

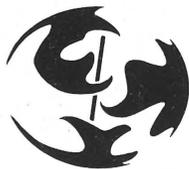
# A GEOLOGICAL CROSS-SECTION THROUGH THE VARISCIDES IN THE GERMAN DEMOCRATIC REPUBLIC (EASTERN ERZGEBIRGE, CENTRAL SAXONIAN LINEAMENT, SAXONIAN GRANULITE COMPLEX, HARZ MOUNTAINS)<sup>1</sup>

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## ABSTRACT

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Two cross sections of the Variscides in the territory of the GDR are described. The section of the Saxothuringian Zone (Eastern Erzgebirge, Central Saxonian Lineament, Granulite Complex) includes deeper tectonic levels with metamorphic rocks of Barrow type (Erzgebirge) and granulite facies (Granulitgebirge). In shear zones in the Central Saxonian Lineament low-grade, high-pressure rocks with a tendency to glaucophanitic facies occur. Intercalated mafic and ultramafic rocks are considered to be tectonically displaced relics of the upper mantle. The cross-section of the Rheno-Hercynian Zone (Harz Mountains) demonstrates a higher tectonic level with tectonic structures and rocks typical of slate regions and a low to very low grade of metamorphism. Whilst in the Saxothuringian Zone the vertical component is stronger, horizontal movements directed towards the margin of the orogen dominate in the internal Rheno-Hercynian zone. Therefore in the Harz a strong NW-vergence and gravitational sliding is exhibited (i.e. olistostromes and downsliding nappes).



## INTRODUCTION

The Variscides in the territory of the German Democratic Republic belong to the Saxo-Thuringian and the Rheno-Hercynian zones of the Rhenids. The geological-tectonic structure of these two zones show important differences, caused primarily by their different positions in the tectogene. The geotectonic development at the time of geosynclinal formation was differentiated by BRAUSE (1970) with the terms Saxotype and Siegenotype. Saxotype structures are characterized by small regions each with reduced sedimentary thickness and a geotectonic development controlled by stable basement blocks. They dominate in the Saxo-Thuringian Zone and the Mid-German Crystalline Rise. The Siegenotype

structures of the Rheno-Hercynian Zone are shaped by an essentially independent geotectonic development with migration of basin formation and structural activity (BRAUSE, 1973). The transverse subdivision of the Rhenids in the GDR territory is produced by structural highs (Erzgebirge, Granulite Complex, Mid-German Crystalline Rise), basins (Saxo-Thuringian Trough, Rhenish Trough), and lineament zones (Central Saxonian Lineament, northwestern part of Mid-German Crystalline Rise). The two lineament zones have a NW vergence in the suprastructure and are connected with deep-seated fractures (SCHOLTZ, 1930; WATZNAUER, 1965; STETTNER, 1972; NEUMANN, 1975; AHORNER & MURAWSKI, 1975; WEBER, 1978). An association with ultrabasites has been ascertained previously only for the Central Saxonian Lineament (ROESLER ET AL., 1970). This paper discusses two examples in the Rhenids (Fig. 1): (1) the Eastern Erzgebirge, Central Saxonian Lineament and Granulite Complex (MATHÉ, Fig. 2) and (2) the Harz Mountains (SCHWAB, Encl. I).

Due to the sedimentary cover, the structure of the crystalline rise is not discussed. The limited number of exposures (Kyffhäuser: NEUMANN, 1968) and drillings (BEHR, 1966) does not yet permit any profile construction.

