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THE POST-CADOMIAN EARLY PALAEOZOIC TECTONOSTRATIGRAPHY OF GERMANY
(Attempt at an analytical review)

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(4 figures)

ABSTRACT.- Current knowledge is presented on the structural-stratigraphic development of post-Cadomian to earliest Silurian depositional environments and the palaeogeography of western and eastern Germany. The German segment of Late Proterozoic Europe belonged to an outboard rampart of the Afro-Mediterranean portion of Gondwana during an Early Palaeozoic interval of crustal extension after Cadomian (late Riphaean) multi-plate collision. This extensional crustal thinning produced assemblages of rifted microplates during Vendian to Early Ordovician times, but basaltic volcanics emerged only within incipient localized grabens. Mid-Palaeozoic extensional movements concentrating along the «Moldanubian/Saxothuringian» interface started with Late Ordovician or Early Silurian foundering of a narrow basin which developed into the incipient Rheic Ocean during the deposition of Silurian graptolitic alum shales and cherts in an initial fore-arc setting. Back-arc Variscan basins developed in the Devonian and Early Carboniferous. Upon completion of an anti-clockwise rotational course, the East European Platform docked with the North German microplate of peri-Gondwana along the Tornquist Lineament during Late Ordovician to Early Silurian time. An attempt at an event-stratigraphic analysis for the Vendian-Early Palaeozoic deposits of Germany is proposed.

INTRODUCTION

The pre-Variscan development of Germany is not only very largely concealed by post-Variscan cover but most significantly by Variscan crustal telescoping and disturbed by metamorphism, which assembled a collage of post-Cadomian to Early Paleozoic fragments of the upper crust (W. FRANKE *et al.*, 1990) in Central Europe. Only thick massifs of largely pre-Cadomian consolidated crust reveal glimpses of the history of this pre-Variscan collage. Examples are: the Midland-Brabant Massif, North German, Lusatian-North Saxonian, and Thuringia-Bohemian («Tepla-Barrandian» or «Perunica») Massifs and subsurface «wrench» massifs (e.g. Ringköping-Fyn, Rügen-Pomorze, and Swietokrzyskie Massifs) along the pre-Devonian Tornquist-Teisseyre Lineament, as well as Variscan tectonic «rafts» of 10-100 km^3 size, such as the Münchberg, Frankenberg, Wildenfels, and Granulit-«Zwischengebirge»-massifs. In a few cases, such as on the Bohemian and Lusatian-North Saxonian crustal blocks parts or even entire supra-cratonal basins (e.g. the «Barrandian Basin») succeeded in riding, piggy-back fashion, through the deformational stress history of the Variscides relatively unharmed, whereas other obducted slivers of Variscan basement formed tectonic «comet-halos» around dislocated raft-like bodies of the minor «Zwischengebirge» and thus also preserved at least parts of their stratigraphic histories (W. FRANKE, 1989). Although not yet conformed by subsurface data, it appears reasonable to assume that beneath the folded and thrust Devonian-Carboniferous cover of the Rheinische Schiefergebirge a less deformed southeastern extension of the Midland-Brabant Massif may be hidden, as indicated by the upthrust slices of Ordovician and Silurian rocks in the Remscheid-Altena and Ebbe Anticlinoria. Whereas starved-basins formed during the Ordovician extensional evolution of the Rhenish-Welsh Basin, the extensively deposited black shales later functioned as ductile horizons for northward thrusting of the Variscides. Further to the east, however, an elevated shelf and basin development formed during the Cambro-Ordovician in Thuringia, Saxony, and the

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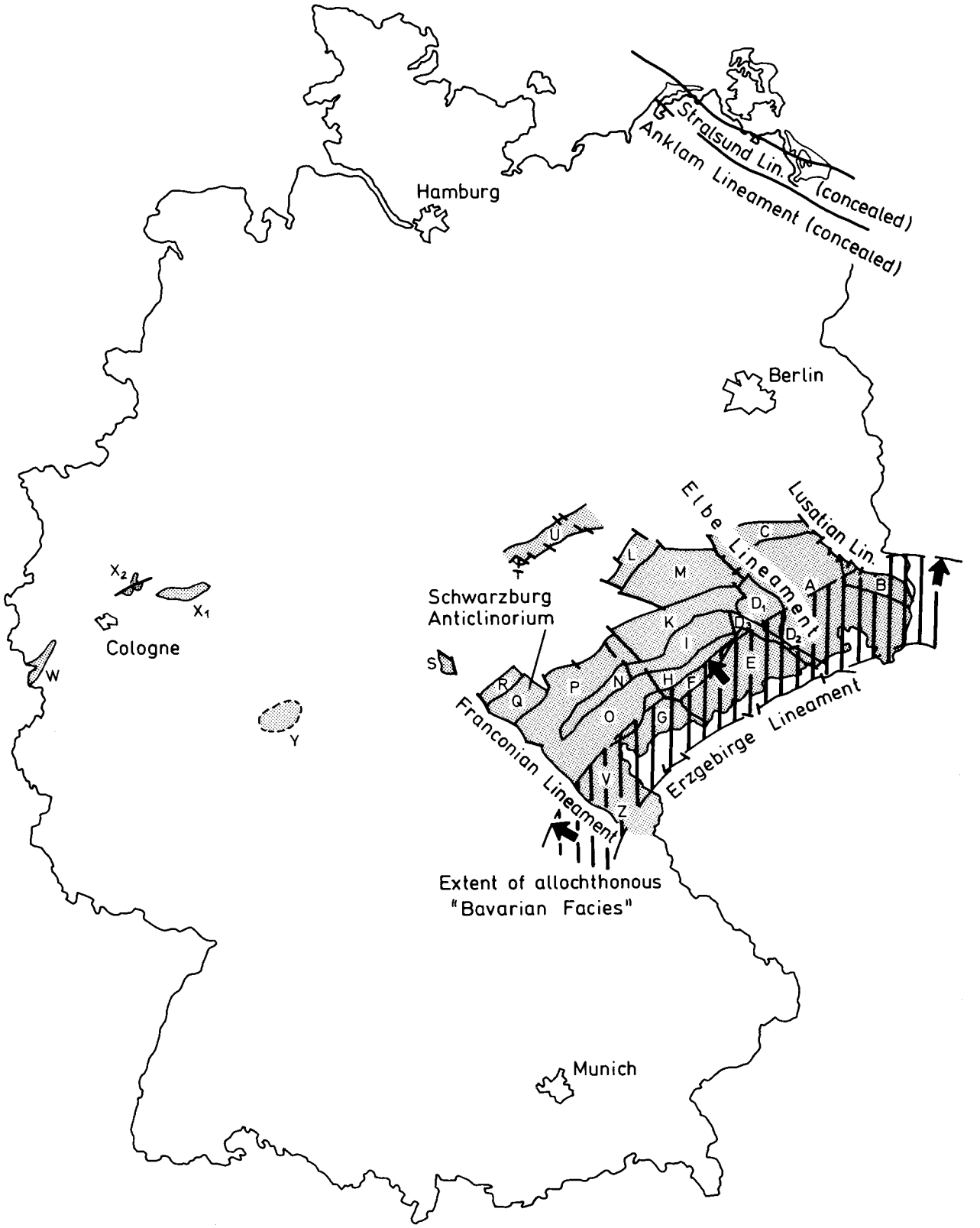
Hamburg
Stralsund Lin. (concealed)
Anklam Lineament (concealed)
Berlin
Elbe Lineament
Lusatian Lin.
Schwarzburg Anticlinorium
Cologne
Franconian Lineament
Erzgebirge Lineament
Extent of allochthonous "Bavarian Facies"
Munich
U
C
L
M
A
B
K
I
E
P
N
H
F
R
Q
O
G
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X1
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D1
D2
D3

Leipzig-Doberlug area (region C in Fig. 1) which did not permit similar listric thrust movements and decollement structures parallel to the northern Variscan front. Eastern Germany is in contrast dominated by incipient rift zones and basins which opened during Vendian to Ordovician times usually along a WSW-ENE or, more rarely, along NW-SE trends. The resulting rhomboidal structural framework apparently became reactivated during late Variscan (Rotliegend, Early Permian) and Cretaceous to Recent block movements, and obviously now controls the subsurface mosaic of most of eastern Germany.

Although major structural differences may have pre-set the depositional histories of the post-Cadomian shelves and basins in central, western and southern Europe, there appears to have existed overall similarity of climate and environment across this «outboard» terrane of Gondwana (between the central Sahara and the English Lake District) during Vendian to Late Ordovician time. Contrary to some palinspastic reconstructions (e.g. of PERROUD *et al.*, 1984, P. ZIEGLER, 1984, W. FRANKE, 1989, PARIS & ROBARDET, 1990) there is no evidence to support the existence of major active oceanic rifts nor of oceanic arc systems anywhere palaeogeographically between the North African portion of Gondwana and the Iapetus-Tornquist-Teisseyre Lineaments including virtually the entire region of «Variscan» Europe during pre-Silurian time, possibly with the exception of broader rifts in marginal cratonic settings, e.g. in France (MATTE, 1986). All indications are that a Cadomian consolidated basement existed as a (neo-) northern rampart of Gondwana in western and central Europe, which became largely affected by rifting and subsequent «fracturing» into small localized basins and platforms during the Vendian to Early Ordovician. The small basins received locally derived sediment together with volcanics and volcanoclastic debris. Beginning with the Llandovery transgression and during oblique strike-slip docking of the Baltic-Podolian (East European) Shield along the Tornquist-Teisseyre Lineament, this Early Palaeozoic outboard rampart of the Gondwana continent began to founder and/or detach from Gondwana, probably along an axis parallel with the Moldanubian/Saxo-thuringian Lineament of the Variscides. There an elongated basin may have developed during the Silurian into the initial stage of the Variscan trough (or the Rheic Ocean), either within a crustal thinning belt or by extensive crustal rifting. Regardless of the many debated Variscan orogenic models (ZWART & DORNSIEPEN, 1978, P.A. ZIEGLER, 1984, BEHR *et al.*, 1984, W. FRANKE, 1989) and the apparent telescoping of pre-Variscan crustal elements in Central Europe, the Vendian to Ordovician depositional framework seems to have been intimately linked to the contemporaneous depositional record in structurally much less disturbed areas of northern Africa, especially in Libya and the Magreb region (KLITZSCH, 1981, DESTOMBES *et al.*, 1985, LEGRAND, 1985a, 1985b).

The subsequent text outlines, probably for the first time in English, the tectonostratigraphic record of Vendian to Late Ordovician deposits in the German part of Central Europe. The discussion of relevant depositional systems is drawn from numerous local and regional reports from many geographical areas, especially of eastern Germany; these regions being shown in Figs. 1 and 2. The stratigraphic history will be outlined along the generalized sections as shown in Fig. 3. Only limited attention is given to medium to high grade metasediments of the Moldanubian Zone in the Oberpfalz and of the Fichtelgebirge (NE Bavaria), Vogtland and Erzgebirge regions of Saxony (Fig. 1, regions Z, V, G and E). The biostratigraphic resolution within these metasediments is very incomplete, and stratigraphy in these areas is largely based on lithological comparisons with similar but less metamorphosed suites in the adjacent Saxo-Thuringian and Rhenohercynian Belts (sensu KOSSMAT, 1927).

Fig. 1: Map of the (united) Federal Republic of Germany illustrating all major outcrop (incl. partially covered) locations of Vendian to Silurian rocks :

- A - Lusatian Platform ("Lausitz Platte")
- B - Görlitz Synclinorium ("Görlitzer Schiefergebirge")
- C - Doberlug-Torgau Synclinorium
- D1 - Granite Massif of Meissen
- D2 - Elbtal-Schiefergebirge
- D3 - Nossen-Wilsdruff Complex
- E - Erzgebirge Anticlinal Zone
- F - Erzgebirge Northern Marginal Zone
- G - Vogtland-Erzgebirge Anticlinal Zone
- H - Central Saxonian Synclinal Zone
- I - Central Saxonian Anticlinal Zone incl. "Granulitgebirge" Allochthonous Complex
- K - North Saxonian Anticlinal Zone
- L - Delitzsch-Synclinorium
- M - Leipzig-North Saxonian Anticlinal Block
- N - Berga Anticlinorium incl. "Gera-Ronneburg Prong"
- O - Vogtland Anticline ("Vogtland Schiefergebirge")
- P - Thuringian Synclinorium ("Teuschnitzer Mulde")
- Q - Centre and eastern flank of Schwarzburg Anticlinorium
- R - Western flank of Schwarzburg Anticlinorium
- S - Ruhla Complex
- U - Wippra Anticlinal Zone of eastern Harz Mountains
- V - Fichtelgebirge (Bavaria)
- W - Hohes Venn (eastern "prong" of Stavelot Massif)
- X1 - Ebbe Anticlinorium (incl. Plettenberg)
- X2 - Solingen-Remscheid-Altena Anticlinorium
- Y - Region of "Andreasteich" and "Münzenberg" olistoliths
- Z - Oberpfalz region (site of German ultradeep drilling ("KTB") at Windischeschenbach)

