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**MUSEI RERUM NATURALIUM
BOHEMIAE OCCIDENTALIS**

Václav Havlena

Late Palaeozoic Palaeogeography
of Czechoslovakia and the Plzeň Basin

Geologica 7

Západočeské muzeum Plzeň

KNIHOVNA ZÁPADOČESKÉHO MUZEA



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Plzeň 1976

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Katkovna p. 500.000.000

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RL 41/42

RL 1988

11 412

FOLIA MUSEI RERUM NATURALIUM BOHEMIAE OCCIDENTALIS, PLZEŇ
Fol. Mus. Rer. natur. Bohemiae occident., Plzeň, Geologica 7.

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Abstract: In the Lower Carboniferous time two Palaeozoic geosynclines are believed to trench on the territory of Czechoslovakia. The Upper Carboniferous and Permian deposits of Czechoslovakia are classified with regard to the evolutionary pattern of a geosyncline established by AUBOUIN (1965). The Bruno-Vistulikum platform is delineated which played the role of Aubouin's intermediate foreland during the times concerned. The marine Carboniferous and Permian deposits of the Spiš-Gemer Mountains appear to be laid down in a special molasse intra-deep. The Verrucano basins of the West Carpathians are regarded as limnic basins of the Upper Permian time-interval.

THE STRUCTURE OF THE VARISCIDES, BOHEMIAN MASSIF

During the Sudetic orogenesis the central European archipelago consisting of the northeast-trending cordilleras and depicted e. g. by PAPROTH (1969) or SCHMIDT & FRANKE (1975) coalesced into a monolithic land mass. This mass has been called the Czech-Rhine „Zwischengebirge“ by MĀŠKA (1960), central European cordillera by PRUVOST (in AUBOUIN 1965), „alemanisch-böhmische Insel“ by BRINKMANN (1966) and „mitteleuropäische Insel“ by KÖLBL (1968).

STILLE (1951) emphasized this constructive role of the Sudetic orogenesis in the domain of the European Variscides, and AUBOUIN (1965) closed up with it his geosynclinal period of the Variscan geosyncline. The later orogenic phase, the Krušné hory phase (the Erzgebirge phase), is not to be exactly dated in the classical area (SCHROEDER 1968). It is then to be included into the Sudetic phase.

The above mentioned land mass or the *central European Variscan mountain chain* is flanked by two external molasse troughs of AUBOUIN (1965), i. e. by two fore-deeps. I have termed the southern one the Upper Silesian fore-deep (HAVLENA 1974). It came into being at the edge of a platform quoted by ZAPLETAL (1957), KUMPERA (1972) and many others as Brunnia which is commonly interpreted as the south-eastern foreland of the central European chain. In the present concept this platform is delineated as follows:

In the west it includes the pre-Cadomian Brno pluton (1,065—1,410 m. y., DUDEK & MELKOVÁ 1975) which is proved to extend today beyond the Boskovice furrow (compare JAROŠ & MĀSAR 1974), and the Moravian blocks of various authors. In the east it terminates along the West Carpathian Klippen belt and in the north along the East European platform. The southern termination is as yet unknown but the line of the river Dyje (Thaya) comes minimally into consideration.

Disturbed by great transversal faults the western limit of the platform reaches its westernmost site along the Boskovice furrow in a course bent rectangularly (compare Fig. 1).

The platform which I call the Bruno-Vistulikum embraces KNOPP's „ostsudetische Zwischenschwelle“ (1933), STILLE's Vistulikum (1951) — however, without the Kielcides, ZAPLETAL's Brunnia (1957), MĀŠKA's Moravian block (1960), DVOŘÁK's pre-Carpathian platform (1968), ANDRUSOV's „Vindelizisch-Beskidischer Rücken“ (1968), the Upper Silesian block of KOTAS (1972) and the „Brunnia Schwelle“ of SCHÖNENBERG (1973).

The central European Variscan mountain chain possesses a striking zonal framework controlled by the symmetrically divergent structure of the chain. The axis of divergence is believed to occur (1) somewhere between the Bohemian Massif and the Eastern Alps, or (2) in the median zone of the former.

(1) In this concept which is based on the ideas of KOBER (1928) the Bohemian Massif appears as the northern flank of the central European chain. The Variscan elements of both Eastern Alps and West Carpathians belong to the southern flank of the chain concerned. These ideas are maintained e. g. by MĀŠKA (1960) or by ZNOSKO (1970).

(2) STILLE (1951) is the originator of the second concept. The axis of divergence — Stille's „*alemannischer Scheitel*“ — is lying in the median or Moldanubian zone of the Bohemian Massif. Either flank of the central European chain is then incorporated in the Bohemian Massif. The north-western flank of the chain has been called by STILLE (1951) the Rhenides, the south-eastern one the anti-Rhenides.

In the northeast the Variscan mountain chain terminates at the East European platform. There are three meanings how this termination is to be interpreted.

(1) The NNE-striking eastern Sudetes or Moravosilesian structural elements of the Bohemian Massif are linked together with the ESE-trending structures of the Świątokrzyskie Góry, Poland. The folds of the related arch which was called by ZAPLETAL (1928 b) the „*ostvariszischer Bogen*“ and by BEDERKE (1930) the „*ostsudetisch-polnischer Bogen*“ should exhibit the vergence to the south. They envelope the Upper Silesian basin (Fig. 1, A).

(2) Toward the east the central European Variscan mountain chain splits into several separate ranges enveloping important Upper Palaeozoic basins. Anticipated by Limanowski's ideas dealing with two ranges only lying on the Polish territory this concept was discussed in particular by KNOPP (1933). Now it is to be found mostly in the Polish papers (e. g. BUKOWY 1972). See Fig. 1, B.

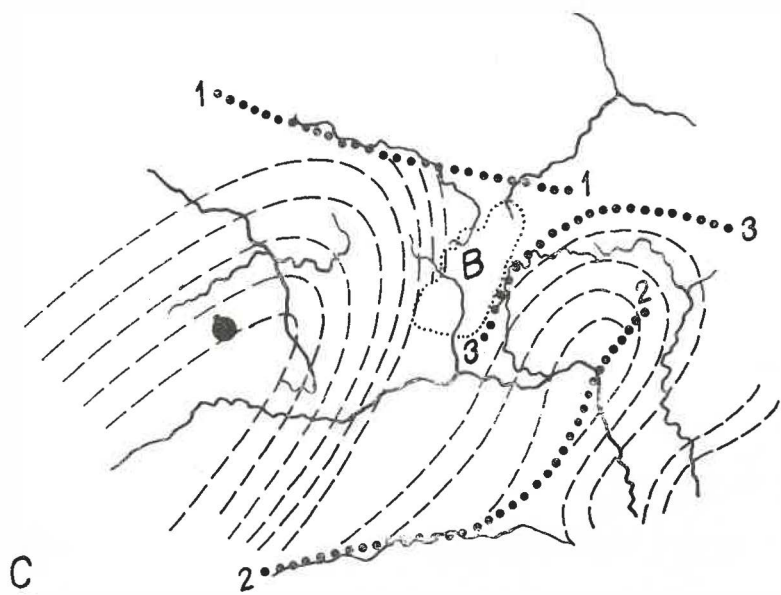
(3) In the north-eastern sector of the Bohemian Massif the central European chain closes up periclinally due to the remarkable arcuate grouping of the structural elements of both Rhenides and anti-Rhenides (STILLE 1951). This „*Scharung*“ of Stille has been anticipated as „*sudetisches Bogenstück*“ by SUESS (1888) and as „*sudetische Schlinge*“ by FRECH (1899). Today this arcuate framework of the Bohemian Variscides is regarded to be even of pre-Cambrian provenience (HOLUBEC 1974).