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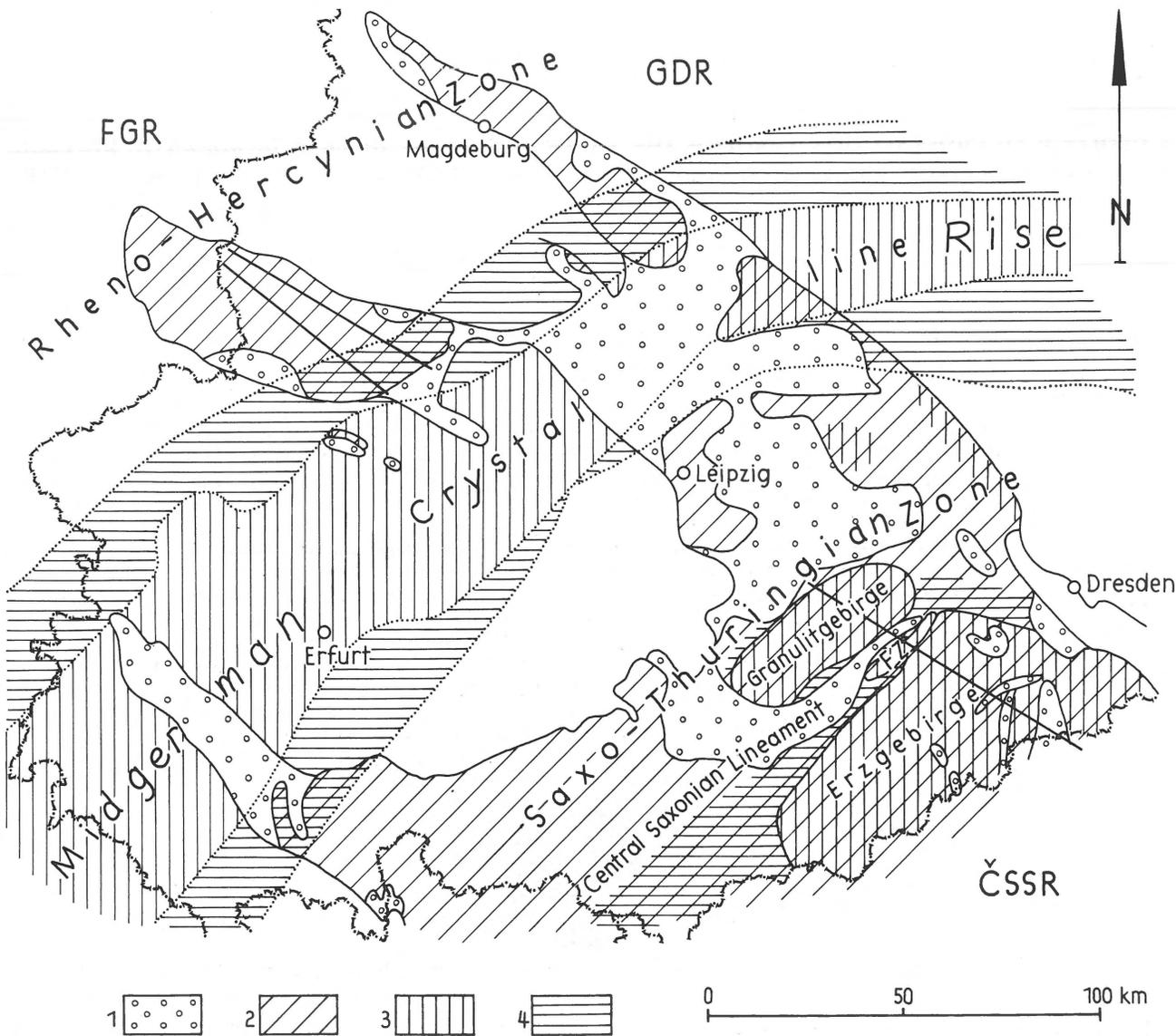


Fig. 1  
 Map of the Hercynides in the southern part of GDR (after Paech, 1975).  
 1 = molasse; 2 = stockwork of slate mountains; 3 = stockwork of crystalline rocks; 4 = phyllitization.

**EASTERN ERZGEBIRGE - CENTRAL SAXONIAN LINEAMENT - GRANULITE COMPLEX**

The cross section (Fig. 2) intersects a zone of 60 km width of the eastern Erzgebirge. The metamorphic rocks in this part of the Erzgebirge consist mainly of paragneisses, originally deposited, according to LORENZ & HOTH (1964) and HOFMANN (1974), in a late Proterozoic trough. A Cambro-Ordovician meta-sedimentary complex overlying the Proterozoic rocks outcrops principally in the western Erzgebirge. In the eastern part metamorphic rocks are preserved as relics in a tectonic position only (phyllite-micaschists of Hermsdorf-Rehefeld, the phyllite-micaschist series at the western border of the Erzgebirgian gneisses and the mantle of the Granulite Complex).