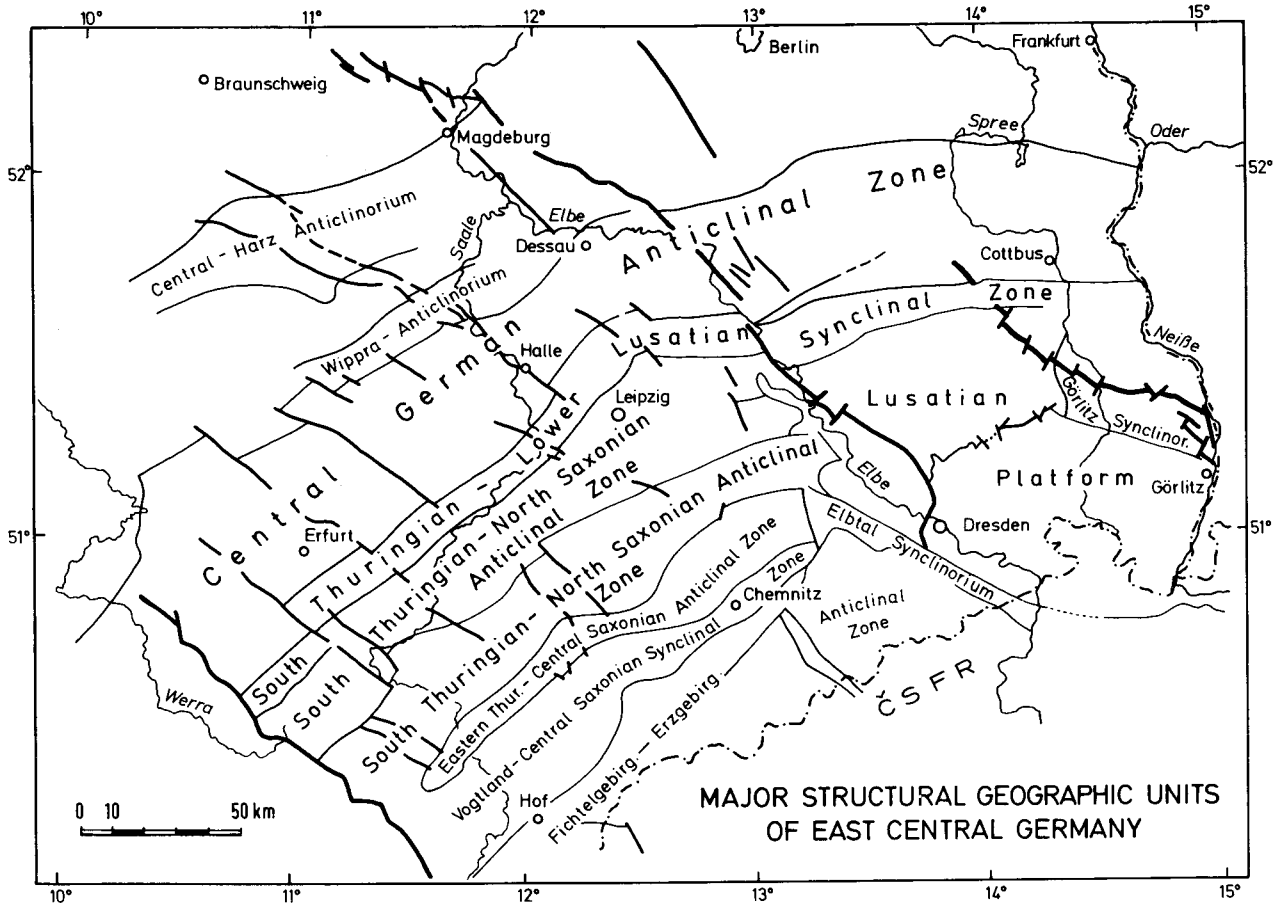

Fig. 2 : Map of major structural geographic units of Early Palaeozoic in east central Germany. Major fault zones in bold lines. The SW-NE striking trends are induced by Variscan NW-directed compressional movements.

RIPHEAN AND VENDIAN DEPOSITS IN GERMANY

Presumed Riphean and Vendian deposits are known at outcrop only from the Lusatian-North Saxonian Platform (L and M in Fig. 1; HIRSCHMANN, 1966; BRAUSE, 1968), from the Schwarzburg Anticlinorium in the «Thüringische Schiefergebirge» (Fig. 1, region Q; von GARTNER, 1931, 1934, 1944; E. BANKWITZ & P. BANKWITZ, 1975), and from the «Elbtal-Schiefergebirge» (D2 in Fig. 1) SE of Dresden (PIETZSCH, 1917, 1962; LINNEMANN, KURZE & SEHNERT, 1988). In Thuringia these rocks cover more than 200km^2 and in the NW Lausitz area ca. 2000km^2. Subcrops of undivided «Leipziger (or Clanzschwitzer) Grauwacke» of probable Riphaean-Vendian age occur also beneath rather thin Tertiary and Pleistocene cover in the area north and south of Leipzig (M in Fig. 1), as well as to the east near Strehla, N. Saxony (eastern part of area K in Fig. 1). In the NW and E Lausitz HIRSCHMANN (1966) subdivided a supposedly older «Görlitzer» from a younger «Kamenzer Grauwacke», but more recently the term «Lausitzer Grauwacke» has been applied for the entire group (KEMNITZ, pers. comm., 1990). The biostratigraphic evidence is as yet limited to algal structures ascribed to *Bavlinella* (BURMANN, 1966, 1969, 1972) which were observed in mudrocks of the upper part of the Görlitz Grauwacke Group near Ossling in the northern Lausitz area (A in Fig. 1). Several hundred meters of rather homogeneous, medium to fine grained partly turbiditic greywackes apparently unmetamorphosed, of the Lausitz Group are exposed in a large quarry NE of Ossling. In the Schwarzburg Anticlinorium of Thuringia (Q and R in Fig. 1) the Katzhütte Grup is ca. 2000m thick, consisting of at least four cycles of coarse to fine-grained suites which may reflect eustatic or tectonic cycles (E. BANKWITZ & P. BANKWITZ, 1975). FALK (1966) described a polymict conglomerate from the top beds of the Katzhütte Group, showing rounded as well as angular pebbles suspended in mudstone matrix; this also being quite characteristic of the pebbly mudstone fabric of the Weesenstein Group in the Elbtal-Schiefergebirge (D2 in Fig. 1; LINNEMANN, pers. comm.) and of certain beds in the Leipzig Greywacke (A. MUELLER, 1964; ROELLIG *et al.*, 1989). More tangible evidence in support of possible

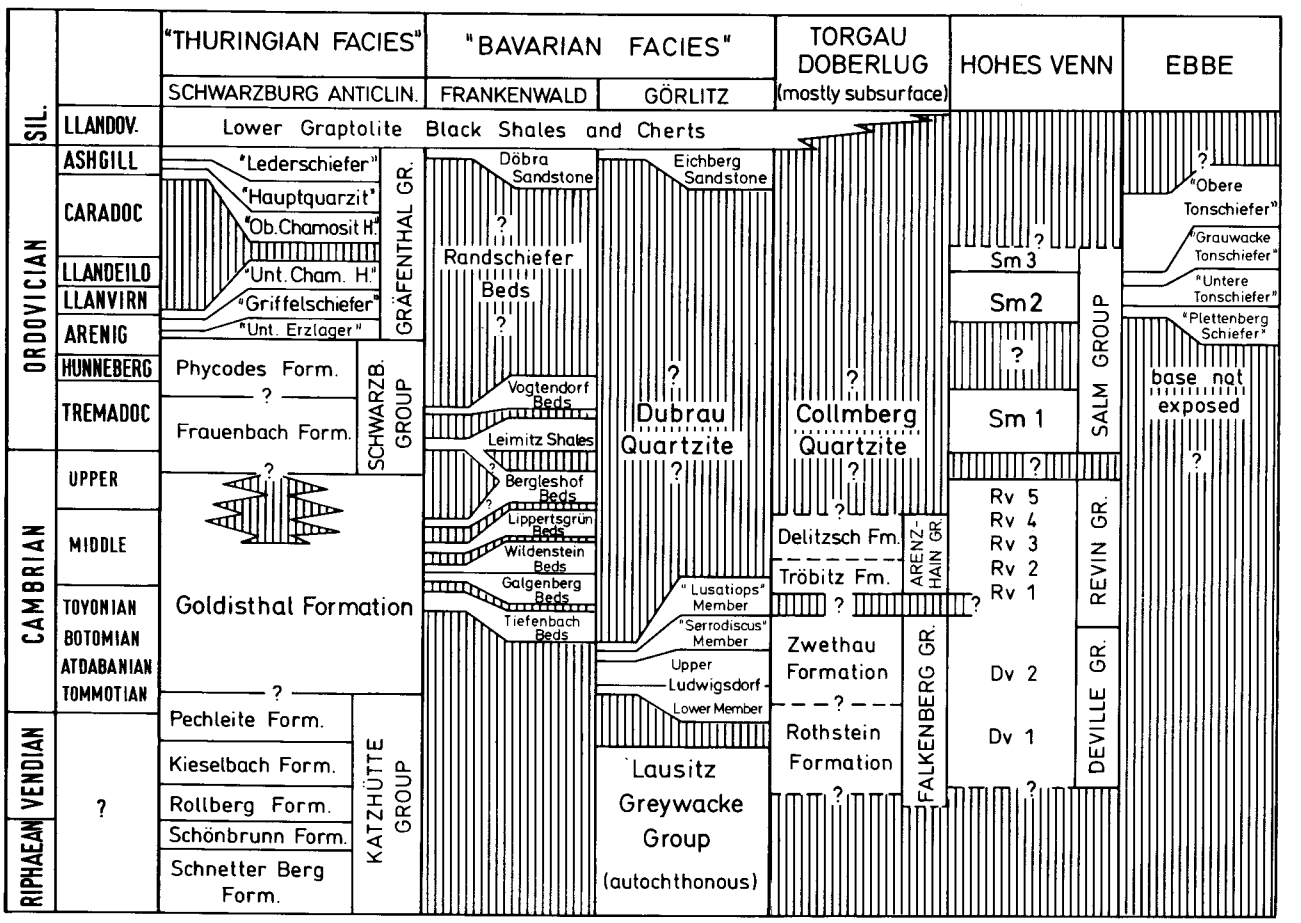

Fig. 3 : Simplified stratigraphic table for the Late Riphaean to Early Silurian of Germany. The generalized section of the Schwarzburg Anticline in Thuringia is regarded as the German standard section ("Richtprofil") for the Early Palaeozoic.

glacial origin for these diamictites is absent, however. The acritarchs *Protosphaeridium* spp. and *Micrhystridium* spp., indicative of Late Riphaean to Vendian age, were recently obtained from the Katzhütte Group in the Schwarzburg Anticlinorium (HEUSE, 1990).

CADOMIAN MOVEMENTS AND THE PRECAMBRIAN/CAMBRIAN BOUNDARY

With the exception of the apparently conformable contact between the Katzhütte and Goldisthal Groups in the Schwarzburg Anticlinorium (DEUBEL, 1959; BANKWITZ, 1970), all contacts between the Vendian and younger sediments, e.g. Leipzig Grauwacke and overlying (presumed Tremadoc) Collmberg Sandstone (BARTSCH, 1956; FREYER, 1981b), as well as between the «Lausitzer (or Kamenzer) Grauwacke» and the (presumed Tremadoc) Dubrau Sandstone, are disconformable. Nor are conformable contacts observed in the «Elbtal-Schiefergebirge» (D_2 in Fig. 1); but a granodiorite pluton near Dohna (a SE suburb of Dresden), cutting into the Weesenstein Group, is dated at 600±25 ma, indicating Cadomian movements (LINNEMANN, pers. comm.). Additional evidence of ?Cadomian disturbances are seen in gabbroic, dioritic and granitoid plutons (Massifs of Pretting-Drehna) which form a rather dense network in the Halle-Dessau-Leipzig region (L and M in Fig. 1) and which are intruded into the «Leipziger Grauwacke» but offer rather young (Rb/Sr) ages (ROELLIG *et al.*, 1989) of 495±3 to 503±11 ma, too young for characteristic Cadomian dates. Great significance was therefore attributed to the stratigraphic dating of a mudrock - pebbly sandstone unit, the «Rothsteiner Folge», which was drilled at several locations within the Torgau-Doberlug Synclinorium (region C in Fig. 1) extending for about 120 km W-E beneath Tertiary cover between Delitzsch (NW of Leipzig, area M in Fig. 1) and the intersection with the East Lusatian Lineament (see Fig. 2) W of Cottbus in SE Brandenburg. Acritarchs recently recovered from the Rothstein Formation, which was formerly considered to be Carboniferous in age (SCHUELLER, 1949), indicate a Vendian to ?Lower Cambrian age

(BURMANN, 1972). According to the «Stratigraphic Standard of the GDR - Kambrium, 1978») the Rothstein Formation now belongs to Falkenberg Group (base unknown) of transitional Vendian/basal Cambrian age, but the precise stratigraphical and structural relationships to the underlying Lausitz Grauwacke and the overlying Lower Cambrian Ludwigsdorf carbonates (see below) have still to be worked out.