STILLE (1951) explained his „*Scharung*“ as axial dipping of the chain axis, which appears to be supported by the southwest-striking axial elevation in the geosynclinal furrows to be found in the Bohemian Massif (p. 11). BRAUSE (1973) suggested to move the chain axis more to the north and to turn it to the south-southwest up to the Boskovice furrow. However, the trend of the structural lines in the north-eastern part of the Bohemian Massif is not compatible with this hypothesis. Compare also DVOŘÁK (1973).

Fig. 1 — Various concepts of the periclinal closure of the Variscides. Plzeň basin indicated by a point.

A — Concept of ZAPLETAL (1928a, b), BEDERKE (1930), PATTEISKY (1938) and others. B — Concept of KNOPP (1933), BUKOWY (1972) and others. C — Concept used in this paper.

1 — 1: Border of the East European platform, 2 — 2: peri-Adriatic line and Balaton line, 3 — 3: Klippen belt, West Carpathians.



ŠATSKIJ & BOGDANOV (1961) suggested to extend the aforesaid axis of divergence up to the edge of the East European platform without any dipping. The Świętokrzyskie Góry unit is to be regarded as an intra-craton element of the platform concerned. With the same in mind DVOŘÁK (1968, 1973) limited the East European platform by the rectilinear Odra lineament and emphasized the role of the transversal faults in the central European Variscan mountain chain. The East European platform should be thrust over this Variscan unit during the Westphalian time (DVOŘÁK 1973).

Having examined the results of boreholes executed in the Bohemian Massif and its vicinity, the structural setting of the Variscan limnic basins as well as various structural aspects revealed in the Upper Silesian basin I find the classical concept of STILLE (1951) extended by AUBOUIN (1965) to be the most plausible interpretation of the Variscan structural framework of the Bohemian Massif (HAVLENA 1971, 1972, 1974).

In the Stille-Aubouin's concept the geosynclinal period of the central European Variscides is characterized by the existence of the Rhenides eugeosyncline-miogeosyncline couple in the north-western flank and of the anti-Rhenides couple in the south-eastern flank of the Variscan geosyncline. A detailed treatment of the inner organization of these couples was given by AUBOUIN (1965) and DVOŘÁK & PAPROTH (1969). The southwest-striking axis elevation of the relevant geosynclinal furrows was described by DVOŘÁK (1968, 1973).

THE STRUCTURE OF THE VARISCIDES, WEST CARPATHIANS

In the older meanings the Variscan chain of central Europe has been extended into the area of the West Carpathians without any detailed discussion (e. g. KOSSMAT 1936). The Variscan orogenesis was thought to take place before the Moscovian transgression evidenced in the Spiš-Gemer Mountains which in turn should introduce the Neoidic regeneration of the Variscan geosyncline (STILLE 1953). The fossiliferous deposits of the transgressive Carboniferous are commonly interpreted as belonging to the miogeosynclinal domain (e. g. KÖLBL 1968).

PATTEISKY (1938, 1971) inspired by the ideas of BEDERKE (1930) regarded the West Carpathian area as flooded by the sea of his „ostsudetische Bucht“ opened to the south. The NNE-striking Upper Silesian and eastern Sudetes elements were said to continue up to the Eastern Alps and to form the northern marginal zone of the south-eastern Carboniferous geosyncline of the author (PATTEISKY 1971). The fossiliferous Carboniferous of both West Carpathians and Bükk Mountains should form the southern marginal zone of the above geosyncline.

Recalling the ideas of STILLE (1951, 1953) MĀŠKA & ZOUBEK (1960) pointed out that the pre-Neoidic basement of both Eastern Alps and West Carpathians should belong to the Mediterranean province. The last Variscan orogenesis was said to take place at the Lower Carboniferous/Upper Carboniferous boundary, i. e. in the Sudetic phase. ANDRUSOV (1958, 1968) first established a marked Variscan mountain chain in the West Carpathians which he linked together with the central European Variscides by a V-bent curve in the territory of Moravia (*invagination*, ANDRUSOV 1958; *Moravian sigmoide*, ANDRUSOV — BYSTRICKÝ — FUSÁN 1973).

The Variscides of both Eastern Alps and West Carpathians are today scattered and engulfed in the Neoidic structural pattern which is marked by nappes translated to a greater or lesser extent. As a first approximation the palinspastic setting of the attached and detached Upper Palaeozoic rocks has been compiled for this paper at the level of the co-ordinates of the tectogen. The total „unfolding“ of the original geosyncline which would certainly produce more precise palaeogeographies remains in most aspects still really hypothetical.

At the level of the first approximation my analysis presents arguments in support of an independent geosyncline trending from the Eastern Alps in the West Carpathians in the Palaeozoic times. For convenience this geosyncline will be called the *Austro-Slovak geosyncline*.

This new concept is based on new lithofacies and palinspastic data gathered by Slovak geologists (REICHWALDER 1973, ABONYI 1974, VOZÁROVÁ & VOZÁR 1975) as well as by Austrian experts (CLAR 1971, KAHLER 1971, LAUBSCHER 1971, SCHÖNENBERG 1973, FLÜGEL 1963, 1975). The concept is in good accordance with the new borehole records in Hungary (BALOGH & BARABÁS 1972, BALOGH — BARABÁS — MAJOROS 1973) and conforms well to modern principles concerned with the structure organization of the pre-Neoidic basement of Hungary (SZALAI 1969, DANK & BODZAY 1971, WEIN 1973, SZÁDECZKY — KARDOSS 1975).

The northeast-striking Austro-Slovak geosyncline had its intermediate massif somewhere in the Tisia massif of Hungarian geologists. To the northwest the intermediate massif was flanked by an eugeosyncline-miogeosyncline couple the eugeosyncline-mio-

geosyncline boundary of which is believed to be indicated by the Balaton line today. To the west this line is supposed to join the Insubric line = the peri-Adriatic line (FLŰGEL 1975, SZÁDECZKY — KARDOSS 1975). Since the domain of the eugeosynclinal furrow of the aforesaid couple is to be compared to the Igal — Bükk eugeosynclinal trough introduced by WEIN (1973), I will term the north-western couple of the Austro-Slovak geosyncline the *Igal Couple*.

To the eugeosynclinal furrow of the Igal couple the pre-Namurian deposits of both Carnian Alps and Karawanken range as well as of the Uppony, Szendrő and Bükk mountains in Hungary are belonging. The Zemplín area in Slovakia is regarded as a part of the relevant eugeosynclinal ridge or even of the relevant intermediate massif.

The miogeosynclinal furrow of the Igal couple extended northward of the eugeosynclinal-miogeosynclinal boundary concerned. To this furrow the Variscan geosynclinal domains of the Oberostalpinum (Eastern Alps) and of the Tatrikum, Veporikum and Gemerikum (West Carpathians) appear to belong.

The geosynclinal history of the Igal couple ended in the time of the Sudetic orogenesis when a northeast-striking median land mass was brought into being in the Austro-Slovak geosyncline. This land is to be called the *Austro-Slovak Variscan mountain chain*.

In contrast to the central European Variscides, however, this chain was flooded by a sea again which was a narrow and shallow offshoot of the Mediterranean Palaeozoic Tethys. This sea traced the eugeosynclinal-miogeosynclinal boundary of the Igal couple and persisted there up to the time of the Neoidic remobilization of the Austro-Slovak geosyncline.

In the sea offshoot a special molasse intra-deep may be recognized which came into being immediately after the Sudetic orogenesis. This special structural and time setting will have controlled the peculiar lithologies of its marine infilling which in littoral facies only could be regarded as a molasse. The off-shore deposits of the intra-deep are of shallow-water neritic lithologies and are therefore referred to as of miogeosynclinal origin. All these peculiar epi-miogeosynclinal or quasi-miogeosynclinal lithologies are obscured by remarkable southwest-trending depression of the intra-deep axis which is responsible for the semi-platform facies of the Carboniferous and Permian deposits in the Spiš-Gemer Mountains. To call this intra-deep I will maintain the term „*Dinaric*“ trough introduced by BALOGH & BARABÁS (1972).