The gneisses of the eastern Erzgebirge belong to the complexes of Freiberg and Glashuette-Lauenstein, which form slightly undulating anticlinal structures. They are divided lithologically, following HOFMANN (1974), into a lower and an upper Erzgebirgian series. The lower series (= Osterzgebirgische Serie of the recent nomenclature) is characterized by a monotonous sequence of gneisses with rare intercalated amphibolites, calc-silicate rocks and quartzites. The upper series (= Pressnitzer Serie) is composed of a lithologically varied sequence, consisting of alternating paragneisses, orthogneisses, and amphibolites. The eastern Erzgebirge, unlike the western Erzgebirge is characterized by:  
 (1) strong uplift and denudation, resulting in the virtual absence of the younger micaschist-phyllite series of Cambrian and Ordovician age;

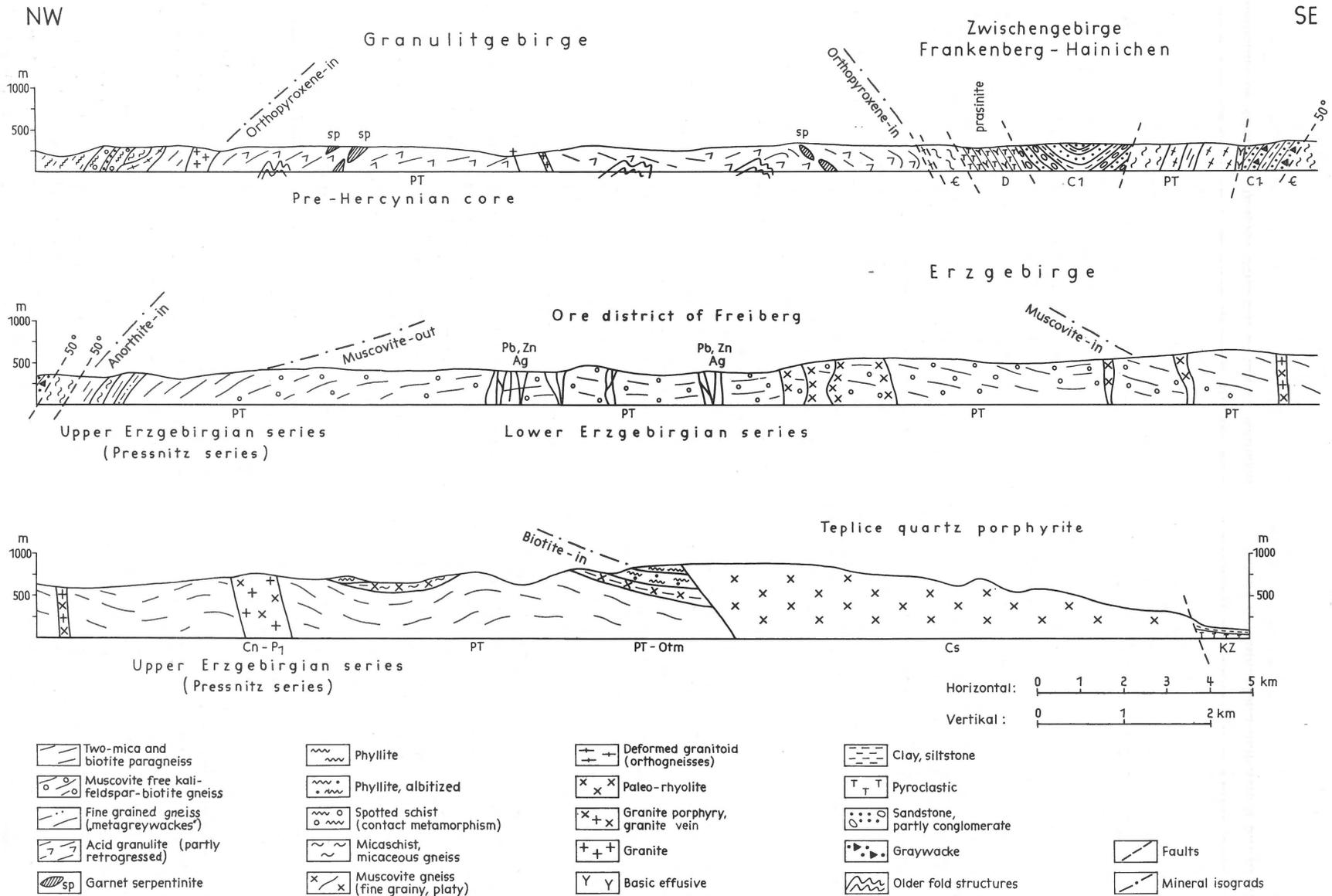


Fig. 2  
Cross-section of the Saxothuringian Zone between the Eastern Erzgebirge and the Granulite Complex (by G. Mathé).

- (2) high geothermal gradients. Regional anatexis of the gneisses of Glashuette-Lauenstein;
- (3) presence of cordierite instead of almandine garnet in the anatectic parts of the Lauenstein-Fuerstenwalde gneiss;
- (4) absence of great masses of syntectonic and posttectonic granites;
- (5) frequency of posttectonic acid volcanics (rhyolites);
- (6) a flat schistosity of the gneisses defining a large open anticlinal structure (the brachyanticline of Freiberg);
- (7) discordancy of lithostratigraphic and metamorphic zonation;
- (8) presence of isolated flat-lying phyllites and micaschists (complexes of Hermsdorf-Rehfeld and Nassau) of which the tectonic and stratigraphic position in relation to the gneisses is still under discussion;
- (9) steeply dipping late Proterozoic gneisses of the Pressnitz Series at the Central Saxonian Lineament zone (at the eastern margin of the 'Zwischengebirge of Frankenberg-Hainichen').