At present the most promising location for a Precambrian/Cambrian contact is a ca. 2000 m long forestry road-cut section along the SW slope of the Wurzelberg between the villages of Goldisthal and Scheibe in the Schwarzburg Anticlinorium (FALK, 1964; P. BANKWITZ, 1970; E. BANKWITZ & P. BANKWITZ, 1975). Here a conformable contact is observed between grey to black mudstones of the «Obere Katzhütter Schichten» and banded quartzites and arkoses of the «Basisfolge» of the superjacent Goldisthal Group (FALK, 1964; P. BANKWITZ, 1970). There is no disconformity anywhere within the well exposed succession of the Katzhütte and Goldisthal Groups as originally claimed («Assyntische Diskordanz») by von GAERTNER (1944). Recent biostratigraphic investigations by HEUSE (unpubl. dissertation, 1990) of the Wurzelberg section have shown that the acritarch genus *Cymatiosphaera,* which has never been reported from Proterozoic strata, occurs ca. 75 m below the lithostratigraphic base of the Goldisthal Group within the Frohnberg Formation of the Katzhütte Group. On present information the position of the Precambrian/ Cambrian boundary must lie somewhere within the upper part of the Katzhütte Group. No disconformity suggestive of Cadomian movements exists within the ca. 2000 m thick probably Riphaean to Vendian Katzhütte Group, although volcanic activity is seen at various levels both within the Katzhütte Group and the younger Goldisthal and Frauenbach Groups. This volcanic evidence, however, may be related to the presumed Early Phanerozoic rifting which is so characteristic of many cratonic platforms, especially of peripheral Gondwana, at that time. At least within the autochthonous Schwarzburg Anticlinorium there is no apparent evidence for tectonic activity, nor for any breaks in sedimentation between ?Riphaean-Vendian and Lower Palaeozoic deposits.

CAMBRIAN DEVELOPMENTS IN GERMANY

Cambrian strata are more widespread in Germany than Late Proterozoic sediments. More detailed reviews of the Cambrian of eastern Germany are given by SDZUY (1960, 1964), D. FRANKE (1968) and WUCHER (1974). However, with the exceptions of the allochthonous «Bavarian Facies», the Cambrian outcrops in the Frankenwald Mountains in northern Bavaria (southern margin of areas O and P in Fig. 1) and in the allochthonous German extension of the Belgian Ardennes, the «Hohe Venn» region S of Aachen (W in Fig. 1), the Cambrian deposits are more or less autochthonous and connected to the same eastern German areas from where the Late Proterozoic was reported. As stated above, a key section for the Cambrian, though without any reliable micro- or macrofossil evidence, is seen in the full extent of the clastic Goldisthal Formation (ca. 215 m thick) and probably also in the lower parts of the Frauenbach Formation exposed in the Schwarzburg Anticlinorium, especially well demonstrated in the yet unpublished analysis of the Wurzelberg road section (see above). Here partly finely laminated, partly coarse-bedded pelitic to sandy beds of the Goldisthal Formation are magnificently exposed, displaying several coarsening upward cycles and possible indications of hummocky cross beds and horizons with *Diplocraterion* and *Tigillites,* indicative of shallow subtidal environments (P. BANKWITZ, 1970). HEUSE (unpubl. dissertation, 1990) lists *«Bavlinella, Leiosphaeridia, ?Micrhystridium,* colonies of *?Protosphaeridium,* acanthomorph acritarchs and ?scolecodonts» from the Goldisthal Formation of the Wurzelberg section; none of these fossils convincingly proves a Cambrian date. Conventionally the superjacent conformable Lower Frauenbach Quartzite Member of the Frauenbach Formation is also regarded as Cambrian in age, but there are so far virtually no fossils lending support to this assigment.

Evidence for the Cambrian is much better in the Frankenwald Mountains of northern Bavaria than in Thuringia. The evidence derives, however, only from large olistholiths of Middle Cambrian age (W. FRANKE, 1984), which, following WURM (1925), are regarded as belonging to the «Bavarian Facies» (allochthonous according to W. FRANKE, 1984 versus the autochthonous «Thuringian Facies» of WURM, 1925). The rich trilobite faunas of the disjunct Galgenberg, Wildenstein, Triebenreuth, Lippertsgrün, and Bergleshof Exotic Blocks (all found within a Carboniferous flysch matrix, W. FRANKE, 1984) were described by SDZUY (1964, 1986) and assigned to the three Middle Cambrian *Paradoxides* stages by biostratigraphic correlation with the Barrandian development of Bohemia. The variegated sandy siltstones of the allochthonous «Tiefenbach-Schichten», which are generally referred to the Lower Cambrian in northern Bavaria, show certain lithological similarities to the Goldisthal Formation (P. BANKWITZ, 1970). The stratigraphic dating of the Bergleshof Beds as being of upper Middle Cambrian age (SDZUY, 1966, 1986) based on trilobites, has recently been queried due to the

discovery of early Tremadoc acritarchs by REITZ (1991), although the current resolution of acritarchs hardly permits this kind of precision dating. According to W. FRANKE (1984) the derivation of these Middle Cambrian exotic blocks must be located to the southeast, now buried beneath a large stack of Variscan nappes and several hundred meters of post-Variscan cover. For the Saxonian Erzgebirge Belt the «Bavarian Facies» sources were probably subducted during the Sudetic phase of northwestward collision of the Bohemian (Tepla-Barrandium) microplate (W. FRANKE, 1989, fig. 7).

Although unrelated to both the «Thuringian» and «Bavarian Facies» are a few outcrop and borehole records from the Variscan Thrust Block of the «Hohes Venn» of the Belgian Stavelot Massif with its northernmost «prong» extending to a few kms S of Aachen in westernmost Germany (see W in Fig. 1). Here, the quartzitic and partly silty Deville and Revin Formations, well described by GEUKENS (1965, 1981); WALTER (1980a, b, c) and LAMENS (1986), display certain similarities in lithological development with the Goldisthal-Lower Frauenbach sequence of Thuringia. However, from this ca. 2500 m thick Lower to Upper Cambrian clastic sequence VANGUESTAINE (1973) was able to establish a good palynological record not only for the Deville and Revin, but also for the superjacent Salm Group (Tremadoc and basal part of Middle Ordovician) of the Stavelot Massif (see below). A research borehole was drilled in 1982-1983 near the village of Konzen to prove the stratigraphy of the German prong of the Stavelot Massif. According to von HOEGEN *et al.* (1985) the Lower through Upper Cambrian depositional development reflects a progressively deepening basin which probably initially received terrigenous clastic debris (Deville) within tidal channels, then deepened through a submarine fan stage as evidenced by contour currents (during Revin times). This megacycle at the top of the Revin (Rv5 of GEUKENS, 1963) concludes with a «lacune stratigraphique importante» (ibid. p. 41) prior to the early Tremadoc Salmian transgression, which is well documented by the occurrence of *Rhabdinopora parabola* and subsequent lower Tremadoc graptolites (BULMAN, 1973; ERDTMANN, 1986a) through the lower part of the Salmian sequence. It should be mentioned here that this «hiatus» is limited to the southernmost outcrops of the Stavelot Thrust Block only, and that continuous black shales cover the interval between upper Revinian sandstones and basal Salmian siltstones in the northeast, e.g. near Solwaster.

In the southeastern parts of Germany several Lower Cambrian outcrops have been known since a long time: these are represented by two deep (now abandoned) limestone quarries near Ludwigsdorf and Kunnersdorf, ca. 5-8 kms N of the city of Görlitz, and a few outcrops, now flooded by a reservoir only a couple of hundred meters to the west of Ludwigsdorf. Geologically the disjunct klippen sections may belong to tectonic thrusts of «Bavarian Facies» (JAEGER, 1988) of the NW-SE trending «Görlitzer Schiefergebirge», which, like the «Elbtal-Schiefergebirge» near Dresden, belongs to the pair of extensive deep crustal faults of the «East Lusatian» and «Elbe» Lineaments forming respectively the eastern and western tectonic margins of the Lusatian Platform (or «Lausitz Block» see A in Fig. 1 and Fig. 2). From the flooded quarry near Ludwigsdorf ZIMMERMANN (1908) and SCHWARZBACH (1934) listed a rich trilobite and brachiopod fauna from the reddish to green mudstone «roof beds» on top of the carbonates, the so-called «*Lusatiops* Member». The trilobites, initially considered to be of Devonian age by ZIMMERMANN (1908), were described by R. RICHTER & E. RICHTER (1923) and FREYER (1977) and assigned to the Lower Cambrian; brachiopods were investigated by FREYER (1981a). The underlying carbonates of the Ludwigsdorf Member were reported by SCHWARZBACH (1934) and LEE (1938) to contain archaeocyathids, but this has not been confirmed later. Instead ROSANOV *et al.* (1969) listed a diverse fauna of small shelly fossils, with hyolithids and poriferid spicules, from the upper beds of the Ludwigsdorf Member in the deep quarry near Ludwigsdorf. This discovery led to a reinvestigation by ELICKI & SCHNEIDER (1991, in press), who present a greatly enlarged faunal list of typical upper Atdabanian/lower Botomian small shelly assemblages together with poriferid, helcionellid, pelagiellid and echinoderm fragments, which were hitherto unknown from anywhere in Central Europe, or only from few other localities of the peri-Gondwana biofacies region (BRASIER, 1984, 1986; HINZ, 1987; see Fig. 4). The discovery of small stromatolitic structures and of other environmental evidence permitted a first attempt at a facies analysis of these allochthonous platform rim deposits in the Görlitzer Schiefergebirge (ELICKI & SCHNEIDER 1991, in press).

The aforementioned North Saxonian fault-bound blocks of Delitzsch, NW of Leipzig (L in Fig. 1), and of Doberlug-Torgau (C in Fig. 1) probably yield the best subsurface Lower and Middle Cambrian development in Germany. The succession of the Doberlug-Torgau region is known from publications by SDZUY (1957, 1962, 1970) and FREYER & SUHR (1987); the latter authors described a richly fossiliferous core containing 630 m of mostly limestones and dolostones (with marly mudstones and volcanics dominating in the top 300 m) which are called Zwethau Carbonate «Serie» (= Formation). However, the Zwethau Formation, though much thicker than at Ludwigsdorf-Kunnersdorf, is not strictly comparable

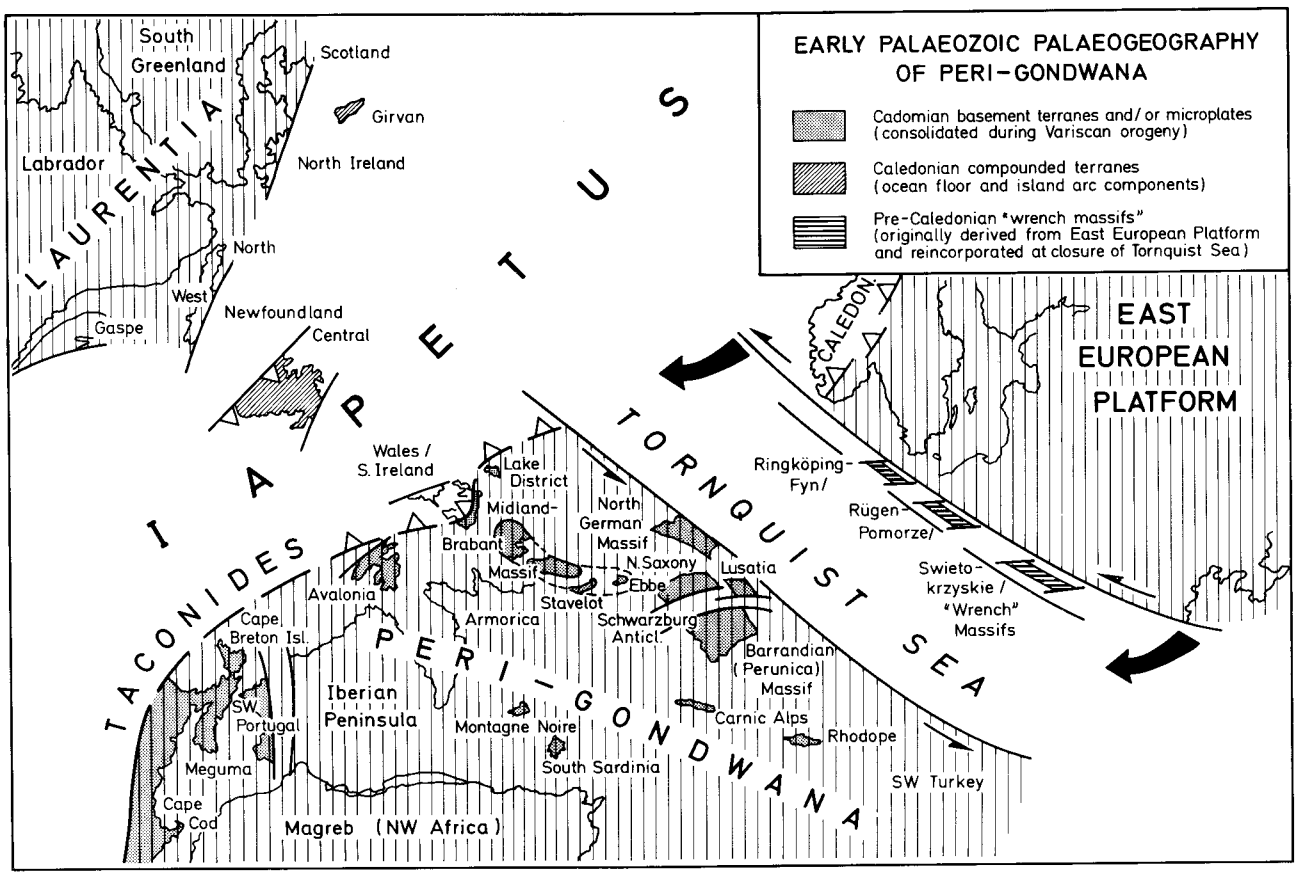

Fig. 4 : Generalized Early Palaeozoic (Late Ordovician) palaeogeography of peri-Gondwana. Individually shaded "blocks" within the general framework of peri-Gondwana may have been detached from one another and located differently during Early Palaeozoic time. The extensive Early Palaeozoic regions of the Iberian Peninsula, Armorica, and of Magreb (NW Africa) are regarded as mostly autochthonous to parautochthonous. Note that no oceanic basins existed within peri-Gondwana during pre-Silurian time.