The deposits of the „Dinaric“ trough are exposed in both Spiš-Gemer and Bükk mountains. Further records have been made by recent boreholes in Hungary; some of them are given in the Fig. 5 and 6.

With respect to the Alpine tectogenesis the „Dinaric“ trough sea is to be compared to the post-geosynclinal Tertiary sea which penetrated through the channel between the Eastern Alps and West Carpathians toward the interior of the Carpathian arc.

In the present concept the real contact of the anti-Rhenides couple with the Austro-Slovak Igal couple, i. e. the real ~~zone~~ zone of convergence (AUBOUIN 1965), does not exist as between both couples the Bruno-Vistulikum platform acts as a foreland. Hence this foreland is to be regarded as the *intermediate foreland* of AUBOUIN (1965).

Since the Neoidic tectogenesis has strongly reworked the pattern of the West Carpathian Variscides, we find the relevant Upper Carboniferous and Permian rocks not only *in situ* but also in both *attached* and *detached* setting. The autochthonous Upper Palaeozoic sediments are to be found in both Tatrikum and Veporikum as well as in the Zemplín area. The Upper Palaeozoic deposits of Tatrikum and Veporikum, red in colour and lacking fossils, are considered to be of Permian age.

The attached Upper Carboniferous and Permian deposits of Gemerikum are exposed in two belts. An Upper Palaeozoic land traced to the southwest as far as Hungary is believed to be responsible for this zonation. This is the Gemer elevation of SZALAI (1969), the Gemer anticline of ABONYI (1974) and the Gemer land of the present paper.

In the southern belt the Upper Carboniferous deposits are lacking but the Permian sediments are present. They constitute the south Gemerikum Permian of Slovak authors. In the northern belt the Upper Carboniferous deposits form the border Gemer syncline of ABONYI (1974). The famous „magnesite Carboniferous belt“ and, with caution, the Carboniferous deposits at Dobšiná and Rudňany are both belonging to the Abonyi's structure mentioned. The Permian deposits of the northern belt are of Lower and Upper Permian age.

The detached rocks of both Upper Carboniferous (?Stephanian) and Permian ages belong to the Choč nappe which is found on both Tatrikum and Veporikum. The area of the border Gemer syncline is thought to be the homeland of this nappe (ABONYI 1974).

In the presented palaeogeographical maps all the attached and detached Upper Carboniferous and Permian deposits of both Eastern Alps and West Carpathians are drawn up in palinspastic position.

THE NAMURIAN PALAEOGEOGRAPHY IN CZECHOSLOVAKIA

The genesis of geosynclinal furrows and ridges as well as their subsequent evolution is controlled polarly and then not isochronous. Similarly, the forming of the post-orogenic molasse basins materializes successively from the interior toward the exterior. Such is the case with the central European Variscides where the early molasse deposits were laid down in the median part of the mountain chain while in the external parts of the relevant geosyncline the flysch formation was yet deposited.

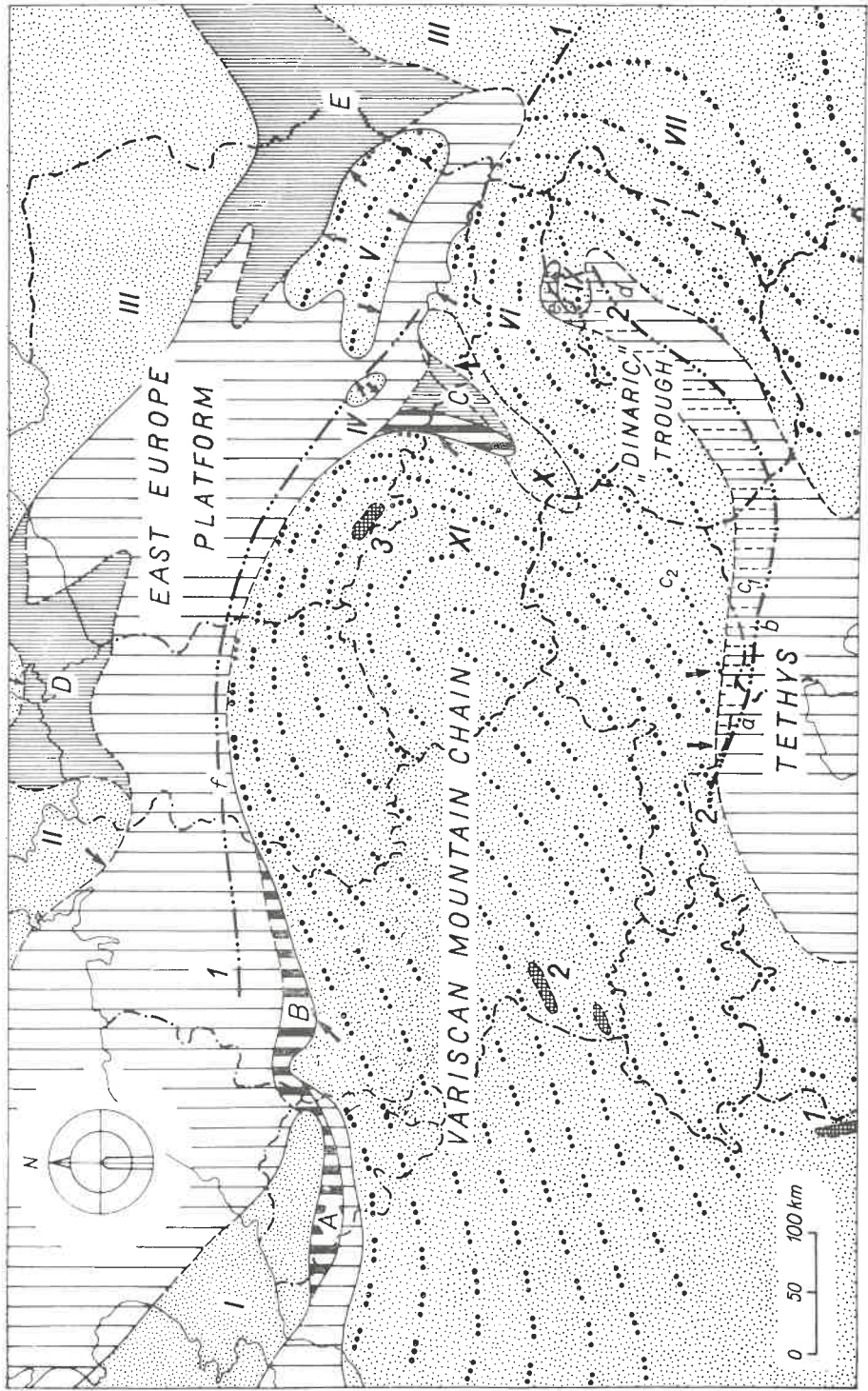
The Carboniferous flysch is invariably said to be represented by the Culmian lithofacies. Unfortunately, the term Culmian lithofacies or „Kulm“ is commonly used in a second meaning too, viz. to designate deposits lithologically similar to the flysch but laid down under conditions distinct from the real flysch environments. AUBOUIN (1965, p. 267) quotes e. g. the case with the „Kulm“ used in the sense of a molasse.

Having examined all the „Kulm“ deposits found in Czechoslovakia I suggest to differentiate them into four types of the „Kulm“: The flysch — „Kulm“ (Nížký Jeseník Mountains), the molasse — „Kulm“ (Drahany Upland), the para-platform — „Kulm“ which is the aleuritic cover of the Bruno-Vistulikum platform, and the intra-platform — „Kulm“ (Inner Sudetes basin).

The late-geosynclinal period of AUBOUIN (1965) is also called the molasse period or the tritogeosynclinal period. In the Bohemian Massif the relevant late-geosynclinal molasse basins are of intra-deep and fore-deep character. The former are referred to as „intramontane Spezialbecken“ by SCHMIDT & FRANKE (1975). With respect to the polar control of their forming the Lower Carboniferous age of the early intra-deep fill is to be stated only.