In the western Erzgebirge the mineral isograds generally follow the lithostratigraphic units. Here a continuous sequence of prograde metamorphosed rocks is developed, beginning with the phyllites of the Frauenbach Series (probably Tremadocian) in greenschist facies and ending at the top of the muscovite-biotite-plagioclase gneisses of Annaberg (probably latest Proterozoic) metamorphosed in the kyanite-almandine amphibolite facies. The thickness of this sequence is 3500 to 4500 meters (LORENZ & HOTH, 1964; HIRSCHMANN ET AL., 1968). From these data a geothermal gradient of 55 to 70 °C has been deduced (HOFMANN ET AL., 1979).

Two types of regional metamorphism are observed in the eastern Erzgebirge. In the northwestern area (Freiberg gneiss complex) a medium-pressure facies (Barrow type) like that of the central and western Erzgebirge is developed, while in the southeastern area (gneisses of Lauenstein-Fuerstenwalde) a high-temperature metamorphism took place recognizable by the presence of cordierite and by a regionally extensive anatexis of the gneisses. Some authors suggest a poly-metamorphic history for the eastern Erzgebirge (e.g. BRAUSE ET AL., 1968). This, however, cannot be proved by any discontinuity of the metamorphic facies. Geological and geochronological data suggest a time span of the metamorphism from Late Ordovician to Middle Devonian (HOFFMANN ET AL., 1979). The Central Saxonian Lineament zone is characterized by strong compression and imbrication. The cross section (Fig. 2) intersects this synclinal structure for 7 km in the region of the so-called Zwischengebirge of Frankenberg-Hainichen.

The rocks of this zone consist of an incomplete sedimentary succession of Ordovician, Silurian, Devonian and Early Carboniferous age, partly of abnormal facies (KURZE, 1966), and of ortho- and paragneisses with a tectonic contact with the non-metamorphic Palaeozoic rocks. Some of the Middle and Late Devonian volcanics (diabases, spilites, keratophyres) show signs of a low-grade high-pressure metamorphism with a tendency to the glaucophane facies by blastesis of barroisitic

amphiboles. In the older literature these rocks are called prasinites (WEG, 1930; MATHÉ, 1977).