with the occurrences from the Görlitz Synclinorium because the latter may have been transported to their present site from a fairly distant southern source («Bavarian Facies», see figs. 1 and 3), and there appears to be a similarity in the principal succession of basal carbonates, overlain by grey-green mudrocks, with an intercalation of basic volcanics near the top in both sequences. Unfortunately, no trilobites or brachiopods have been recorded from the mudrocks of this particular core nor any small shelly fauna from the underlying carbonates; however, a rich archaeocyathid fauna was described by FREYER & SUHR (1987) from the lower carbonates of the Zwethau borehole. This discovery may suggest the existence of platform marginal reefs probably having originally fringed the Lusatian-North Saxonian Platform (A, B, C in Fig. 1; FREYER & SUHR, 1987, fig. 2). It should be noted here that the author (ERDTMANN) recently inspected a core from the Delitzsch area N. of Leipzig (L in Fig. 1), where also stromatolitic and possibly archaeocyathid structures could be recognized. From the Delitzsch area SDZUY (1962) described the Atdabanian redlichiid trilobite *Dolerolichia pretiosa*. He regarded its horizon as lower than the higher Lower Cambrian sequence of Ludwigsdorf-Kunnersdorf (see above) and the occurrence as part of the «Mediterranean» biofacies. Recently discovered acritarchs from cores penetrating the Delitzsch Formation confirm a Middle Cambrian age of this fairly coarse-clastic formation. Together with the discovery of chancellorid spicules and hyolithids (*Circotheca*) in a carbonate sequence of the Heinersdorf cores in SE Thuringia (BLUMENSTENGEL, 1980) and presumed archaeocyathids (now considered as echinoderm remains: J. SCHNEIDER, Freiberg, personal comm., 1991) from a limited allochthonous outcrop near Rabenstein-Auerswalde in the Erzgebirge (FREYER & GEISSLER, 1982), a possibly penecontemporaneous carbonate margin could indeed be postulated for parts of the Lusatian-North Saxonian Platform rims during the Lower Cambrian. The Middle Cambrian of the North Saxonian Torgau-Doberlug Synclinorium is well documented by several boreholes which encountered grey mudstones and coarsening upwards cycles containing light-grey sandstones as well as slumped micaceous sandstones. Keratophyres and tuffites are often intercalated into the sediments (FREYER &

SUHR, 1987), e.g. into the upper clastic part of the Zwethau Formation. They continue into the Middle Cambrian beds, especially in the unfossiliferous beds above the «*Lusatiops*»-Shales in the Ludwigsdorf area near Görlitz, but also in northwestern Saxony near Delitzsch. SDZUY (1970) identified trilobites such as *Condylopyge rex, Peronopsella inaequalis, Paradoxides* cf. *insularis, Acadoparadoxides saxonicus* and *Ellipsocephalus incultus,* some of which are known from Bohemia, from cores in the Delitzsch-Torgau-Doberlug region penetrating Middle Cambrian rocks. There is no evidence for the existence of Upper Cambrian deposits in this or in other areas of Germany (the aforementioned Goldisthal or Lower Frauenbach Formations in Thuringia are unfossiliferous or without unequivocal evidence for Upper Cambrian).

THE CAMBRIAN-ORDOVICIAN BOUNDARY

Lithologically continuous sections across the Cambrian-Ordovician boundary exist only in the Schwarzburg Anticlinorium of Thuringia, potentially in the Fichtelgebirge of NE Bavaria (V in Fig. 1), and in the Stavelot Massif. At none of these sections, however, it is as yet possible to recognise and exact biostratigraphic representation of this boundary. On the other hand, at numerous locations in Germany «Tremadocian» deposits are reported, but their unequivocal Tremadoc assignment is either in doubt, or these sections belong to the stratigraphically discontinuous allochthonous «Bavarian Facies».

Following investigations of the stratigraphy of the Schwarzburg Anticlinorium by von GAERTNER (1932) this region is considered as a reference area («Richtprofil») for the Early Palaeozoic depositional development and stratigraphy of Germany. With the exception of spurious trace fossils (P. BANKWITZ, 1970) and a few scattered reports about rather undiagnostic acritarchs (HEUSE, unpubl. dissertation, 1990) the earliest fossils found are poorly preserved obolellid brachiopods (LORETZ, 1880) from the uppermost beds of the Frauenbach Group (Frauenbach Quarzit) near Siegmundsburg in Thuringia. These were initially given various names but were referred to «*Obolus barrandei*» by KOLIHA (1936) and described by A.H. MUELLER (1956) as *Obolus* (now: *Thysanotos*) *siluricus.* Recent work on this species by POPOV (pers. comm., 1990) has shown that *Thysanotos siluricus* is limited to the post-Tremadoc and pre-Arenig Leetse stage of Estonia which corresponds to the «inter Tremadoc-Arenig» Hunneberg stage of Sweden. Furthermore, the earliest truly indicative graptolite, «*Dictyonema* cf. *uralense*» («*uralensis*» in VOLK, 1966), which was referred to the typical early Hunnebergian zonal species *Araneograptus murrayi* by ERDTMANN & VANDENBERG (1985), occurs in the top beds of the «Untere Lauschenstein Schichten» of LUETZNER *et al.* (1986). The stratigraphic consequences of the above fossil ranges suggest that the entire interval between the «Obere Frauenbach Quarzit» and the «Untere Lauschenstein Schichten», ca. 1500 m of mostly coarse to fine-clastic sediments, belongs to an interval encompassing less than 1-2 million years of the lower Hunneberg stage. A second consequence would be that either no Tremadoc is developed in the Schwarzburg Anticlinorium or that the lower part of the Frauenbach Formation belongs to the Tremadoc (instead of to the ?Cambrian as hitherto postulated, see above, and Fig. 3). Regardless of the stratigraphic significance of *Thysanotos siluricus,* so far no diagnostic acritarchs (HEUSE, unpubl. dissertation, 1990) nor other fossils are known to substantiate the existence of either Upper Cambrian or Tremadoc beds in the German Early Palaeozoic reference section in the Schwarzburg Anticlinorium, although no disconformity has been detected within this part of the sequence. . .

The second potential Cambrian-Ordovician boundary section could be drawn at a specific locality in the aforementioned Stavelot Massif, however, not on German territory, but in Belgium. Besides the many listed occurrences of *Rhabdinopora flabelliformis,* a triradiate species which, however, is not the earliest Tremadoc representative, one locality in Belgium (an easily accessible road cut, 1 km N of Solwaster along the road Solwaster-Jalhay at the intersection with the stream «Ruisseau de Sawe»; see BULMAN, 1970; ERDTMANN, 1986a) is of great interest here because of the occurrence of a 3 cm thick benthonitic black shale horizon replete with specimens of the quadriradiate *Rhabdinopora parabola* (incl. gerontomorph varieties). This nematophorous graptolite is quadriradiate in proximal habitus and truly indicates the oldest planktic graptolite to mark the Cambrian-Ordovician boundary here and elsewhere in the world (ERDTMANN, 1988; COOPER & LINDHOLM, 1990). At present, however, the exact depositional succession and biostratigraphic controls below and above this horizon are not investigated in detail. It is worth repeating it here, however, that the underlying top Revin (Rv5) beds consist of ca. 300 m of pure black shales with few black carbonate concretions reminiscent of the Upper Cambrian Alum Shales of Scandinavia and Random Island in eastern Newfoundland. With the «stratigraphic lacuna» between the Revin and Salm Groups (of GEUKENS, 1963) possibly not being developed at Solwaster (see above), this section could be considered a potential stratotype for the Cambrian-Ordovician boundary, although the biostratigraphic evidence for the top Cambrian has not yet been given.

Further sections and localities have been assigned to Tremadoc in Germany: Best known for its Asian and North African-types of trilobites, cystoids and a single dendroid graptolite specimen (*Aspidograptus* sp.) is the wildflysch block of Leimitz Shales located only a few km SE of Hof in the NE corner of Bavaria. The quite well preserved deeper water trilobite fauna, known since the description by BARRANDE (1868), was revised and discussed by SDZUY (1955a, 1955b, 1961, 1964, 1979). This allochthonous occurrence of a fairly diverse Lower Tremadoc (*Proteuloma*-type) trilobite and cystoid fauna suggests derivation of the Leimitz Beds from the Barrandian or the existence of a similar basinal subcrop in the deep subsurface to the southeast (see also W. FRANKE, 1984). The early Tremadoc age of the Leimitz Shales was confirmed recently by acritarchs (REITZ, 1991).

Additional occurrences of doubtful Tremadoc include outcrops of unmetamorphosed strongly cross-bedded sandstones which are preserved as fault-bound slivers around the tectonic margins of the Lusatian-North Saxonian Platform. These sandstones are called Collmberg Sandstone in northern Saxony and Dubrau Quartzite in the Lausitz region (Fig. 3). There are three major exposure areas: 1. near the villages and towns of Otterwisch, Hainichen and Borna, ca. 20 kms S of the city of Leipzig (M in Fig. 1), 2. in the "Collmberg Hills" near the town of Oschatz, ca. 50 kms ESE of Leipzig (eastern part of K in Fig. 1), and 3. along the hilltop of "Hohe Dubrau" near the village of Groß Radisch (northern part of B in Fig. 1) in the Niederlausitz, ca. 22 kms NW of Görlitz (HIRSCHMANN, 1966). The sometimes highly mature, but also occasionally immature greywacke sandstones usually show excellent crossbeds, cut-and-fill structures, occasional multidirectional crossbeds (herringbone-type), oscillation? ripples, occasional mudcracks and usually extensive scolithid pipes just above their conglomeratic bases. From the northern Saxonian localities a rich occurrence of *Cruziana semiplicata* is also recorded (PIETZSCH, 1910; FREYER, 1981b), and from nearly all localities individual occurrences or even coquinoid mass occurrences of lingulellid and obolellid brachiopods are known, especially from the "Hohe Dubrau" (GEINITZ, 1873). As in the case of the Upper Frauenbach Quartzite of Thuringia these brachiopods were referred to *Thysanotos siluricus*. In most references on the Collmberg and Dubrau Sandstones these beds are conventionally assigned to an Early Ordovician or Tremadoc age based on these brachiopods, although this was questioned by FREYER (1981b), who relied more on the occurrence (and questionable stratigraphic value, see MAGWOOD & PEMBERTON, 1990) of *Cruziana semiplicata*, a trace fossil which is well known from Upper Cambrian shallow-water sandstones in northern Wales (Ffestiniog) and from the Polish Holy Cross Mountains. At present new investigations are being carried out, aided by the discovery of a well preserved acritarch flora (HERMSDORF, pers. comm., 1990) from the Hohe Dubrau, which are aimed at a better stratigraphic definition of the parautochthonous Collmberg and Dubrau Sandstones (as well as younger sandstones). If a Tremadoc-Early Arenig position could be verified, it may be possible to regard these sandstones as the northeasternmost equivalent of the Grés Armoricaine (NOBLET & LEFORT, 1990). Despite the autochthonous (or parautochthonous) and superjacent depositional nature of these fragments of a post-Cadomian cover of the Lusatian-North Saxonian Platform, the unresolved stratigraphic position does not allow, at present, an improved recognition of the Cambrian-Ordovician boundary in these regions.

THE ORDOVICIAN SYSTEM.

Sediments of Ordovician age are not only more widespread in Germany than those of Cambrian age, but they are also far more accurately dated biostratigraphically. This is true not only because of a better fossil record, but also due to a more intensive research into the Ordovician of Germany since von GUEMBEL (1861) and BARRANDE (1868) first discovered the "Untersilur" (as the Ordovician was officially called in Germany until 1972) in the Frankenwald Mountains (Leimitz Shale near Hof, see above).

