION

There is much uncertainty concerning the early history of the area. Caledonian folding and metamorphism involved Precambrian sediments, but it is difficult to judge, whether the orthogneisses which intruded 550-500 Ma ago are related to the Cadomian or to a later event. They were certainly affected by several tectonometamorphic events from Ordovician up to Devonian time according to Rb-Sr data. We are inclined to interpret the relations between the two gneiss areas as a southward underthrust of the northern gneiss area. The central gneiss block terminates in the south with a steeply northward dipping fault against the Palaeozoics of Badenweiler-Lenzkirch. This fault could either be interpreted as another, but northward dipping underthrust, or as a simple reverse fault. A notable uplift of the northern block occurred in any case from Ordovician up to Carboniferous time. Marine Tournaisian and lower Visean deposits contain many slump complexes (especially in the southern Vosges), partly with metamorphic and gneissose components. In 'late Visean' time a sudden increase in volcanic activity took place combined with molasse sedimentation (partly detritus from foliated granites). The quantity of Variscan plutonic rocks implies an important anatectic activity. All Variscan granites, the older foliated ones as well as the younger postorogenic ones, are now to be found in the same level as the anatexites, dated by the Rb-Sr method as Ordovician. If this age is correct there is no genetic relationship between the anatexites and the Variscan granites. Hence the corresponding Variscan anatexites are still at greater depth, implying that the Variscan granites intruded into a higher level. These facts indicate a vertical uplift, having affected especially the central and southern gneiss blocks. Another southward-dipping underthrust near Baden-Baden carried weakly metamorphosed older Palaeozoics under the northern gneiss area. In its continuation in the northern Vosges the metamorphism near the gneiss border (and the underthrust) appears to be older (about 360 Ma) than folding 10 km away from it (the Devonian-Carboniferous complex probably having been deformed after the Visean).

South of the zone Waldkirch-Triberg/Schiltach the shape and directions of structures are variable. This is valid for gneisses as well as for the Devono-Carboniferous sediments. The structural trends are dictated partly by gneiss-block margins (as in the narrow zone of Badenweiler-Lenzkirch) or have no particular orientation (as in the southern Vosges). In the latter region one gets the impression that the predominance of fold tectonics is somewhat replaced by fault tectonics (especially strike-slip faults). This irregular pattern can perhaps be understood, if one assumes a rather stable block between opposing underthrusts with diverging trends.

There is some difficulty involved in determining the age of folding. Not a single occurrence in the Black Forest (or Vosges) is known where metamorphic 'older Palaeozoic' grades into Devonian-Carboniferous sediments. Both units show in the zone of Badenweiler-Lenzkirch the same deviation from the Variscan NE-trend. No large-scale unconformities within the Devono-Carboniferous complex have been observed although there are local erosions and unconformities. We oppose firmly the existence of a 'Bretonic phase', which is mentioned by many authors. Also a widespread Sudetic phase seems to be absent. Unfortunately there are no outcrops showing the complete sequence from Visean to Upper Carboniferous. Isolated Namurian-Westphalian deposits occurring in the northern gneiss area show a similar facies and structural style as the Visean. Their folding, the only one determined with good accuracy, happened at the end of Westphalian stage.

It seems reasonable to propose the following sequence of events:

(1) Ordovician anatexis before compression of the higher levels;

(2) Uplift of the gneiss blocks causing local metamorphism and deformation near the fault zones;

(3) Folding of the Palaeozoic sediments due to lateral compression. The major faults often remained in some way active during Stephanian up to Permian time, resulting in troughs or in graben-like structures.

In the regions between such major faults there are scattered occurrences of Permo-Carboniferous deposits confined to erosional depressions or local faults.

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