The Saxonian Granulite Complex (Granulitgebirge) occupies 22 km of the cross section. It shows an anticlinal structure, the limbs of which are built up by gneisses, mica-schists, and in the NW by phyllites. These rocks are lithologically comparable with those of the Erzgebirge and have been thought to be of late Proterozoic to Tremadocian age. Underlying the gneisses in the core of the anticline occur rocks that have preserved granulite-facies characteristics, but they have been subjected to upper amphibolite-facies metamorphism superimposed during the Variscan orogeny (BEHR, 1961). Leucocratic Al-rich rocks (granulites s.s.) rhythmically alternating with thin layers of mafic composition (pyroxene-granulites, pyriclasites) suggest a sedimentary origin (WATZNAUER ET AL., 1971), the estimated age of which is about 1000 Ma (NEUMANN, 1975). Intercalated mafic and ultramafic rocks of peridotitic, pyroxenitic and gabbroic composition, which have been affected by granulite-facies metamorphism, are considered to be tectonically displaced relics of the upper mantle (MATHÉ, 1969). At present these rocks appear as garnet-bearing serpentinites and pyroxenites.

The diapir-like uplift of the granulite complex started in the Ordovician and ended in the Dinantian. The contacts with the overlying gneisses are developed as shear planes. Acid and mafic rocks were intruded into these contacts and were deformed during a discontinuously occurring uplift. The granulite complex as a whole can be regarded as a Precambrian tectonic unit reworked by the later Variscan orogeny (BEHR, 1961; WATZNAUER & BEHR, 1964).

## HARZ MOUNTAINS

A cross-section of the Harz Mountains shows the structure of the interior part of the Variscan externides, lying at the NW flank of the Mid-German Crystalline Rise. The regions of the Harz Mountains within the G.D.R. territory are termed the Lower and Central Harz (SCHWAN, 1956) and can be grouped into the tectonic units (Encl. I) shown in table I.

The geosynclinal sequences accumulated in the inner Rhenic trough. From the Cambrian to the Silurian uniform sedimentation occurred in contrast to the Saxo-Thuringian with its partial troughs. The shallow-water facies in the Ordovician of the Wippra anticlinorium corresponds with the quartzose Graefenthal strata in the Thuringian trough. The Silurian slates occurring at various places in the Harzgerode synclinorium are allochthonous, and slid down under the influence of gravity. Their primary deposition took place in the region of the Mid-German Crystalline Rise which was not yet a swell in the Silurian. In the Devonian, the region was subdivided by swells within the trough (LUETKE, 1978). It can be demonstrated that the swells in the Upper and Central Harz, consisting mainly of mafic volcanics, were still in exist-

Table I Tectonic units of the Lower and Central Harz.

Lower Harz:	Wippra anticlinorium	- epizonal metamorphic series
	Harzgerode synclinorium	- olistrome complex
	Tanne unit	- parautochthonous greywacke complex
	South Harz-Selke syncline	- nappe complex
Central Harz:	Elbingerode complex	- reef complex
	Blankenburg anticlinorium	- slate complex

ence, whereas in the Lower Harz they were obliterated in the Dinantian by submarine slides (olistostromes). The reef of the Elbingerode complex (Givetian-Famennian) was constructed on the submarine volcanoes (Eifelian, Givetian) of the Central Harz swell. The so-called Hercynian limestones (Emsian to Frasnian: RUCHHOLZ, 1972) developed on the Lower Harz swell and the NW flank of the Mid-German Crystalline Rise. In the troughs, clastics, especially pelites, were deposited (BORS DORF, 1978). The flysch commences with a calcareous turbidite sequence (Late Devonian) (LUETKE, 1976). Temporally and spatially three greywacke series followed successively: South Harz greywackes (Famennian II $\beta$ , Tanne greywackes (Dinantian II-III $\beta$ ) and Culm greywackes (Dinantian II-III $\gamma$ ) (LUTZENS & PAECH, 1975). In the Dinantian subaquatic mud flows detached from the slopes resulted in olistostromes (Harzgerode, Huettenrode, Bodetal olistostrome). Their age is still disputed. Apparently part of these originated after deposition of the Late Devonian greywackes, and another part during the formation of the Early Carboniferous greywackes (SCHWAB, 1977). According to LUTZENS (1978) the geosynclinal sedimentation ends with these olistostromes.