The most complete autochthonous Ordovician sequence is observed in the eastern limb of the Schwarzburg Anticlinorium, Thuringia (WIEFEL, 1974). Recognition of Ordovician strata there dates back to von FREYBERG (1923a, 1923b), with descriptions of trilobites by R. & E. RICHTER (1927) and of graptolites by DAHLGRÜN (1930). The regional structural and stratigraphic context of the Ordovician part was first mapped by von GAERTNER (1934). The Ordovician is more than 2500 m thick (90 % of which is pre-Llanvirn) both in the Schwarzburg Anticlinorium and also in the Berga Anticlinorium, ca. 30 kms to the east (see N in Fig. 1); and similar Ordovician deposits are known in the Vogtland-Fichtelgebirge (V and G in Fig. 1; STETTNER, 1964), another 30 kms to the southeast (with increasing metamorphic overprint). Together with the few outcrops of Ordovician rocks of autochthonous "Thuringian Facies" (of WURM, 1925) in the Frankenwald and Fichtelgebirge, all these sequences between the western limb of the Schwarzburg Anticlinorium and the Vogtland-Fichtelgebirge show a general similarity of lithological environment, which is also observed in parts of the Barrandian Ordovician in Czechoslovakia (HAVLIČEK & VANĚK, 1966). This suggests that the "Thuringia-Fichtelgebirge Platform" was an integral part of the Bohemian Platform at that time. Quite different lithofacies are developed in the allochthonous "Bavarian Facies" to the SW (the probable provenance of this tectonic facies according to W.

FRANKE, 1984), as well as the arenitic development of Ordovician rocks on the Lusatian-North Saxonian Platform, and the mostly pelitic development of the Brabant-Stavelot-Ebbe region (see Figs. 1 and 4) to the west. For the Early Ordovician, therefore, three discrete lithofacies areas existed reflecting quite different lithogenetic regimes between NW and SE Germany and the Barrandian region. Furthermore, Ordovician rocks have been encountered in deep boreholes on the Baltic Sea island of Rügen (see NE part of Germany on Fig. 1). These show a development virtually identical to that along the southern margin of the Baltic-Podolian (East European) Shield (D. FRANKE, 1967, D. FRANKE *et al.*, 1989, PISKE & NEUMANN, 1990), or rocks of a "flyschoid" character as described from a core within the Tornquist-Teisseyre Belt by JAEGER (1967).

The base of the Ordovician in the Schwarzburg Anticline is in dispute, as stated above. In general no disconformity is recorded at or above the Goldisthal/Frauenbach contact nor at any higher position within the 250 m thick Frauenbach Formation, or above. There are distinct lateral facies changes in the middle "Frauenbach Wechsellagerung" beds, such as lenses of pebbly mudstone ("Scheibe Gerölltonschiefer" of FALK, 1966), which may indicate locally slumped beds at the village of Scheibe, and a few kms to the NE, where arkoses, tuffites, porphyritic tuffites and claystone clasts occur in coeval beds. The top Frauenbach Quartzite Member is rather coarse-grained, but for the most part diagenesis conceals primary fabric and even structural features. However, channelling of fairly large-scale crossbeds are observable at weathered outcrops; this apparently indicates a rather shallow environment. From these beds *Thysanotos siluricus* is recorded (see above; A.H. MÜLLER, 1956). The transition to the 600 to 2000 m thick socalled "Phycodes Group" (named after the trace fossil *Phycodes circinatum*; now integrated with the Frauenbach Formation into the "Schwarzburg Group" by LÜTZNER *et al.*, 1986; see fig. 3) is formed by a silty slate ("Dachschiefer") which alternates laterally with magnetiferous quartzites, the so-called "Magnetitquarzit" (von GAERTNER, 1936). For the most part the succeeding "*Phycodes* Folge" (VOLK, 1938) consists of silt-shales and sandstones of a characteristic light greenish colour becoming more coarse-grained toward the top. LÜTZNER *et al.* (1986) have established several cycles starting with a general deepening trend for the basal beds of the "*Phycodes* Folge" (succeeding the shallow-water Frauenbach Formation), followed by a coarsening upwards sequence (shallowing trend?), and a distinct disconformity at the top of the Schwarzburg Group (LÜTZNER *et al.*, 1990; see Fig. 3). The middle portion of the "Phycodes Folge" (= upper part of the Schwarzburg Group in Fig. 3) is rich in well preserved hummocky cross-beds and *Phycodes* burrows indicating sedimentation at or near storm wave base (LÜTZNER & MANN, 1988). The main biostratigraphic control is by a single almost complete rhabdosome of *Araneograptus cf. murrayi* (J. HALL, 1865) described as "*Dictyonema cf. uralensis*" by VOLK, 1966; this, the index species of the lower Hunneberg stage (between the Tremadoc and Arenig Series in Great Britain (RUSHTON, 1985) and elsewhere (ERDTMANN & VANDENBERG, 1985; COOPER & LINDHOLM, 1990), was found in the middle portion (top of "Untere Lauschenstein Formation" of LÜTZNER *et al.*, 1986) of the "*Phycodes* Folge". From shaly interbeds near the top of this sequence several graptolites were listed by SCHMIDT (1939), all of which are difficult to identify to specific level, but which show similarities to large clonograptids characteristic of either top Hunneberg or basal Arenig horizons in Scandinavia (COOPER & LINDHOLM, 1990), Bohemia (KRAFT & MERGL, 1979), and in the Barriga Shales of the Sierra Morena in Spain (ERDTMANN, MALETZ & GUTIERREZ MARCO, 1987). Depending on the yet unknown position of the base of the Ordovician (probably somewhere within the Frauenbach Formation) the entire Schwarzburg Group (ca. 2600 m according to LÜTZNER *et al.*, 1986) could be interpreted as ?Tremadoc and Hunneberg in age, probably one of the thickest sequence of this age interval in the world. It may be of note that, except for within the Frauenbach Formation, volcanic injections or derivatives are not encountered in this Early Ordovician sequence. Basalts and tuffites are known from corresponding beds on the Barrandian Platform, however (HAVLIČEK & SNAJDR, 1956).

At most places in the Schwarzburg and Berga Anticlinoria there is a dm-thick chamositic ore horizon developed between the top of the *Phycodes* Sequence and the overlying black, sparsely graptolitic "Griffelschiefer" (="Stylus-Shales" because, due to the obliquity of cleavage to bedding, the manufacture of styluses was for centuries concentrated on this shale). Because of the relatively small thickness of the entire post-*Phycodes* Ordovician (max. 600 m) in Thuringia this sequence is conventionally placed in the "Gräfenthal Group" (see fig. 3). The uniformly black "Griffelschiefer", between 100 and 250 m thick, contains a few extensiform graptolites (identified as *Didymograptus cf. simulans* by this author) suggesting a middle Arenig age, but which have not yet been investigated in detail and may yield a younger date. Regardless of the exact stratigraphic position of the "Griffelschiefer", a Llanvirn age is very doubtful, and this author agrees with a recent revision of the biostratigraphic positions of the Ordovician units in Thuringia by FUCHS (1989, 1990), who based his evidence on conodonts and placed a probable hiatus between the topmost beds of the Phycodes Quartzite (early Arenig) and the overlying "Griffelschiefer" (ibid., fig. 2) at the position of the "Unteres Erzlager" horizon, and who indicated that the "Griffelschiefer" may not represent the full range of Arenig. Likewise, the "Griffelschiefer" trilobites *Hungio-*

ides graphicus, Asaphellus desideratus and *Colpocoryphe inopinata*, revised by R. and E. RICHTER (1927, 1954a) and by VOLK (1960), are long-range forms and do not contribute a better biostratigraphic resolution. Acritarchs from the "Griffelschiefer" were described by BURMANN (1968, 1970, 1973b) and HEUSE (1989), who also noted the lack of truly zone-diagnostic palynomorphs. It is possible that the "Griffelschiefer" represents a major black-shale transgressive event within the Arenig (like the Postolonnec of the Armorican Massif) and is thus not correlable with the transgressive base of the Llanvirn, which in turn correlates well with the well-known "*Neseuretus tristani* event" of Spain (FORTEY, 1984). Lacking an investigation of the poorly preserved graptolite fauna and due to presence of extensiform (cf. *Didymograptus cf. simulans*) rather than tuning-fork pendent didymograptids, the "Griffelschiefer" may provisionally be placed at a middle Arenig level. Based on the above assumptions the "Unteres Erzlager" horizon below the "Griffelschiefer" would correlate well with the middle Arenig chamosites of the Powers Steps Formation of Bell Island, Avalon Peninsula of eastern Newfoundland (RANGER *et al.*, 1984, WILLIAMS, 1990) and with coeval beds in Czechoslovakia (PETRANEK, 1964; HAVLIČEK & VANĚK, 1966, fig. 1) and elsewhere (YOUNG, 1989).

The remainder of the Gräfenthal Group is depositionally and biostratigraphically rather complex. The succeeding chamositic oolitic ore beds ("Unterer und Oberer Chamosit Horizont", see fig. 3) and the locally intervening "Lager-" or "Hauptquarzit", together called Schmiedefeld Formation, either represent a lacuna due to emergence (ELLENBERG, 1964, 1988, YOUNG, 1989) or "omission" or "corrosion" beds due to the opposite, due to submarine redeposition and condensation (FUCHS, 1990). Biostratigraphically a major hiatus encompassed by the two chamositic beds of the Schmiedefeld Formation is supported by conodont evidence (KNÜPFER, 1967, 1968); FUCHS (1990). Although ELLENBERG´s (1988) emergence model is very convincing, the absence of subaerial weathering phenomena in this economically significant chamosite band may sway the arguments in the direction of FUCHS´ (1990) model calling for repeated redepositional "lag" and condensation. This model attempts to explain the obvious stratigraphic gap according to conodont evidence (most or all of the British Llanvirn, Llandeilo and most of the Caradoc Series are missing) as being caused by non-deposition due to deeper water contour currents (as postulated for similar large-scale stratigraphic omission horizons in the Devonian by OCZLON, 1990). This environment, however, may have been only deeper in a relative sense, i.e. a more submerged stable shelf during prograding transgression which would be responsible for a reworking and hematization of the ooids due to lowering of clastic sediment input. Furthermore, ELLENBERG´s (1988) genetic model requires rather warm tropical temperatures for the initial generation of oolites, whereas the FUCHS (1990) model better complies with the general cold climatic position of the German-North African shelves (SPJELDNAES, 1961, FORTEY, 1984, PARIS & ROBARDET, 1990, *et al.*). The chamositic ore beds are widespread in contemporaneous deposits of the peri-Gondwana region (Bohemia, Armorica, Avalonia, North Africa and the Near East) and are probably directly related to eustatic changes at early Llanvirn and early Ashgill horizons in this broad peri-Gondwana shelf apron (see YOUNG, 1989; see fig. 4). The intervening "Lagerquarzit" between the "Unteres" and "Oberes Erzlager" is interpreted by ELLENBERG (1990) to indicate nearshore sandbanks having laterally substituted oolitic shoals. It also must be restated here that, although a general deepening trend for the entire Ordovician in the Schwarzburg-Berga region is observed (LÜTZNER *et al.*, 1986), there is no evidence for oceanic basin development prior to Silurian-Devonian anywhere between Central Europe and North Africa and certainly not within the Thuringian-Bohemian Platform region.

The upper Caradoc-Ashgill part of the Gräfenthal Group, in the "Thuringian Facies" consists of the "Lederschiefer" (="leather shale": descriptive for its texture and colour), which according to several investigations should be regarded as a true diamictite (LÜTZNER *et al.*, 1990). As a subfacies in the eastern part of the Schwarzburg Anticlinorium, the "Lederschiefer" may be underlain and a lateral equivalent of the "Hauptquarzit". Strong elements of cyclic directional deposition (fining upwards cycles, fluted sole markings, channelling, and oscillation ripples, hummocky crossbeds) are indicative of a gentle slope environment at or near storm wave base. The controversies regarding either marine paraglacial (ice rafting) or a non-glacial submarine mass-flow origin of the "Lederschiefer" date back to DEUBEL (1929) who was first to suggest the ice rafting hypothesis. However, HEMPEL & WEISE (1967) and GREILING (1967) favoured the idea that the heterogeneous but usually quite well-rounded pebbles were emplaced into the dark silt to clay matrix by submarine mass-flows or turbidity currents, whereas KATZUNG (1961), PFEIFFER (1972) and STEINER & FALK (1981) pointed to the multiple-direction striae, the random orientation of the clasts, and to the occasional impingement of matrix laminae (HÄHNEL, 1964) as convincing evidence of glacial derivation of the "Lederschiefer" macroclasts (infrequently up to 0.4 m and even several meters in diameter according to JAEGER, 1988). It is also of palaeogeographic significance that fairly fossiliferous silicified carbonate clasts have been found indicating youngest Caradoc ages for the pre-indurated rafted clasts (VOLK, 1959, BLUMENSTENGEL, 1965, KNÜPFER, 1967, 1968). The provenance of these fossil bearing (ostracods, echinoderms, etc.) rocks is not yet ascer-

tained, but is suspected to be from the south, where upper Caradoc to Ashgill limestones ("Uggwakalk", "Wolayerkalk") are known from the Carnic Alps (SCHÖNLAUB, 1979). Due to the climatic deterioration in the North African-Mediterranean region during the Caradoc and Ashgill, these limestones (and their rafted clasts) may themselves not be of "Bahamitic" genesis, but rather indicate condensed or diagenetic carbonates.