One of the Lower Carboniferous intra-deeps in question exhibits also the post-Dinantian fill. It is the Inner Sudetes basin where the terrestrial coal-bearing Namurian beds are found to be interpreted here as a limnic molasse (more correctly: terrestrial molasse). Similar molasse intra-deep, also Namurian in age, occurs in the Schwarzwald area (BURGATH & MAASS 1972).

There are two molasse fore-deeps in the central European Variscides, viz. the west European fore-deep and the Upper Silesian fore-deep (Fig. 2). In both fore-deeps



the Carboniferous flysch passes gradually into the molasse (HAVLENA 1971, 1974, Paech 1973).

Situated at the immediate edge of the Bruno-Vistulikum foreland the Upper Silesian fore-deep shows a very narrow shape and rapid decrease of its lower Namurian fill toward the east (PATTEISKY 1938). Moreover, it exhibits the SSW-striking elevation of the axis clearly manifested in both structure and lithofacies of the basin: To the south-southwest the marine bands of the paralic Ostrava formation die out, the thickness of the same formation thins considerably, its coal amount decreases etc.

The similar affair is found within the Lower Carboniferous „Kulm“ of the adjacent eastern Moravia miogeosyncline (DVOŘÁK 1968, 1973): To the southwest the flysch — „Kulm“ of the Nížký Jeseník Mountains passes into the molasse — „Kulm“ of the Drahaný Upland which in turn terminates in the southwest in a marked brachysynclinal closure near Brno; to the southwest the quality of folding changes impressively etc.

This striking axial elevation of the Variscan basinal structures in Moravia and Silesia lends great support to the hypothesis of the axial dip closure in the Bohemian Massif (p. 11). It is due to the gradual advancement of the Bruno-Vistulikum platform to the west (p. 3). With this in mind we have to regard the Namurian coals of the borehole NĚmčičky 1 (southern Moravia, ŘEHÁK 1975) as the foreland basin coals.

To the east the structure, thickness and lithofacies of the paralic Ostrava formation of the Upper Silesian fore-deep intensely change along a NNE-striking line, which



Fig. 2 — Namurian palaeogeography of central Europe.

1 — Land, 2 — terrestrial environments: Variscan molasse intra-deeps, predominantly detrital fill, 3 — 4: paralic environments, 3 — Variscan fore-deeps, predominantly detrital fill (important coals present in Upper Silesia), 4 — foreland and intra-platform basins with detrital or carbonate sediments, 5 — 6: marine environments, 5 — neritic deposits, 6 — shallow-water deposits (reef limestones present in places), 7 — known and reputed boundaries, 8 — prevalent direction of transport, 9 — reputed course of Variscan folds, 10 — 1-1: southern border of the East European platform, 2-2: peri-Adriatic line and Balaton line.

Land areas: I — Wales-Brabant island, II — „Ostelbisches Massiv“, III — Fenosarmatia, IV — Dębnik island, V — Świętokrzyskie Góry land, VI — Austro-Slovak Variscan mountain chain, West Carpathian sector, VII — Lóczy ridge and Tiszia, VIII — not present in this figure, IX — Gemer land, X — Bruno-Vistulikum, XI — Bohemian Massif.

Basins with terrestrial fill: 1 — Briançonnais, 2 — north: St. Hippolyte — Offenburg, south: Müllheim (BURGATH & MAASS 1972), 3 — Inner Sudetes basin (Lower Silesian basin).

Basins with paralic fill: A — Synclitorium of Namur, B — Ruhr basin, C — Upper Silesian basin, D — Rügen and Pommern basin (boreholes), E — Lvov basin and Lublin basin (boreholes).

Sea deposits: a — Carnian Alps, b — Karawanken range, c₁ — „Veitscher Decke“ unit, Nötsch and Craz (before thrusting), c₂ — the same, present position, d — Bükk Mountains, e — Spiš-Gemer Mountains, f — Flechtingen.

mirrors the transition of the mobile edge of the Bruno-Vistulikum foreland (or the western unstable zone of the Upper Silesian block, KOTAS 1972) into the stable foreland platform. Eastward of the above line marked in the map by the Orlová fault, the isopic deposits of the Upper Silesian foreland basin are to be found.

In this way the Upper Silesian basin falls into the narrow fore-deep in the west and the vast foreland basin in the central part and in the east (STILLE 1951, HAVLENA 1974 — compare Fig. 2). It is just in the fore-deep concerned where the latest Variscan orogenic episode producing actual folds took place in the Bohemian Massif area (Westphalian A/B boundary, HAVLENA 1971).

In the Austro-Slovak geosyncline the Namurian time-interval is represented by the flysch deposition which took place in the eugeosynclinal furrow of the Igal couple. The Hochwipfel series of the Carnian Alps and the isopic deposits in the Bükk Mountains are belonging here. The termination of the flysch sedimentation, i. e. the end of the geosynclinal period, coincides then with the early Westphalian.

In the West Carpathian sector of the Igal miogeosyncline the geosynclinal period is to be terminated with the Rakovec series of the Spiš-Gemer Mountains (Devonian to Lower Carboniferous). A sedimentary break corresponding with the Sudetic phase separates it from the attached quasi-paralic fossiliferous beds with magnesite bodies which occur in the border Gemer syncline of ABONYI [1974]. The lithofacies of this quasi-paralic formation relates closely to the upper Viséan deposits of the detached „Veitscher Decke“ unit (northern Greywacke zone, Eastern Alps). The relevant sediments of the „Veitscher Decke“ unit appears to be deposited closely to the Viséan sediments of Nötsch and Gailtal or even of Graz (FLÜGEL 1975). The homeland of all these Viséan rocks is presupposed to lie not far to the north from the peri-Adriatic line (TOLLMANN 1963, 1975, RICHTER 1974).

BOUČEK & PŘIBYL (1960) attributed the Namurian B/C age to the above deposits with the magnesite bodies. This fact, of course, did not support the aforesaid lithofacies correlation between the Spiš-Gemer Mountains and the „Veitscher Decke“ unit (see Flügel 1975). However, PATTEISKY [1971] changed by rights the Namurian B/C age of the quasi-paralic formation into the Namurian A (zone E₂). I believe that even the lower part of the zone E₂ must be considered in this respect, and, moreover, that the upper Viséan age might be also valid.

These new stratigraphical facts lend great support to the meaning that the marine deposits of the „Veitscher Decke“ unit are to be correlated with the quasi-paralic Carboniferous beds of the border Gemer syncline. With this in mind all the correlations of Tollmann's Oberostalpinum with the Gemerikum and both Choč and Strážov nappes seem to me to be most likely (e. g. ANDRUSOV 1968, TOLLMANN 1963, 1975). Contrarily, the linking of the Moravian and Silesian paralic Namurian with that of Eastern Alps (PATTEISKY 1938, 1971) is to be regarded as misleading. The same conclusion may be inferred from the fact that to the south the Bruno-Vistulikum foreland enlarges gradually westward, which causes the axial dying out of the Upper Silesian Namurian beds (p. 11).

THE WESTPHALIAN A—C PALAEOGEOGRAPHY IN CZECHOSLOVAKIA

The Westphalian A—C time-interval is to be referred to as the time of the onset of the taphrogenic evolutionary period [CHAIN 1964] or of the post-geosynclinal period [AUBOUIN 1965] in the central European mountain chain. The genesis of the „*fault-bound*“ basins is regarded to be the most typical phenomenon over there [AUBOUIN 1965, p. 181, 285]. The comparison of the Fig. 2 and 3 indicates convincingly this fact.

In central Europe these basins are commonly referred to as limnic basins or taphrogenic basins. HAVLENA [1971] called them *pre-platform intramontane basins*, which has been inferred from the fact that their fault-bound forming, and mainly their particular filling, decidedly mark the transitional position of the post-geosynclinal period between the whole geosynclinal history and the typical platform: The relevant mountain chain becomes cratonized [AUBOUIN 1965, p. 100] or continentalized [AUBOUIN 1965, p. 101] or it enters the period of „platformization“ [HAVLENA 1972, 1974].