The diabase-spilite volcanicity (ROESLER & WERNER, 1978) finished when the sedimentation of greywackes started. The main direction of the mud-flow transport is similar to the S to N movement of the structures. Before the main folding, more gravitationally sliding masses originated: nappes (South Harz nappe, Selke nappe) and blocks (East Harz Silurian region, Zilberbach mass) (SCHWAB, 1979). Along the sole of the sliding masses a tectonic breccia was formed in the Stiege beds (KREBS & WACHENDORF, 1974). The overriding distance could lie anywhere between 10 (LUETKE, 1978) and 20 km (SCHWAB, 1976). The allochthonous and autochthonous complexes were in many places folded and internally deformed by the compression which followed the nappe formation. Rock series of different competency were imbricated on existing sliding surfaces (the allochthonous series), or, in case of an intact sedimentary sequence, folded and internally deformed (the autochthonous series). A distinction between the Harzgerode olistostrome and the tectonic breccia in the underlying rocks of the South Harz-Selke nappe is difficult, due to later tectonic

overprint (LUETKE, 1978). The fragments of the breccias and the olistolites became phacoidal in shape elongated in the direction of tectonic transport and oriented into the general foliation. The age of the olistolites increases upwards so that allochthonous blocks in the East Harz consisting of Silurian rocks form the cap of the olistostrome.

Folding started in the region of the Mid-German Rise during the Late Devonian and reached the Upper Harz in the Namurian A-B. The gravitative movements of the nappes probably occurred during the Dinantian III to Namurian period. The derivation from the south of the South Harz nappe is quite certain (SCHWAB, 1976), but for the Selke nappe it is dubious (LUETKE, 1978; LUTZENS, 1978). A gradual transition exists from the gravitational sliding tectonics to compressive orogenic folding, imbrication and schistosity development (REICHSTEIN, 1965). The two processes reflect the progress of the Variscan movement from SE to NW.

The result of all these tectonic processes is the discordant stockwerk tectonics, typical of the Harz. Four different types of deformation, dependent on the properties of the rocks and the depth of burial during the orogenesis can be distinguished: (1) open to close folds of bedding with cross cutting axial-plane cleavage; little vergence; (2) tight folds also with axial-plane cleavage; moderate vergence; (3) close to tight folds with a flat-lying bedding cleavage ( $S_1$ ), local kink bands ( $S_2$ ), close to tight; strong vergence; (4) close to tight folds with steep bedding cleavage ( $S_1$ ), marked  $S_2$  cleavage; slight to moderate vergence.

According to the stratigraphy we can distinguish four tectonic levels:

- (1) structural level of the molasse sediments: autochthonous, not folded;
- (2) structural level of the flysch sediments: autochthonous to parautochthonous, folded and internally deformed;
- (3) structural level of olistostromes and sliding nappes: allochthonous, folded and internally deformed;
- (4) structural level of the pre-Early Carboniferous rocks: autochthonous, folded, internally deformed and with cleavage.

The regional units recorded in enclosure I can be correlated to the stages of deformation and structural levels listed above as follows: Wippra and Blankenburg anticlinoria belong to (4), the deepest level. The rocks of the Wippra anticlinorium belong to deformation type 4 (phyllite tectonics). The anticlinorium is characterized by cleavage folds and a steep vergency fan (NW-SE). The rocks occur in greenschist facies (higher-temperature epidote-muscovite-chlorite-stilpnomelane facies). The Ordovician to Late Devonian phyllites consist of the paragenesis quartz-muscovite-illite-chlorite-albite-rutile-hematite. Because of the occurrence of carpholite, stilpnomelane, and pumpellyite the conditions for the metamorphism of these rocks can be estimated. Carpholite is stable under pressures up to 3 kb only and temperatures to a maximum of 420 °C. The paragenesis quartz-carpholite-chlorite developed in zones of low pressure during late-stage stretching (LÖFFLER & SCHWAB, 1979), whilst otterlite formed during an earlier stage of deformation. Starting from a geothermal gradient of 50-60 °C/km and a pressure gradient of 300-400 bar/km one can estimate a depth of burial for the rocks of the Wippra anticlinorium of at maximum 6-8 km (350-400 °C, 1.8-2.4 kb).