The top Ordovician "Lederschiefer", at many localities, grades conformably into the Early Silurian "Lower Graptolite Shale", the characteristic Llandovery rhythmic black alum and siliceous shales which apparently transgessively overlie virtually all Ordovician rocks regardless of their facies (see fig. 3). However, the highest Ordovician *Glyptograptus persculptus* zone is not represented here and the virtually complete Llandovery graptolite succession usually begins with *Akidograptus acuminatus* (although specimens of the older *A. ascensus* are reported from Hohenleuben (ALDER, 1963, SCHAUER, 1971). The very widespread distribution of black shales bearing *A. acuminatus*, even in areas of eastern Germany where there are extensive gaps or which are underlain by shallow water sandstones ("Bavarian Facies" type Döbra Sandstone, see below) presents problems for those depositional models (JAEGER, 1964) which require deeper basinal subsidence for this alum shale-chert facies. This author, however, rather believes in a short-term shallow anoxic water ingression resulting from a postglacial "quiet" encroachment of already flooded but well-aerated shelves and islands during the Hirnantian glaciation. This would be analogous to the early Tremadoc Dictyonema Shale ingression of the Baltic (East European) Platform. On the other hand, the rhythmic intercalations of banded black cherts may lend some support to a deepening of the marine environments during Llandovery; this also indicating tensional trends revealed by the initial rifting or "foundering" of the Rheic Ocean during the entire Silurian near to and parallel with the Saxothuringian-Moldanubian margin (i. al. W. FRANKE, 1989).

To the south, but close to the "Thuringian" development of the Ordovician, is the allochthonous "Bavarian Facies". It occurs in the Frankenwald and Fichtelgebirge region, and is also represented as tectonic "outliers" in southern Saxony (Wildenfels, Frankenberg, Granulitgebirge, the so-called "Zwischengebirge": W. FRANKE, 1984). Here the major problem is the fully allochthonous occurrence and usually stratigraphically "piecemeal" distribution of all sections belonging to the "Bavarian Facies" (W. FRANKE, 1984). A descriptive summary of the Ordovician stratigraphy of the "Bavarian Facies" is given by von HORSTIG (1964) and SDZUY (1971), with new genetic aspects discussed by W. FRANKE (1984). The klippen comprising the early Tremadoc Leimitz Shales and its fossils were discussed in the previous chapter. In a wildflysch block surrounded by Carboniferous "matrix" near the village of Vogtendorf is a suite of volcaniclastics and immature siltstones, the "Vogtendorf Beds", from which SDZUY (1971) and the present author have obtained brachiopod coquinas (not unlike those of the Dubrau Sandstone from the Lausitz, see above) and trilobite exuvia which according to SDZUY (1971: 385) include the late Tremadoc *Euloma ornatum*, *Pilekia* sp. and *Agerina* n.sp. Obviously these shallow water sediments rafted to their present location from a (southern?) source together with thick Lower Ordovician keratophyres as olistholiths incorporated into Lower Carboniferous flysch sediments (W. FRANKE, 1984: 16).

Of unknown biostratigraphical range but possibly younger is the "Randschiefer Serie", a tectonically disjunct succession of grey to black shales, sandstone beds and occasional cherts which are especially well-developed along the NW and SW margins of the "Münchberg Gneiss Massif" (the southernmost of the Saxothuringian "Zwischengebirge"). Scanty non-descript brachiopods, including small lingulids and acrotretids, as well as sponge spicules of ?Arenig to ?Llandeilo age were reported from the "Randschiefer" by SANNEMANN (1955) and SDZUY (1971). Acritarchs from the "Randschiefer" studied by REITZ (pers. comm., 1990) show that portions of this suite also include Late Proterozoic (W. FRANKE, 1989: 74) palynomorphs similar to those recently discovered in the northern Vosges Mountains of westernmost France (REITZ & WICKERT, 1989).

Metasediments and volcaniclastics of unconfirmed Cambro-Ordovician age have been reinvestigated in the small "Elbtal-Schiefergebirge" (D2 in Fig. 1) and in the "Nossen-Wilsdruff Schiefergebirge" between Dresden and Meissen (D3 in Fig. 1) in Saxony (KUPETZ, 1987, LINNEMANN *et al.*, 1988, KURZE & TRÖGER, 1990). Both "complexes", are only of a few km^2 in extent, and exposed along strike of the Variscan-reactivated Elbe Lineament, which strikes NW-SE and extends for several hundred kms from Dessau in the NW (or possibly from Gifhorn-Wittlingen in eastern Lower Saxony) to the southern tip of the Jesenik Mountains near Olomouc (Olmütz) in northern Moravia, CSFR in the SE (figs.1 and 2). The small outcrops of the "Elbtal-Schiefergebirge" and the "Nossen-Wilsdruff Schiefergebirge" parallel the "Görlitzer Schiefergebirge" on the other side of the Lusatian Platform. Considering that the "Erzgebirge Lineament" which strikes WSW-ENE, follows the major lineament of upthrust "Bavarian Facies" toward the NW, it seems reasonable to include the "Elbtal-Schiefergebirge" and the Görlitzer Schiefergebirge" in the allochthonous "Bavarian Facies" nappe belt (see fig. 1). There are similar gravity-tectonic relations between these complexes and the surrounding Carboniferous flysch sediments to call for the same wildflysch transport model as was postulated by W. FRANKE (1984) for the Münchberg Massif in

NE Bavaria and for the south Saxonian "Zwischengebirge" (see above). As noted by LINNEMANN *et al.* (1988), the degree of metamorphism decreases upsection, and despite the lack of fossils there are many lithostratigraphic parallels with fragmentary "Bavarian Facies" sections elsewhere. Even the strong volcaniclastic content of the "Randschiefer" and slices of the Döbra Sandstone are repeated in the "Elbtal-Schiefergebirge" (LINNEMANN *et al.*, 1988: 45), but here also no biostratigraphic evidence has as yet been established.

Going back to the Ardennes, another sequence of Ordovician rocks, probably incomplete at the top, is found in the "Hohe Venn". Beginning with the basal part of the Tremadoc (see above) the Salmian succession in Germany probably only extends into the middle or upper (?) Tremadoc (von HOEGEN *et al.*, 1985), although, at present, biostratigraphical dating is limited to the *Rhabdinopora flabelliformis* bearing lower part of the "Salmian 1a", from which also the coprolite *Tomaculum problematicum* is recorded (BOSCHEINEN, 1983). In Belgium VANGUESTAINE (1973) was able to show that the highest Salmian (Sm 3) beds extend to the Llanvirn-lower Caradoc by means of diagnostic acritarchs, but this has not been achieved on the German side so far (von HOEGEN *et al.*, 1985, LAMENS, 1986). However, D.RICHTER & SCHOLZ (1972) and von HOEGEN *et al.* (1985) attempted to reconstruct the petrographical and palaeoenvironmental history of the Salmian (Sm 1) on the German side, concluding that this was to be seen as the sequential development of a prodelta, delta front and delta platform, i.e. a distinctly regressive sequence. It is possible that this regressive sequence only represents a Tremadoc cycle because a global regressive event is clearly demonstrated from many other parts of the world, as from the Barrandian (HAVLIČEK & VANĚK, 1966), Morocco (DESTOMBES, 1985), the Baltic (East European) Platform (ERDTMANN, 1965), the classic Tremadoc/Arenig hiatus in northern Wales (LYNAS, 1973, ZALASIEWICZ, 1986) and from elsewhere (FORTEY, 1984, BARNES, 1984, ERDTMANN, 1986). So far there is no biostratigraphic evidence in support of an Arenig age for the reddish or brownish Sm2 in the Stavelot area. Nor can Arenig strata be confirmed by macro- or microfossil evidence in the presumed coeval sections of the Condroz Anticline and the Brabant Massif (the debated occurrence of pendent didymograptids at Sart Bernard is no prove for Arenig!). The stratigraphic gap between the Llanvirn-lower Caradoc Sm3 and Lower Devonian in the Belgian "Haut Fagne" is conventionally referred to Caledonian distortion, but Late Ordovician Taconian movements are also suggested (WALTER, 1980, GEUKENS, 1984). However, it should be noted that part of the "disconformable" contact, such as that seen between the penecontemporaneously deformed slumped Salmian beds and the overlying Gedinnian conglomerates at Salmchateau is more apparent than true (GEUKENS, 1984).

During the Ordovician the cover of the autochthonous Midland-Brabant Massif is considered to represent shallower facies than in the Ardenne Basin (WALTER, 1980a, LAMENS, 1986). The shaly Llanvirn-Llandeilo Rigenée and Ittre Formations are sporadically to well documented by graptolites and acritarchs (SERVAIS, 1988), but stratigraphically succeeding units, such as the Gembloux and lower Caradoc black Fauquez Shales are observed only in faulted contacts with the underlying Lower Ordovician suite. Although a conformable contact between Ordovician and Lower Silurian is supposed to exist in the Brabant and Condroz areas (WALTER, 1980a), there is no direct proof of such a transition. A shallowing is observed during the Caradoc/Ashgill of the Condroz Anticline (the "Conglomerat de Cocriamont" and overlying Fosse Shales and limestones of Sart Eustache which are rich in deep shelf brachiopod assemblages, SHEEHAN, 1987), but little is as yet known about the Upper Ordovician-Silurian contact in the Brabant Massif itself. The macrofossil record of the Gembloux and Fauquez Formations is poor, but lower Caradoc *Dicellograptus cf. patulosus* and large rhabdosomes of *Orthograptus sp.* have been collected by the author from Fauquez near Ittre. It should also be noted that the late Caradoc and Ashgill sequence of the Brabant Massif is strongly affected by intrusive and exhalative andesitic to rhyolitic volcanism which may be referred to a Taconian rotational movement of the Midland-Brabant Massif relative to the Ardennes (ANDRE, 1989). Similar plate-marginal volcanic suites are observed from various microplates (Lausitz/Elbtal-Schiefergebirge) during different episodes in the Ordovician. This lends support to the hypothesis that individual microplate adjustment and rotational movements of these blocks and massifs occurred during the Ordovician following their decoupling from a common basement during the Vendo-Cambrian rifting phase.

The significance of the brief preview of the Middle to Upper Ordovician stratigraphy of the Brabant-Condroz region is to be seen in the presumed general lithogenetic and biofacies similarities of a few tectonically affected coeval sections exposed in the Remscheid-Solingen and Ebbe regions in the Sauerland area of the "Rheinische Schiefergebirge", ca. 150 km to the east of the Belgian outcrops. Despite the lithogenetic parallels, however, the suite of intensely foliated and fractured black and greenish slaty shales and siltites, seen in small outcrop (of few 100 m^2 to 2-3 km^2) near Herscheid and Plettenberg, ca. 25 kms SE of Hagen in Westfalia, and a single outcrop 3 kms SW of Solingen, are not only depositionally and stratigraphically disjunct, but also badly documented by fossils. A. FUCHS (1922) named these the "Herscheider Schiefer" and placed them, together with surrounding "Verse Schiefer", in the Lower Devonian. R. & E. RICHTER (1937, 1954b) recognized the Ordovician age of the "Herscheider Schiefer" by identifying cyclopygid and asaphid trilobites and likewise by the disco-

very of acritarchs (EISENACK, 1939). At about the same time BEYER (1941a, b, c, 1943) remapped both the Ebbe area (Herscheid-Plettenberg) and the small Solingen (Wüstenhof-Sattelsberg) outcrops in detail and revised the stratigraphy by subdividing the Herscheid Group into a basal "Plettenberger Bänderschiefer", followed by "Unterer" and "Oberer Tonschiefer" Formations separated by a "Grauwacken-Schiefer" below (Fig. 3). Stratigraphically the oldest unit is the "Plettenberger Bänderschiefer", a buff black shale containing lower Llanvirn pendent didymograptids (*Didymograptus "bifidus"*, now probably *D. artus*), the trilobites *Cyclopyge, Pricyclopyge, Novakella, Micropa-ria, Ogygiocaris, Dionide,* and *Selenopeltis* (SIEGFRIED,1969); the stratigraphic ranges of all these genera exceed Llanvirn. This is followed (?) by the "Unterer Tonschiefer" from which the coprolite track *Tomaculum problematicum* (BEYER, 1941a, 1943) is found in great profusion and in which JENTZSCH & STEIN (1961) discovered the upper Llanvirn *Nicholsonograptus fasciculatus*. The succession is continued by the "Grauwackenschiefer" and topped by the virtually unfossiliferous "Obere Tonschiefer". BEYER (1941b, c) assumed a complete Middle to Upper Ordovician succession to be represented in the Herscheid-Plettenberg, if not also in the Solingen-Remscheid area. The latest revision by W. ZIEGLER, 1970, TIMM, 1981, TIMM et. al., 1981 and EISERHARDT *et al.*, 1981 of the Ordovician stratigraphy only concentrated on the Ebbe region between Herscheid and Plettenberg. In the latter paper (ibid. p. 202-203) newly found graptolites were quoted, with identifications made by this author in 1980, showing diagnostic Llandeilo climacograptids which are reported from a sliver of presumed "Plettenberger Bänderschiefer" (the oldest (?) unit, supposedly of lower Llanvirn age) which outcrops at a new road section within the town of Herscheid. During a recent visit there samples were taken from this section for acritarch investigations by the Liege laboratory. According to SERVAIS (oral comm., 1990) the fairly rich acritarch assemblage confirms a Llanvirn-Llandeilo age for the rocks of this particular outcrop. The initially contradictory assessments of litho- and biostratigraphic data is not unusual in the lithologically homogeneous and strongly deformed, but biostratigraphically insufficiently dated Lower Palaeozoic successions of Germany. It is hoped to bring a better solution to these cases to by future investigations aided by acritarchs and chitinozoans, which are sometimes richly available in these sediments (e. g. see EISENACK, 1939, HEUSE, 1989, REITZ & HÖLL, 1989, REITZ & WICKERT, 1989, REITZ, 1991). The present writer strongly doubts that the Herscheid Group represents a continuous succession spanning the Arenig-Ashgill interval as hitherto postulated; slight evidence favours the hypothesis that this "sequence" is a "package" of tectonically "mylonitized" but stratigraphically discontinuous segments representing only Llanvirn to possibly Llandeilo ages (Rigenée equivalents as in Brabant, see above). By comparison with the autochthonous Rigenée beds it may be suggested that the entire Ordovician "Tonschiefer" suite served as a tectonically incompetent "lubricant" rather than representing a superincumbent stack of stratigraphically ordered beds. This would also comply better with the apparent lack of competent Ordovician and Early Silurian beds above and below these incompetent mudrocks. This hypothetical model also fits rather well with a recent tectonic analysis of the Ebbe by SCHREINER & SEMERAK (1980) and SCHREINER (1982), who described the existence of a major listric thrust plane cutting virtually bedding-parallel along parts of the highly ductile Ordovician shales in the Herscheid-Reblin core of the Ebbe Anticline. Thus the widespread Llanvirn shales in the Brabant-Ebbe region may be present here only as completely disjunct slivers from any coarser-grained originally adjacent lithologies which may still rest in the deep subsurface of the Rheinische Schiefergebirge. On the other hand, if a generally autochthonous structure could be verified at Herscheid, a research borehole at this location would guarantee new insights into underlying beds and possible facies correlatives with the Midland-Brabant Massif.