Implicitly, the post-geosynclinal period is mostly quoted in the sense of the first platform stage or — as suggested by VACHTL [1974] — it should be regarded as an independent transitional period.

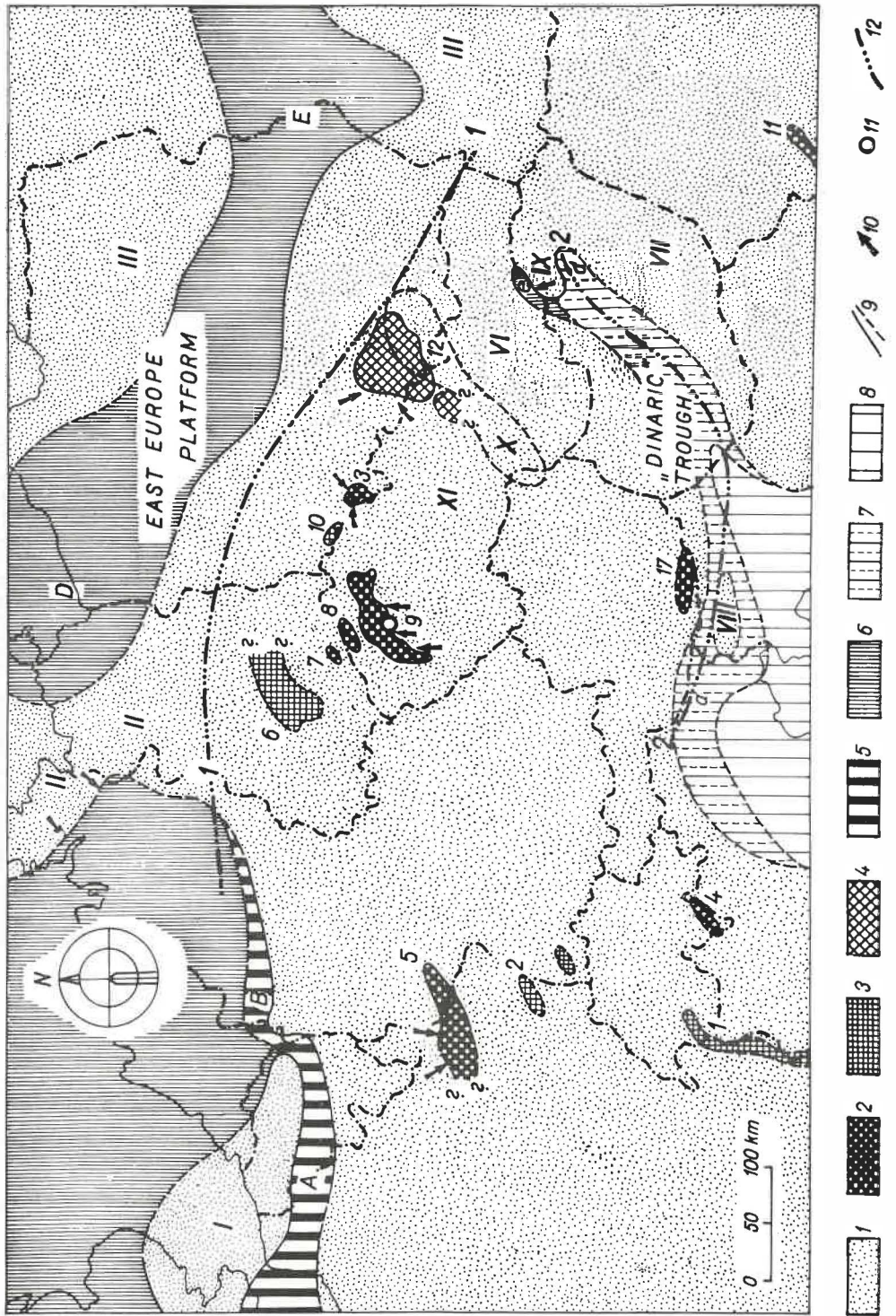
The limnic infilling of the post-geosynclinal basins is currently referred to as the molasse, e. g. „*Innenmolasse*“ [BUBNOFF 1956], „*intraorogene Molasse*“ [KATZUNG 1970] etc. I have proposed the more pertinent term, viz. the formation of the *intramontane (or posthumous) red beds* [HAVLENA 1971]. Besides, two periods of both forming and filling of the central European limnic basins have been recognized (1. Westphalian, 2. late Stephanian) and their classification with regard to the structural setting and to the shape of the basins in question has been suggested [HAVLENA 1971, 1974].

With regard to the geographic position, three groups of Variscan limnic basins are to be distinguished. The *western group* embraces the basins of the eastern Massif Central in France; they came into existence in the second period of both forming and filling. They are all of inherited structural setting. The limnic basins of the Western Alps should also belong here. Their linear shape seems to be of primary origin.

The *central* or *Rhine group* of limnic basins occupies the territory of the Vosges and Schwarzwald. Basins of either time-interval of forming are found here all exhibiting the inherited structural setting.

To the *eastern* or *Bohemo-Saxonian group* the limnic basins of the Bohemian Massif and its surroundings are assigned. The basins of the Westphalian period of both forming and filling display the inherited structural setting and are of a more or less isometric shape. Two other basins formed in the second period are typical „*trenches*“ of AUBOUIN [1965]. They are implicitly called the furrows in Czech language: the Blanice furrow, the Boskovice furrow [Fig. 4 and 5].

The geographic arrangement of the Variscan limnic basins into three groups is believed to be controlled by the transversal fault systems which have cut the central European Variscan mountain chain into transversal blocks moving upward or downward. I suppose that the limnic basins were brought into being upon the transversal blocks with negative vertical movement which became extinct during the Lower



Permian to reappear progressively in the inverse sense before the end of the same time-interval. The implication is that the Upper Permian sea penetrated to the south in a lowered area situated between two simultaneously lifted transversal blocks; these blocks, however, were sinking during the Upper Carboniferous time (compare Fig. 3 and 6).

The Upper Carboniferous sinking tendency of the transversal block of the Bohemian Massif finds expression in the broad materialization of limnic basins. This sinking turned into a marked uplift at the Lower Permian — Upper Permian boundary.

It may be inferred from these facts that the key role of the transversal fault systems which manifested itself so clearly during the geosynclinal period of the Variscides (DVOŘÁK 1968, DVOŘÁK & PAPROTH 1969) is no less important in the post-geosynclinal period of the Variscan mountain chain.

Among the limnic basins of the newly established Bohemo-Saxonian group of basins the Central Bohemian basin is the most important one. In the basal beds it displays two important coal seams separated respectively by a marked volcano-detritic parting. Very similar lithologies are found within the isochronous basal beds of the Bran-



Fig. 3 — Westphalian A—C palaeogeography of central Europe.

1 — Land, 2—4: terrestrial environments, 2 — Variscan limnic basins, detrital fill [coals present], 3 — Variscan limnic basins, detrital fill (no coals, red beds in places), 4 — foreland basin of Upper Silesia (coals present), 5 — paralic environments: west European fore-deep, detrital fill (coals present), 6—8: paralic to marine environments of various structural setting, 6 — west European foreland basin, east European intra-platform basin, Westphalian intra-deep deposits near Dobšíná and Rudňany (Spiš-Gemer Mountains) — detrital deposits, reef limestones, 7 — shallow-water monotonous detrital deposits (Hochwipfel flysch and equal deposits), 8 — neritic deposits, 9 — known and reputed boundaries, 10 — prevalent direction of transport, 11 — important acid volcanic activity, 12 — 1-1: southern border of the East European platform, 2-2: peri-Adriatic line and Balaton line.