In the Blankenburg anticlinorium the type of deformation (3) dominates, that has NW-vergent folds and subordinate imbricate structures. The anchimetamorphic mineral facies here belongs to the low-temperature muscovite-chlorite facies, the depth of burial was 4-6 km (250-350 °C, 1.2-1.8 kb). As a result of the competent behaviour of the reef limestones of the Elbingerode complex (more than 500 m thick) only type (1) of deformation occurs. In the enclosing rocks of the complex the deformation is assigned to type (3) (Huettnerode olistostrome) and (1) (Culm greywackes). The Harzgerode synclinorium belongs to the structural level (3) and type (3) deformation dominates. The depth of burial produced the conditions for the muscovite-chlorite facies. The greywackes of the Tanne unit, the South Harz and Selke greywackes and the Culm greywackes form structural level (2) and show deformation type (1).

In general, shears exist between the tectonic units dipping gently SE (SCHWAN, 1956). For the Tanne unit a parautochthonous origin is supposed (SCHWAB, 1979). A steeply dipping disturbance is assumed at the termination of the Wippra anticlinorium, possibly connected with the fault zone at the northern flank of the Mid-German Crystalline Rise (Hunsrueck fault: AHORNER & MURAWSKI, 1975).

The late Variscan structures of the Harz are closely related with the posttectonic magmatites during the molasse stage (BENEK ET AL., 1973). From the late Westphalian to the Autunian the strike of the volcanic fissures for the subsequent magmatites and volcanites changed from ENE via N to NW. The predominantly meridional direction of these structures can be recognized by the NNE trending intrusion of the late Late Carboniferous granites (Brocken and Ramberg plutons) and by the trend of the Early Permian rhyolite and andesite veins.

## CONCLUSIONS

The cross-sections of the Central-German Variscides demonstrated in the Eastern Erzgebirge, Central Saxonian Lineament, Granulite Mountains and Harz Mountains show individual aspects of the mountain building. The different lithofacial and tectonic structures are substantiated not only by the erosion level of today (in the Erzgebirge and Granulite Mountains the crystalline basement rocks, in the Harz Mountains the structural level of slate tectonics), but also by the position in the orogen (SENCENKO & SCHROEDER, 1977). Whilst in the Saxo-Thuringian zone the vertical component is markedly stronger, a horizontal movement directed towards the margin of the orogen dominates in the inner Rheno-Hercynian zone (PAECH, 1977). The causes for this different behaviour have been interpreted on the strength of different basic geotectonic concepts (BRAUSE, 1978; KREBS & WACHENDORF, 1974; SCHROEDER, 1977; WALLISER, 1977; WEBER, 1978; ZWART & DORNSIEPEN, 1978). The plate-tectonic model is contradicted by the character of the Mid-German Crystalline Rise as a structural high (MATVEVSKAJA & MOEBUS, 1977) and by the absence of a high-pressure mineral facies at its northern border.

An interpretation of the conditions in the Harz Mountains in terms of a subduction zone dipping to the south (ANDERSON, 1975) cannot be proved. The potassium-rich, shoshonitic volcanites in the Rheno-Hercynian zone described by ROESLER & WERNER (1978) should not be looked upon as an island-arc association (DUPUY ET AL., 1977). The assumption of a Benioff zone, dipping to the south against the Palaeotethys (LORENZ, 1976) seems more probable. Folding and metamorphism of the Rheno-Hercynian and Saxothuringian zones would then have to be interpreted as collision (BRAUSE, 1978) or as a consequence of subfluence (WEBER, 1978), both directed towards the south. The individual particularities of the two zones could be explained by the thickness of the sialic crust, which increases from north to south.

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