It may be premature to attempt a longer distance correlation of the Ordovician lithogenetic sequence of the Ebbe and Remscheid suites prior to having achieved a better biostratigraphic resolution. For the Ebbe and Remscheid "highs" only an early Llanvirn to Llandeilo age may at present be regarded as secure, based on graptolite, trilobite, and acritarch evidence. This allows for at least tentative correlation with similar lithogenetic and fossil developments in the autochthonous Brabant and allochthonous Condroz, and possibly even with the upper part of the likewise allochthonous Salm sequences of the Stavelot Massif. Correlation is much more difficult, however, with the autochthonous sequence of the Schwarzburg Anticlinorium in Thuringia (and even more so with the "Bavarian Facies" Middle Ordovician). The "Plettenberger Bänderschiefer" (if this unit proves to be a valid stratigraphic unit vis-a-vis the "Untere Tonschiefer", see above) cannot be correlated with the "Griffelschiefer" because the latter is probably middle Arenig and thus somewhat older. Considering the present-day rather short distance between the Ebbe and the Schwarzburg Anticlinoria (ca. 250 kms) it is surprising not to find the same chamositic ore horizons in the Ebbe area which are so widespread in the Saxothuringian Belt between North Africa and Thuringia. These horizons (one below the "Griffelschiefer" and two above) are apparently good event markers in restricted cold water shelf environments, but fail in water masses with more open-circulation and thus in less "sensitive" sequences, such as in those represented by the dark shales of the Ebbe and Brabant areas or in other "Rheno-Hercynian" facies areas of the Variscan nomenclature.

In the northern vicinity of the Ebbe, but within the post-Variscan Mesozoic Münster Basin (a tectonically inverted structure referred to as "Lippstadt Dome"), the Soest-Erwitte borehole 1/1a (TEICHMÜLLER, 1978, CLAUSEN & TEICHMÜLLER, 1982) yielded graptolite bearing shales, which, in fair analogy with the Ebbe occurrences, were considered by these authors to derive from Ordovician rocks rather than from Silurian because the coarse clastic shallow marine Upper Silurian encountered in the Ebbe area is clearly not of graptolitic facies. However, due to the nature of the borehole sampling, a more detailed analysis of these graptolites is impossible, nor were lithological or other stratigraphically relevant and useful data released in the reports on this borehole.

South of the Ebbe, close to the presumed subsurface "Mid-German Crystalline Rise" (a potentially Variscan-reactivated "high"; KREBS, 1975, 1978), several olistoliths (ENGEL *et al.*, 1983, BIRKELBACH *et al.* 1988) within the allochthonous Late Devonian to Early Carboniferous "Giessener Grauwacke" are known to be of Caradoc age based upon brachiopods, pelecypods, trilobites (R. & E. RICHTER, 1927, KEGEL, 1953, STRUVE, 1962, 1975, BAHLBURG, 1985), and ostracods (SCHALLREUTER, 1991); these are known as the "Quartzite of the Andreasteich". Furthermore, quartzitic pebbles containing the Arenig trilobite *Neseuretus grandior* and the ?Llanvirn *Ogygiocaris henningsmoeni* were described by STRUVE (1975) from quartzitic erratics within a small confined area, called the "Wetterau" (W of the large late Miocene "Vogelsberg" volcano in central Hessia). Since the trilobites originate from stratigraphically unrelated quartzitic rocks, a source area near the "Mid-German Crystalline Rise" is usually given in the literature. However, there is virtually no evidence that such a "crystalline" or "pre-Variscan" plateau was located during the Early Palaeozoic along the southern margin of the subsurface Saxo-Thuringian Zone, crossing Hessia all the way from NW Saxony (where the northern prolongation of the Schwarzburg Anticlinorium apparently exists in the subsurface) to northern Alsace and further west to Brittany (see also ZWART & DORNSIEPEN, 1978)). It appears more likely that these ?Arenig, Llanvirn ("Münzenberg Quartzites"), and the Caradoc "Andreasteich" quartzites derive from possible "shoals". Alternatively, these quartzites may have formed during regressive events coincident with the formation of the "Valhallan" Lower Chamosite Horizon (of the Schmiedefeld Formation - early Llanvirn?) and the "Hauptquarzit" (late Caradoc). The "Münzenberg" quartzite pebbles containing *Neseuretus grandior* from the Wetterau may also correlate with the Collmberg and Dubrau Quartzites farther east (see above) and with the Armorican Quartzite to the west (STRUVE, 1975).

The Early Palaeozoic depositional history of northern Germany is known only through a very coarse network of borehole data, mostly being concealed by more than 10.000 m of Upper Palaeozoic, Mesozoic and Cenozoic cover (see fig. 1). Nevertheless, a few cores in southern North Sea Basin, southern Jutland (Denmark), and in northern Schleswig Holstein revealed disconformable contacts between Late Proterozoic (Dalslandian) consolidated basement rocks and Devonian post-Caledonian molasse (Old Red) or post-Variscan (Rotliegend) molasse further to the east (KREBS, 1978, P.A. ZIEGLER, 1984, D. FRANKE, 1990). The southern margin of the Baltic-Podolian (East European) Craton is rather well explored by now, extending from the NW along an arcuate line leaving the Norwegian coast south of Stavanger, re-entering the deep subsurface of the northern Schleswig-Holstein coast near the Island of Sylt (BUSCH *et al.*, 1974), continuing almost W-E in the deep subsurface of the Danish Isle of Fyn, turning SE beneath the Islands of Lolland and Falster, then entering Mecklenburg at the western coast of the Darß Peninsula N of Rostock and continuing in the deep subsurface S of Stralsund and Greifswald, north of the Polish city of Szeczin, to follow a trend toward the region north of the Holy Cross Mountains (Gory Swietokrzyskie) in south-central Poland (MODLINSKI, 1968, 1976; D. FRANKE, 1990). The exact course of the German segment of the Caledonide deformational belt ("Scholle von Grimmen" between "Stralsunder Tiefenbruch" (= Stralsund Lineament in Fig. 1) in the north and "Anklam Lineament" in the south) is given in recent papers by D. FRANKE *et al.* (1989) and D. FRANKE (1990). Investigations of core samples by JAEGER (1967), D. FRANKE (1967), D. FRANKE *et al.* (1989) and PISKE & NEUMANN (1990) showed that apparently the German territory north of the "Stralsunder Tiefenbruch" belongs to a "Rügen-Pomorze Terrane". This microplate may be a dislocated fragment of the Baltic-Podolian Craton analogous to the Holy Cross Mountains which probably formed another strike-slip faulted terrane that was wrenched off and later redocked with the Baltic-Podolian (East European) Shield during the Caledonide consolidation of the North German Platform with the Baltic-Podolian (East European) Craton (D. FRANKE, 1990; see also Fig. 4). It is possible that the "Ringköping-Fyn High" formed a similar "wrench terrane" along the strike-slip oblique collision between the peri-Gondwana and Baltica during the Přidoli time (see Fig. 4). D. FRANKE (1967) already remarked the absence of expected Caledonide folding in the Ordovician of Rügen, but the development of a flysch-like deep basin instead. Due to the extremely condensed development of flat-lying "Baltic-type" Ordovician on the Danish Isle of Bornholm (23 m) and similar thickness in the core G 14-1/86 (Petro-Baltic, see PISKE & NEUMANN, 1990) off the coast of Rügen, it is impossible to derive the ca. 1.000 m of Ordovician greywackes, mudstones and breccias of northern Rügen (D. FRANKE, 1967, JAEGER, 1967) from

a Baltic cratonal source. This material presumably originated either from an emerging terrane (such as the above mentioned "Rügen-Pomorze Terrane" or from a rapidly emerging southern source area, possibly from the northward advancing "North German Massif" (D. FRANKE *et al.*, 1989, D. FRANKE, 1990) during the closing phase of the Tornquist Sea (COCKS & FORTEY, 1982). The thick but sparsely graptolitic Llanvirn mudstones of the Arkona core from northernmost Rügen (JAEGER, 1967) may have been transported by contour currents. PISKE & NEUMANN (1990) consider the belt south of northern Rügen and north of the Anklam Lineament as the ?folded and northward thrust part of a Caledonide fold belt. South of the Anklam Lineament to a laterally dissected "Variscan Outer Margin" (transsecting Mecklenburg-Pomerania in an E-W direction ca. 70 kms N of Berlin) there is as yet no borehole control of pre-Variscan basement (D. FRANKE, 1990, fig. 1), although deep seismic data (HOFFMANN *et al.*, 1989) seem to support the presence of a pre-Caledonian consolidated basement in this area, formerly called "East Elbe Massif" (von GAERTNER, 1960), but now presumed to be much larger and thus renamed "North German Massif" (D. FRANKE *et al.*, 1989, D. FRANKE, 1990).

A comment concerning the Earliest Palaeozoic history of the palaeogeographic relationship between peri-Gondwana and Baltica (East European Platform) may be in order here: The biogeographic and facies contrast between these two cratons is well known and largely based on biofacies criteria by WHITTINGTON & HUGHES (1972, 1974), HAVLIČEK (1976) and COCKS & FORTEY (1982). It is remarkable, however, to note that a much greater similarity exists in fauna, acritarch palynofacies and lithofacies between the northernmost Norwegian Cambro-Tremadocian sequence on the Digermul Peninsula (eastern Finnmark; READING, 1965; NIKOLAISEN & HENNINGSMOEN, 1985; WELSCH, 1986) and coeval peri-Gondwana regions than with the southern regions of the same plate (Scania, Bornholm, etc.). This may be best explained by the hypothesis of a 180º rotation of the Baltic craton from the Vendian rifting of the Iapetus to the Silurian closure of the Tornquist Sea. This hypothesis is strongly supported by recent palaeomagnetic evidence (TORSVIK *et al.*, 1990). Assuming this rotation of Baltica in relation to peri-Gondwana to have developed during Vendian to Ordovician times, a close apposition of the cold water central European peri-Gondwana terranes to the (cool water Bohemian affinity trilobites: NIKOLAISEN & HENNINGSMOEN, 1990) Finnmark marginal cratonic basins may have been realistic for the Vendian to Tremadoc. The palinspastic situation as illustrated in Fig. 4 would therefore depict a rather late (Ordovician) stage of the rotational history of Baltica, shortly before its docking to peri-Gondwana.

Between the suspected "North German Massif" in the north and the fairly densely spaced boreholes into the Lower Palaeozoic in the Halle-Leipzig-Torgau-Doberlug area there is no borehole or outcrop control of pre-Variscan basement rocks. This forms a belt ca. 150 km wide striking almost W-E from the English Midlands (north of the Brabant Massif) to its intersection with the Tornquist-Teisseyre Lineament in western Poland (see D. FRANKE, 1990, fig. 1). At the southern margin of this belt only a few borehole data from the Tertiary-covered "Flechtingen-Roßlauer Scholle" near Magdeburg pertain indirectly to the Ordovician. In several cores penetrating into Carboniferous deposits clastics incorporated into these Variscan deposits have been dated as Llanvirn-Llandeilo in age by means of acritarchs (BURMANN, 1973c). These clastics have apparently been transported there because acritarchs of the same age have also been recovered by BURMANN (1973d, 1973e) from quartzite beds within the autochthonous "Northern Phyllite Belt" of the eastern Harz Mountains and from the "Paschlebener Vorsprung" near Halle.

THE ORDOVICIAN/SILURIAN BOUNDARY.