Land areas: I — Wales-Brabant island, II — „Ostelbisches Massiv“, III — Fenosarmatia, IV — Dębnik island, V — Świętokrzyskie Góry land, VI — Austro-Slovak Variscan mountain chain, West Carpathian sector, VII — Lóczy ridge and Tisia, VIII — Karawanken land, IX — Gemer land, X — Bruno-Vistulikum, XI — Bohemian Massif.

Basins with terrestrial fill: 1 — Briançonnais, Tanninge, „zone externe des Alpes“, 2 — north: St. Hippolyte — Offenburg (Hury), south: Müllheim (BURGATH & MAASS 1972), 3 — Inner Sudetes basin (Lower Silesian basin), 4 — Manno and Cimadera (Ritter 1960), 5 — Saar basin, 6 — Saale basin, 7 — Flöha basin, 8 — Brandov basin, 9 — Central Bohemian basin, 10 — northern Sudetes basin, 11 — Svinița, 12 — Upper Silesian basin, 13 — 16 not present in this figure, 17 — „Veitscher Decke“ unit (before thrusting).

Basins with paralic fill: A — Synclitorium of Namur, B — Ruhr basin, C — not present in this figure, D — Rügen and Pommern basin (boreholes), E — Lvov basin and Lublin basin (boreholes).

Sea deposits (marine to paralic environments): a — Carnian Alps, b—c not present in this figure, d — Bükk Mountains, e — Spiš-Gemer Mountains (Dobšíná, Rudňany).

dov basin and Flöha basin which both are lying not far to the northwest (Fig. 3, basins 7 and 8). For this reason HAVLENA (1964) presupposed the existence of a vast uniform Westphalian basin on the territory of Bohemia and Saxonia. Today the basal filling of the basins in question is regarded as having taken place in special basins separated from one another by the northeast-striking horst-like uplifts of the pre-Carboniferous basement.

The igneous and volcano-detritic rocks richly found in the Westphalian deposits of the basins mentioned above represent the intra-Variscan subsequent volcanic activity attributed by EIGENFELD & SCHWAB (1974) to their „*intra-orogen*“ area and to their „*Beckentypus*“ of the volcanic activity.

As far as the Upper Silesian basin is concerned, its Westphalian A to Westphalian C deposits are to be regarded as a terrestrial late-geosynclinal molasse blanket which covers the subjacent paralic molasse and which extends far toward the interior of the Bruno-Vistulikum foreland. The presupposed occurrence of these coal-bearing deposits in the south inferred from various geological facts (HAVLENA 1964) has been recently confirmed by boreholes at Frenštát pod Radhoštěm (STRAKOŠ 1972).

The paralic molasse-limnic molasse turnover in the Upper Silesian fore-deep took place at the Namurian A/B boundary, which is different from the west European fore-deep. There the event in question falls at the boundary of the Westphalian B and C.

The limnic deposits or correctly the terrestrial deposits of either Variscan fore-deep represent the late-geosynclinal terrestrial molasse formation which is not to be linked together with the limnic (correctly: terrestrial) post-geosynclinal filling of the intra-Variscan limnic basins. The former is a typical late-geosynclinal molasse laid down upon the pre-Variscan platform foreland; the latter represents by no means a molasse but a distinct formation deposited during the post-geosynclinal evolutionary period within the erected Variscan mountain chain. The real contact of these two limnic environments is known northward from the west European fore-deep (Fig. 3).

The basins of the pre-Variscan platforms are to be called the foreland basins, extra-Variscan basins or intra-platform basins.

In the West Carpathian sector of the Austro-Slovak Variscan mountain chain the Westphalian A — Westphalian C terrigenous deposits of the „*intramontane red beds*“ type (HAVLENA 1971) are so far lacking. The fossiliferous detrital deposits and reef limestones occurring northward from the Gemer land at Dobšiná and Rudňany, are of Westphalian A—C age (NĚMEJC & OBRHEL 1959, BOUČEK & PŘIBYL 1960). I regard them as a marine to paralic molasse formation of the late-geosynclinal period. For more detailed lithofacies relations see VOZÁROVÁ & VOZÁR (1975).

In the Eastern Alps the detrital deposits of the Westphalian A—C age are found in the „*Veitscher Decke*“ unit of the Oberostalpinum. This late-geosynclinal terrigenous molasse formation is fossiliferous and bears graphitic shales and thin coals (FLÜGEL 1963).

Table 1. Variscan geosynclines and the classification of the Carboniferous and Permian deposits of Czechoslovakia.

■ — geosynclinal period, II — late-geosynclinal period, I — post-geosynclinal period, : — platform period.

Age		Central European geosyncline		Intermediate foreland (Bruno-Vistulikum)	Austro-Slovak geosyncline, 1gal couple			
		Intermediate massif and adjacent eugeosynclinal areas	Anti-Rhenides couple, miogeosynclinal area and fore-deep		Mioeogeosyncline	Eugeosyncline		
Carboniferous	Upper Permian	Inner Sudetes basin			Tatrikum	Veporikum, Gemerikum	Zemplin area	Hük Mountains, Karawanken range, Carnian Alps
	Lower Permian				Verrucano basins	Meliata series, P ₂ series of the Choč nappe	?	Trogkofel series and younger deposits
Upper Carboniferous	Stephanian	All the limnic basins of the Bohemian Massif		Upper Silesian basin, Cracow area	?	Rožňava-Železník series, P ₁ series of the Choč nappe		Rattendorf series
	Westphalian					Hiatus?		Auernig series
	Namurian	Inner Sudetes basin	Upper Silesian basin, Ostrava district	Upper Silesian basin, Karviná district and Poland	Molasse so far not known	Carboniferous of the Spiš-Gemer Mountains, C ₃ series of the Choč nappe	Molasse so far not known	Hiatus
Lower Carboniferous		Western Sudetes, Lower Palaeozoic of central Bohemia	Flysch-, Kulm" of the Nizký Jeseník Mountains	Para-plat-form-, Kulm" of the Beskydy Mountains boreholes		Hiatus		Hochwipfel series
	Devonian				Devonian of the Malé Karpaty Mountains	Spiš-Gemer Mountains, Rakovec series		

THE WESTPHALIAN D AND STEPHANIAN PALAEOGEOGRAPHY IN CZECHOSLOVAKIA

In this time-interval the climate becomes drier. Progressively less coals and more red beds are therefore found in the sections. The post-geosynclinal period of the central European Variscides reaches its culmination, which may be inferred from the following:

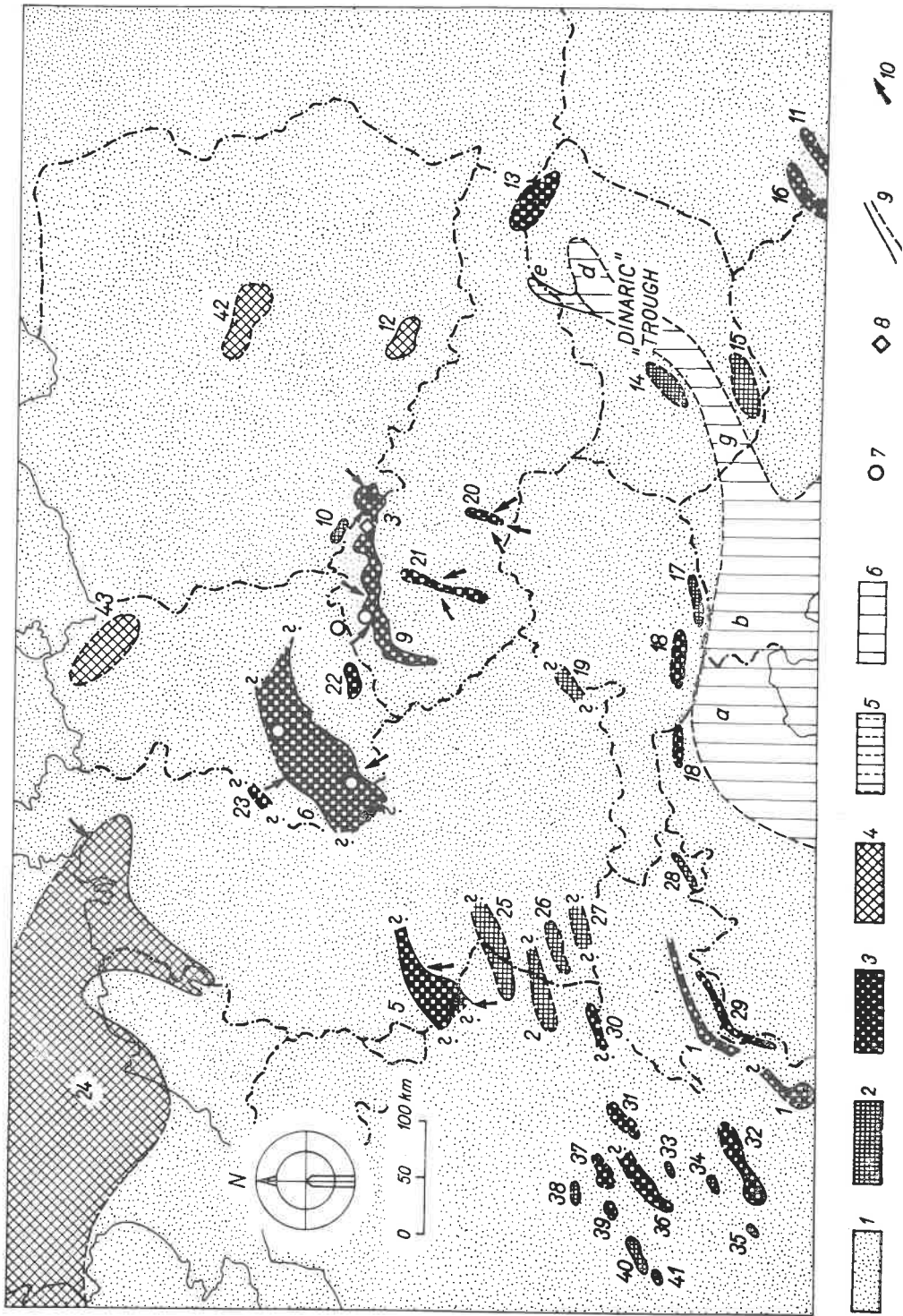
The extent of the limnic basins becomes successively larger due to the transgressive overlap of the filling. The number of limnic basins increases mainly during the late Stephanian since the second phase of their both forming and filling sets on and three groups of basins in question (described on p. 13) are clearly to be seen. The igneous activity increases remarkably and extends toward the exterior of the central European Variscan mountain chain, i. e. into the „*peri-orogen*“ and „*extra-orogen*“ areas

Fig. 4 — Westphalian D and Stephanian palaeogeography of central Europe.

1 — Land, 2—4: terrestrial environments, 2 — Variscan limnic basins, detrital fill (coals present but scarcely), 3 — Variscan limnic basins (detrital fill, mainly red beds), 4 — extra-Variscan intra-platform and foreland basins (detrital fill, mainly red beds), 5—6: marine environments, 5 — trough-like basin of the Spiš-Gemer Mountains, detrital deposits, 6 — shallow-water deposits (aleurolites with limestone nodules and beds), 7—8: important volcanic activity, 7 — acid and intermediary, 8 — basic, 9 — known and reputed boundaries, 10 — prevalent direction of transport.

Basins with terrestrial fill: 1 — La Mûre, Briançonnais, Tanninge, „zone externe des Alpes“, 2 — St. Hippolyte — Offenbourg (Hury), 3 — Inner Sudetes basin and Krkonoše-piedmont basin, 4 — not present in this figure, 5 — Saar basin, 6 — Saale basin, 7—8 not present in this figure, 9 — Central Bohemian basin, 10 — northern Sudetes basin, 11 — Svinița, 12 — Upper Silesian basin (Cracow area), 13 — Zemplín area and borehole at Felsőregmec, 14 — Füle, 15 — Mecsek Mountains and Villány Mountains, 16 — Resița, 17 — Gainfeld and other localities of the western part of the northern Greywacke zone, Oberostalpinum (FLÜGEL & SCHÖNLAUB 1972), position before thrusting, 18 — Brenner and Turrach, 19 — borehole Kastl near Altötting (BÉRGER 1959), 20 — Boskovice furrow, 21 — Blanice furrow, 22 — Lugau-Ölsnitz basin, 23 — Illfeld basin, 24 — Ems basin and the Northern sea basin, 25 — Baden-Baden and Lalay, 26 — Schramberg, 27 — borehole at Dingelsdorf, 28 — Valle di Poschiavo (RITTER 1960), 29 — „zone interne des Alpes“, 30 — Ronchamp, 31 — Lons-le-Sauvier, 32 — St. Etienne and Lyon, 33 — La Chapelle sous Dun, 34 — St. Foy, 35 — Brassac, 36 — Blanzay and Bert, 37 — Autun-Epinac, 38 — Sincey, 39 — Décize, 40 — Villefranche, 41 — Commeny, 42 — central Poland basin (boreholes), 43 — Pommern and Mecklenburg basin (boreholes).

Sea deposits: a — Carnian Alps, b — Karawanken range, c — not present in this figure, d — Bükk Mountains, e — Spiš-Gemer Mountains and the Choč nappe (position before thrusting), f — not present in this figure, g — borehole Karád 1.



of EIGENFELD & SCHWAB (1974). The sea regression attains its maximum in both north and south (Fig. 4).

Contrarily to the facts given above the extent of the intra-platform basins decreases so that no Stephanian deposits are found in the vast Westphalian intra-platform basin near Warsaw (BOJKOWSKI & DEMBOWSKI 1972).

In the Bohemian Massif the culmination of the post-geosynclinal period is clearly to be observed. The Central Bohemian basin extends progressively eastward and coalesces in this way with the westernmost Stephanian basin of the Sudetes region. In the west, the Plzeň basin manifests itself as a NNE-striking elongated depositional area where the maximum thickness of fill attains some 900 m. This „trench“ is to be traced via Žihle basin up to Žatec. Another basin with more than 1,200 m of fill seems to be localized there transversally to the direction of the „trench“ concerned.

Two more expressed NNE-striking furrows which are typical post-geosynclinal „trenches“ of Aubouin (1965) extend in the southern part of the Bohemian Massif (Fig. 4). The eastern one is the Boskovice furrow the Permo-Carboniferous fill of which is assumed to exceed 5,000 m (JAROŠ 1968). The western furrow is called the Blanice furrow.

The seemingly illogical termination of the Blanice furrow fill against the fill of the Central Bohemian basin in the north (Fig. 4) must be of syndimentary origin as in the Lower Permian palaeogeographical pattern the same figure is obtained (Fig. 5). Further evidence stems from the fact that no structural counter-part appears in the strike of this furrow within the Central Bohemian basin.

The terrestrial deposits of the Bavarian boreholes near Altötting (Fig. 4, basin 19) are regarded here as the fill of as yet unknown limnic basin situated upon the depressed part of the Bohemian Massif. Unfortunately no detailed data are available (BERGER 1959).

In the Austro-Slovak Variscan mountain chain, the Westphalian D — Stephanian time-interval is marked by the appearance of the earliest basins filled with the terrigenous deposits. The fossiliferous coal-bearing deposits attributed to the Westphalian D occur at Brenner and Turrach in the Eastern Alps. Similar lithofacies is known at Zemplín in the West Carpathians; it is, however, of Stephanian A age. The detached detrital deposits of Gainfeld regarded as of Stephanian age (FLÜGEL & SCHÖNLAUB 1972) and attributed to the northern Greywacke zone of the Eastern Alps are drawn up in the presupposed original setting. The shape of the Stephanian limnic basins discovered by boreholes in Hungary (BALOGH & BARABÁS 1972, BALOGH — BARABÁS — MAJOROS 1973) is given but likely.