The Ordovician/Silurian boundary is preserved as a fault-disturbed but fairly continuous section within an olistholith incorporated into a Lower Carboniferous nappe of "Bavarian Facies" at the Döbraberg quarry, ca. 20 kms SW of Hof in NE Bavaria (STEIN, 1965: 119). A ca. 40 m thick succession of highly micaceous sandstones at its base passes laterally into *Glyptograptus persculptus* bearing alum shales and stratigraphically up into a nearly complete Llandovery sequence of black graptolite alum shales and cherts. The basal sandstones, ca. 40 m thick (but for the greater part unexposed), are called Döbra Sandstone (SANNEMANN, 1955). More recently JAEGER (1988) re-evaluated the Döbra/Silurian contact not only at the allochthonous Döbraberg locality, but also at similar sites at the Frankenberg and Wildenfels Allochthons in Saxony; these suggest a stratigraphic and structural setting of the Döbra Sandstone comparable with those of the Eichberg Sandstone which is named after a locality near Weissig, E of Dresden. Near the "Hohe Dubrau" in the Lausitz the Eichberg Sandstone has also been encountered in subsurface cores, but probably in autochthonous position overlying the Dubrau Quartzite (HIRSCHMANN, 1966: 55). Furthermore, FREYER (1959) and TROEGER (1960) report fairly thick sandstone intercalations in the top beds of the autochthonous "Lederschiefer" at its easternmost occurrences in the Vogtland (see above). It is possible that these potentially coeval sandstones all represent a similar regressive event (probably the Hirnantian glacial episode) and may provide a homotaxial facies correlation of the allochthonous "Bavarian" with the autochthonous "Thuringian Facies" in the Vogtland region. According to GREILING (1967) the black fine-grained Döbra

Sandstone, occasionally carrying load casts, represents a turbiditic channel deposit within the Thuringian Facies "Lederschiefer", but he failed to give any evidence for the presence of "Lederschiefer" nearby. Considering the lack of a stratigraphical contact it may be more reasonable to propose that the Döbra Sandstone represents a redeposited equivalent (tempestite?) of sandy shoals located to the SE, which became eroded during the Hirnantian glacial regressive event (just as the Eichberg Sandstone may be relict of such shoals, as suggested by FREYER, 1959). JAEGER (1988) pointed out that the *Diplograptus bohemicus* bearing interbeds of the Döbra Sandstone (at the Frankenberg Massif) could be related, both in facies and age, to the Kosov Quartzite of the Bohemian Massif and to the Carnic Alps, where a conformable Ordovician/Silurian contact exists only in the deeper water facies of the "Feistritzgraben" (SCHÖNLAUB, 1979: fig. 19) in contrast to an increasingly disconformable contact in the Cellonetta to the west. Although equivalents of the "Lederschiefer" are not encountered in the Carnic Alps, a regressive development is clearly demonstrable there as well (JAEGER, HAVLIČEK & SCHÖNLAUB, 1975, JAEGER & SCHÖNLAUB, 1977). Though allochthonous in nature, the Döbraberg succession, described in detail by STEIN (1965: 117-125), appears to represent a depositionally continuous and biostratigraphically identified contact between the top Ashgill Döbra Sandstone and the base of the Llandovery in Germany. The autochthonous "Lederschiefer"/Llandovery contact, for example at the Hohenleuben section, is without biostratigraphic control for the Ordovician "Lederschiefer", but starts with the *Akidograptus ascensus* zone in the Llandovery, and thus with the same lithofacies development as the sequence developed in "Bavarian Facies" (JAEGER, 1988, fig. 2). The uniform autochthonous and allochthonous development of the black alum shales and cherts of the Llandovery Lower Graptolitic Shales in Bavaria, Thuringia, Saxony, and in Czechoslovakia (including the segments of "Bavarian Facies" rocks which may have been detached from a deeper source area) is taken to indicate the beginning of an extensional tectonic setting which heralds the opening of the Siluro-Devonian Rheic Ocean. In Germany and Czechoslovakia there are few, if any, indications of oceanic basalts of a reliably earlier dates.

THE STRUCTURAL DEVELOPMENT OF "PRE-VARISCAN" GERMANY.

During the past decade numerous syntheses and models of the Variscan structural and tectogenic framework of central Europe have been proposed, for example: TOLLMANN (1982), MARTIN & EDER (1983), W. FRANKE (1984), BEHR *et al.* (1984), P.A. ZIEGLER (1984), WEBER (1984, 1986), W. FRANKE (1989), W. FRANKE *et al.* (1990). The pre-Variscan opening phase, including the palaeogeographic disposition of minor cratons or microplates during the Vendian-Silurian interval (ERDTMANN, 1984, fig. 1, revised as fig. 4 herein), is not being dealt with in detail in the above publications. The reason for this is to be seen not only in the strong deformational and metamorphic Variscan overprint to which all pre-Devonian rocks were subjected, but also in the apparent primary paucity of fossils and lack of clearly diagnostic palaeoenvironmental indicators. The pre-Variscan structural history of Germany is, indeed, based on only a few and widely spaced observation points. Previously many sedimentologically disconformable contacts between stratigraphic units within the Early Palaeozoic were attributed to Caledonian unconformities, but modern reinvestigations indicate that most of these contacts are related either to regional rift tectonics or to eustatic events. With the exception of the Tornquist-Teisseyre Belt (see Figs. 1 and 4, D. FRANKE *et al.*, 1989; D. FRANKE, 1990; PISKE & NEUMANN, 1990) unequivocal Caledonian unconformities or Caledonian intrusives, etc. are no longer being postulated east of the eastward extension of the Brabant Massif (WALTER, 1980a; W. FRANKE, 1989), although ?Caledonian east of the eastward extended Brabant Massif (WALTER, 1980a; W. FRANKE, 1989). Due to the high degree of Variscan overprint detailed reconstructions of geological history are being frustrated, and geochemical approaches offer little hope of identifying chemostratigraphic markers now or in the foreseeable future. At present, therefore, only broad correlations can be attempted between widely differing facies, using the few observable event-stratigraphical markers.

POTENTIAL EVENT-MARKERS IN THE EARLY PHANEROZOIC OF CENTRAL EUROPE.

During most of the Vendian-Cambrian period long-distance correlation is made difficult not only because of the low fossil yield and high degree of endemism of the sparse fossil record, but also due to the individualized developments of small rift basins, partly with high proportions of local terrestrial clastic input (localized lithofacies). The Early Vendian tillites may be camouflaged in many parts of "Variscan" Europe ("Brioverien" of Normandy) or misinterpreted as rift-graben gravity flows which are quite common in this environment. Moreover, the glacial origin of such possible tillites is doubtful in many regions, especially in Germany, e.g. within the "Weesensteiner Grauwacke" (LINNEMANN *et al.*, 1988) or of the "Gerölltonschiefer" within the "Leipziger Grauwacke". Furthermore, only very approximate biostratigraphic controls exist for these putative diamictites at the present time. On the other hand along the general strike of major Variscan structural belts there are often great similarities of depositional settings, even in detail, at narrowly defined stratigraphic intervals. In this regard the early to middle Arenig

Armorican Quartzite and its peri-Gondwana equivalents are of special palaeoenvironmental and stratigraphic application (DEAN, 1976, NOBLET & LEFORT, 1990). Even more useful for event-stratigraphic correlations are the early/middle Arenig, Arenig/Llanvirn, early Caradoc to early Ashgill chamositic oolitic ore horizons (YOUNG, 1989). These marker beds are known not only from Thuringia but also from the Barrandian Basin (PETRANEK, 1964), from the Armorican Massif (CHAUVEL, 1974), the Avalon Terrane of eastern Newfoundland (HAYES, 1915, RANGER *et al.*, 1984), from central Portugal (ROMANO *et al.*, 1986), the Sierra Morena in southern Spain (GUTIERREZ MARCO & LUNAR (1987), Libya (CHAUVEL & MASSA, 1981) and from Morocco (DESTOMBES, 1971) to areas as far east as the Middle East. Although the genetic history and detailed stratigraphy of these extremely widespread but probably time-specific Ordovician deposits are not fully understood as yet, their event-stratigraphic significance is only beginning to be unravelled (YOUNG, 1989). Similarly the significance of black-shale transgressions ("Griffelschiefer" in the middle Arenig or *"tristani*-Shales" in the early Llanvirn), and the onlap as well as possible offlap nature of certain shore-related sandstone units is beginning to play a major role in a sequence-stratigraphical analysis of the Early Phanerozoic deposits of peri-Gondwana Europe. Although as yet only roughly datable, the suspected Ashgill glacial regression has been recognized in the striated erratics of the "Lederschiefer", in the presumably regressive Döbra Sandstone and the possibly equivalent Eichberg Sandstone; but these units have so far only been observed in the allochthonous "Bavarian Facies" and lack palinspastically reliable parameters. These marker horizons will have to be tested, so far as metamorphism allows, by trace element, rare earth element and various stable isotope investigations.

Certain biostratigraphic indicators could be employed as event-related markers upon careful biofacies analysis. For example, the brief episode of archaeocythid bearing limestones (or, in the case of the Görlitz Synclinorium, of small-shelly fossil bearing limestones) during the Atdabanian to Botomian (middle to upper Lower Cambrian) may respresent a useful stratigraphic marker in the peri-Gondwana shelf. During the Cambrian the vast shelf apron of the Afro-Mediterranean region may have rifted first in the more peripheral (Normandy-Görlitz) regions, and later in the more "central" regions of the Montagne Noire and in Sardinia, because the archaeocyathid build-ups lining the fractured platform margins become progressively younger in the direction toward Africa (COURJAULT-RADE *et al.*, 1990). According to the sparse trilobite records in the Lower and Middle Cambrian a distinct "Mediterranean" biofacies province is indicated by redlichiid-eodiscid elements (SDZUY, 1962). This biogeographic trilobite province apparently remained intact through the Tremadoc Leimitz Shales (SDZUY, 1971) to the Arenig-Llanvirn *Neseuretus*- and *Cyclopyge*-bearing beds (FORTEY & MORRIS, 1982) in the Schwarzburg Anticlinorium ("Griffelschiefer"), in the Ebbe ("Untere Tonschiefer": SIEGFRIED, 1969) as well as in Hessia ("Münzenberg Quartzite": STRUVE, 1975). Ordovician graptolites are only broadly applicable as facies indicators, but remain among the best high-resolution markers at the few stratigraphic horizons where they appear in Germany: at the base of Tremadoc (in "Hohes Venn": *Rhabdinopora parabola* and *R. flabelliformis*), at the base of the Hunneberg Stage *(Araneograptus cf. murrayi)*, near the base of the Arenig (in the Schwarzburg Anticlinorium) and in the mid-Arenig (base of the "Griffelschiefer"). The occurrence of *Didymograptus artus* and *Nicholsonograptus fasciculatus* in the Ebbe Anticlinorium (and in the Arkona core of Rügen) are good Llanvirn indicators; currently the youngest Ordovician graptolites are *Climacograptus angustatus* and *Glyptograptus cf. teretiusculus* from the ?Llandeilo "Untere Tonschiefer" of the Ebbe Anticlinorium, although younger (Caradoc) graptolites are listed from there by BEYER (1941b, c). All Ordovician graptolites found in Germany so far typically belong to an open-pelagic sub-biofacies to which only eurythermic or possibly extreme cold-water forms belong. The most promising fossils for the Early Phanerozoic of this region may prove to be acritarchs, which are well represented in these clastic environments of peri-Gondwana (HEUSE, 1989, 1990, unpubl. dissertation, 1990) from the Late Riphaean into the Silurian (and higher). Although little is known about acritarch palynofacies, it seems that these also indicate cold-water affinities in all European localities southwest of the Tornquist-Teisseyre Lineament between the English Lake District (MOLYNEUX & RUSHTON, 1988) and the Libyan and Magreb regions of North Africa (see Fig. 4; VAVRDOVA, 1974). In addition to acritarchs a few chitinozoans have been recovered from Ordovician black shales ("Untere Tonschiefer" of the Ebbe and "Griffelschiefer" from Thuringia, SERVAIS, pers. comm. 1990) and conodonts are known from calcareous hardgrounds in the chamositic ore beds of the Schmiedefeld Formation of Thuringia (KNÜPFER, 1967, FUCHS, 1989, 1990) and from coeval beds of the "Randschiefer" ("Bavarian Facies") of NE Bavaria (SANNEMANN, 1955). These conodonts, however, may also be useful for future palaeoclimatic investigations (DZIK, 1989, KOVACH, 1988). Minor elements of the Early Phanerozoic fauna include ostracods from calcareous erratics in the Ashgill "Lederschiefer" tilloid (BLUMENSTENGEL, 1965, KNÜPFER, 1968) and various rare occurrences of brachiopods (mostly inarticulates) from Lower Cambrian of Doberlug (SDZUY, 1957) and Görlitz (FREYER, 1981a), from suspected Tremadoc of Thuringia (A.H. MÜLLER, 1956), northern Saxony (BARTSCH, 1956) and the "Hohe Dubrau" of the Lausitz area (HIRSCH-

MANN, 1966). Although Ordovician articulate brachiopods have proved of value for "Mediterranean" palaeogeographic reconstructions (HAVLIČEK, 1976), unfortunately only inarticulate brachiopods have been found in Germany so far, and rather few of these "spurious" elements may render sufficient data for a modern stratigraphic and palaeoenvironmental analysis.

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