From all the aforesaid facts the simultaneous onset of the post-geosynclinal period is obtained for either median part of both Variscan mountain chains, viz. the middle Westphalian time-interval.

The sea of the „Dinaric“ trough displays a lesser extent than before. However, the northeast-striking elevation of the basin axis is more pronounced in this time so that the post-Westphalian deposits of the Spiš-Gemer Mountains exhibit a semi-platform lithofacies. Apart from these autochthonous and attached deposits the detached Upper Carboniferous sediments have been proved palaeontologically in the Choč nappe (SITÁR & VOZÁR 1973). In the Fig. 4 these deposits are drawn up in their presupposed homeland area at the northern border of the Gemer land (ABONYI 1974).

THE LOWER PERMIAN PALAEOGEOGRAPHY IN CZECHOSLOVAKIA

In central Europe the early Permian time is marked by both structural and orographical coalescence of the central European Variscan mountain chain and the East European platform. Moreover, the vertical movement of the transversal blocks

of the chain appears to cease or to change its sense. E. g. the sinking of the Bohemian Massif transversal block terminates in the Stephanian and changes itself into rising the scope of which becomes increasingly more important toward the south. The implication is that the widely coalesced depositional areas of both chain and platform domains contact respectively in a less extent only (Fig. 5).

FALKE (1972) subdivided the Lower Permian terrestrial deposits of Europe into three provinces. The northern or sub-Variscan province extends along the north European sea of the Permian time which progressively flooded the vast SE-striking zone of subsidence within the domain of the East European platform. This is the „*norddeutsch-polnische Senke*“ of German authors.

The terrestrial fill of the basins of the central or Variscan province displays an outstanding lithofacies commonly called the „*Rotliegendes*“. The southern or Verrucano province embraces the terrestrial deposits of the Alps developed as the Alpine Verrucano lithofacies. As the same lithofacies is found in some basins of the West Carpathian area, I suggest to enlarge Falke's Verrucano province from the Alps up to the West Carpathians (Fig. 5).

The Lower Permian sedimentation is accompanied by a wide variety of volcanic activity. In central Europe EIGENFELD & SCHWAB (1974) believe to recognize three structure-bound types of volcanism, viz. the „*Trogtyp*“, the „*Beckentyp*“ and the „*Schwellentyp*“ of the Lower Permian volcanic activity.

The successive migration of the detrital deposition to the east and northeast which is clearly observed in the Stephanian of the Central Bohemian basin attains its top in the Lower Permian. The main depositional area of this time extends therefore in the western Sudetes region of the Bohemian Massif (Fig. 5). The relevant „*Rotliegendes*“ deposits display in places a clearly revealed subdivision into two formations. The upper one bears conglomerates at its base and, locally, covers the subjacent formation with a slight disconformity. The younger formation is currently correlated with the „*Oberrotliegendes*“ of German authors the Saxonian age being invariably inferred. MÁŠKA (1960) and recently ZOUBEK (1974) regard these Saxonian deposits as the earliest post-Variscan platform blanket of the Bohemian Massif.

On the other side, HAVLENA (1972, 1974) points out the identity of both lithofacies and local tectonics within either formation concerned and draws the lower boundary of the Variscan platform stage of the Bohemian Massif at the base of the Upper Permian. In VACHTL's mind (1974) the ideas of MÁŠKA (1960) are to be preferred for the genesis of a so far unknown structural element has marked the onset of the Saxonian deposition. This new element is the NNW-striking Trutnov — Náchod basin of western Sudetes. However, the NNW- to NW-striking both negative and positive structural elements appear in the western Sudetes as early as in the Carboniferous times.

In the West Carpathians the basins filled with the terrestrial Verrucano deposits yield no fossils and are commonly considered as of Upper Permian age. However, the Lower Permian age is not to be excluded.

In the Spiš-Gemer Mountains the Lower Permian deposits display the marine, lagoonal and terrestrial lithofacies. In the Gemerikum they occur in the attached regional setting near the Gemer land and are commonly referred to as the Rožňava — Železník series. In the Choč nappe they are to be found detached from their southern homeland basement. For details see REICHWALDER (1973), ABONYI (1974) and VOZÁR & ZÁROVÁ (1975).

In this time-interval the epi-continental sea with hypersaline lagoons expanded via Hessen area to the south, i. e. toward the interior of the former central European Variscan mountain chain. This is the „Hessische Bucht“ KÖLBL (1968). This place of marine incursion was preferred due to the marked tendency of the neighbouring transversal blocks of the Variscan chain to rise (p. 15). The southmost evaporites of the „Hessische Bucht“ are found near Schweinfurth, the southmost dolomites near Stuttgart.

Fig. 5 — Lower Permian palaeogeography of central Europe.

1 — Land, 2–3: terrestrial environments, 2 — detrital red deposits (lenses or beds of anhydrite often present), — 3 detrital red sediment deposits and weathered bedrock, 4–8: marine environments, 4 — litoral to deltaic deposits, dominantly detrital, 5 — shallow-water to lagoon deposits (aleuopelites, limestones), 6 — neritic deposits, 7 — hypersaline semi-closed sea deposits, 8 — hypersaline litoral deposits, 9–11: important volcanic activity, 9 — acid, 10 — intermediary, 11 — basic, 12 — known and reputed boundaries, 13 — prevalent direction of transport, 14 — northern boundary of the Verrucano province (FALKE 1972).

Basins with terrestrial fill: 1 — Ems basin, 2 — Weser basin (FALKE 1972), 3 — Mühlhausen and Illfeld basin, 4 — Meisdorf and Flechtigen, 5 — Saale basin and Thüringer Wald area, 6 — Saar-Selke-Hessen basin (FALKE 1972), 7 — Wittlich basin, 8 — Weiler-Oos-Main basin (FALKE 1972), 9 — Offenburg, 10 — Stockheim, 11 — Naab basin, 12 — Schramberg, 13 — Ronchamp basin (Burgundian basin), 14 — Autun-Epinac, 15 — Blanzay and Sous, 16 — St. Eloy, 17 — Champagnac, 18 — St. Etienne and Lyon, 19 — Alleverd, 20 — Permian of Aiguilles Rouges range, 21 — Permian of the Penninikum, Western Alps, 22 — boreholes in the Plateau Jura and near Basle, 23 — borehole at Dingelsdorf (Lake Constanze basin, Falke 1972), 24 — Val Müstair (TRÜMPY & DÖSSEGER 1972), 25 — Permian of both Bergamo Alps and Lombardian Alps (Permian of the „Etsch-β 26c“ in the Penninic Permian of the Hohe Tauern range, Eastern Alps, 27 — Permian of central Carnia (Gurktaler Decke, Flügel & Schönlaub 1972), 28 — borehole Kastl at Altötting (BERGER 1959), 29 — Zwickau—Karl-Marx-Stadt basin, 30 — Brandov basin, 31 — Plauen basin (Döhlen basin), 32 — Mnichovo Hradiště basin and Krkonoše-piedmont basin, 33 — Inner Sudetes basin (Lower Silesian basin), 34 — northern Sudetes basin, 35 — Boskovice furrow, 36 — Blanice furrow, 37 — Zöbing, 38 — Bakony Mountains and borehole Tábad, 39 — Staré Hory and Lubietová area, 40 — Cracow area, 41 — borehole Żebrak near Warsaw, 42 — Čierna Hora, Branisko and Zemplín area, borehole at Felsőregmec, 43 — Maramureş, 44 — Muntii Apuseni, 45 — Mecsek Mountains, 46 — Villány Mountains, 47 — boreholes at Battonya and Kelebia, 48 — Gethic nappe Permian (Resița), 49 — Permian of Danubikum unit (Svinița), 50 — Veporikum, southern basin (VOZÁROVÁ & VOZÁR 1975).

Sea deposits: a — Carnian Alps, b — Karawanken range, c—d not present in this figure, e — Spiš-Gemer Mountains and Choč nappe (position before thrusting).

