Preface

The territory of the Czech Socialist Republic is a classical area of ancient prospecting and modern geological investigation. The history of these activities covers almost 5000 years, beginning at the time of Celts and Slavs who had searched for and mined gold, graphite and iron, and continuing with the outstanding researches of G. Agricola and J. Barrande. Modern geological, geophysical and geochemical studies contribute greatly to the raw-material and energy basis of the country and to international science.

The modern history of geology in Czechoslovakia may be divided into two periods: the earlier period of classical geology represented by Kettner's school culminating in the preparation of the 23rd Geological Congress in Prague. This opened a new stage introducing into geology exact geophysical and geochemical data. This book is one of the first summarizing evaluations of the results achieved in this period; it shows the direction and progress of Czechoslovak geology during the last twenty years and demonstrates that geological knowledge then increased at a greater rate than at any previous time. From the volume it is apparent that the direction of geological activity towards the ensurance of fuel-energy and raw-material resources made possible a more intensive development of the earth sciences, which thus could keep pace with progress in the leading countries of the world.

In the first part of this publication the team of authors generalize the results of regional, geophysical and geochemical investigations, providing a picture of the regional and deep structure of the region, its stratigraphy and geological history. Much attention is devoted to the origin of useful mineral accumulations during the magmatic, sedimentary and metamorphic processes. It is mainly in the study of these problems, and in the chapter on the deeper structure of the earth's crust that progress is most apparent, compared with the literature of the 1960's.

The second part of the book contains an overview of promising mineral deposits in the territory of the Czech Socialist Republic. In this part I would attribute importance to the finding that the Hercynian deposits of Sn-W, polymetallic and gold deposits represent reactivated earlier, Precambrian accumulations of the elements. This could lead to the discovery of stratiform deposits poorer in metal content that are associated with older rock complexes. The prospects for oil and natural gas occurrences in Moravia and discoveries of coal-bearing formations in central and northern Bohemia (the areas around Mělník, Slaný and at the foot of the Krkonoše Mts.) and in piedmont of the Beskydy Mts. in Moravia are also relevant. The appraisal of the future of industrial and unconventional mineral materials brings new possibilities and tasks for the Czech geological service.

The authors should be congratulated upon this scientific team work, which is a summary of geological activity in the recent period and an important document contributing to the recognition of natural conditions of our country. As well as being highly instructive to the experts, it will be readily understandable to a wide circle of readers.

Prague, March 19, 1982 *Dr. Josef Pravda*

1. Introduction

More than two decades have passed since the publication of the "Tectonic Development of Czechoslovakia" and the "Regional Geology of Czechoslovakia". These two books presented a summary of the results achieved in geological investigations, which were graphically expressed in a set of general geological maps. These depicted the ideas and opinions of geologists on the composition and structure of the Bohemian Massif and the Carpathian mountain system, as they were visualized in the sixties of this century.

Knowledge of world and European geology, however, has advanced at a high rate during the last twenty years. It has brought a number of new theories and information which have assisted in refining existing hypotheses and in the solution of intricate structural problems.

The coming generation of young geologists has accepted the new theories and findings developed abroad and applies them in detailed investigations.

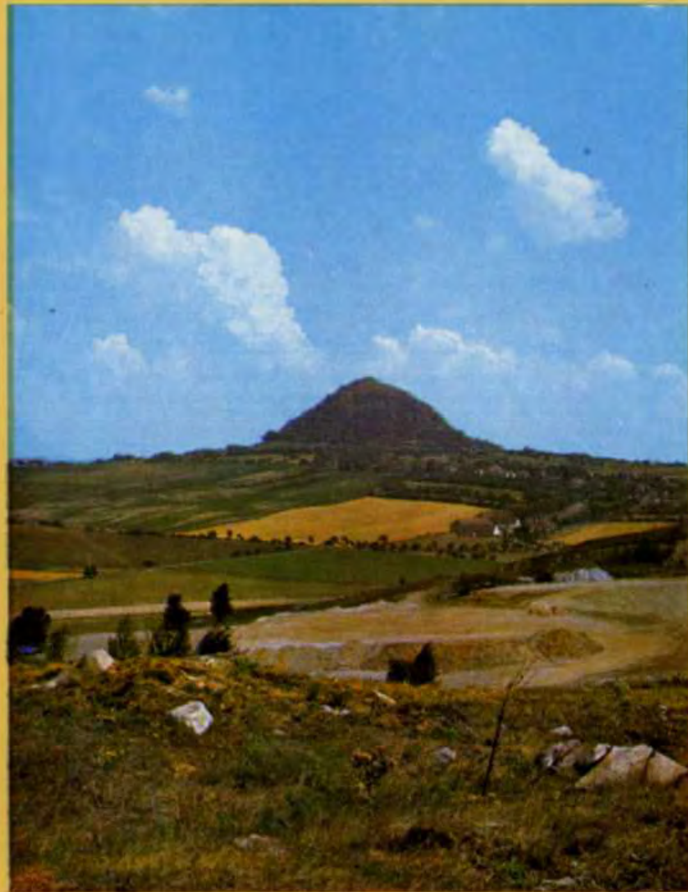
The regional-geological studies of the Bohemian Massif and the Carpathian mountain system combined with detailed geological mapping on a scale of 1 : 25,000, and complemented with geophysical and geochemical research, detailed petrographical, palaeontological investigations and determination of radiometric ages of rocks, have brought many remarkable results. These complement and modify earlier opinions and contribute to a more objective recognition of the geological setting and structure of the country.

The present publication dealing with the Bohemian Massif and the Moravian part of the Carpathians provides a brief summary of the new data concerning the age, composition and structure of the territory of the Czech Socialist Republic. The geological conditions of both the crystalline basement and platform cover are discussed and the stratigraphy of the sedimentary formations of the latter is defined with more precision. Compared with the Regional Geology and Tectonic Development of Czechoslovakia, the publication is somewhat differently divided. It has seven main chapters, the most interesting of which are the chapters on the deep structure, and the magmatic and metamorphic history.

Comparison of the present state of knowledge of the geology and structure of the regions studied with opinions held some twenty years ago shows a definite progress and makes this publication worthy of the attention of experts both at home and abroad.

Prague, March 19, 1982 *Dr. J. Svoboda*

2. Geological structure of the territory of the CSR



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2.1 Milá Hill, České středohoří Mts. Leucite basalt — Photo by J. Svoboda

2.1 Position of the geological units in the structure of Europe

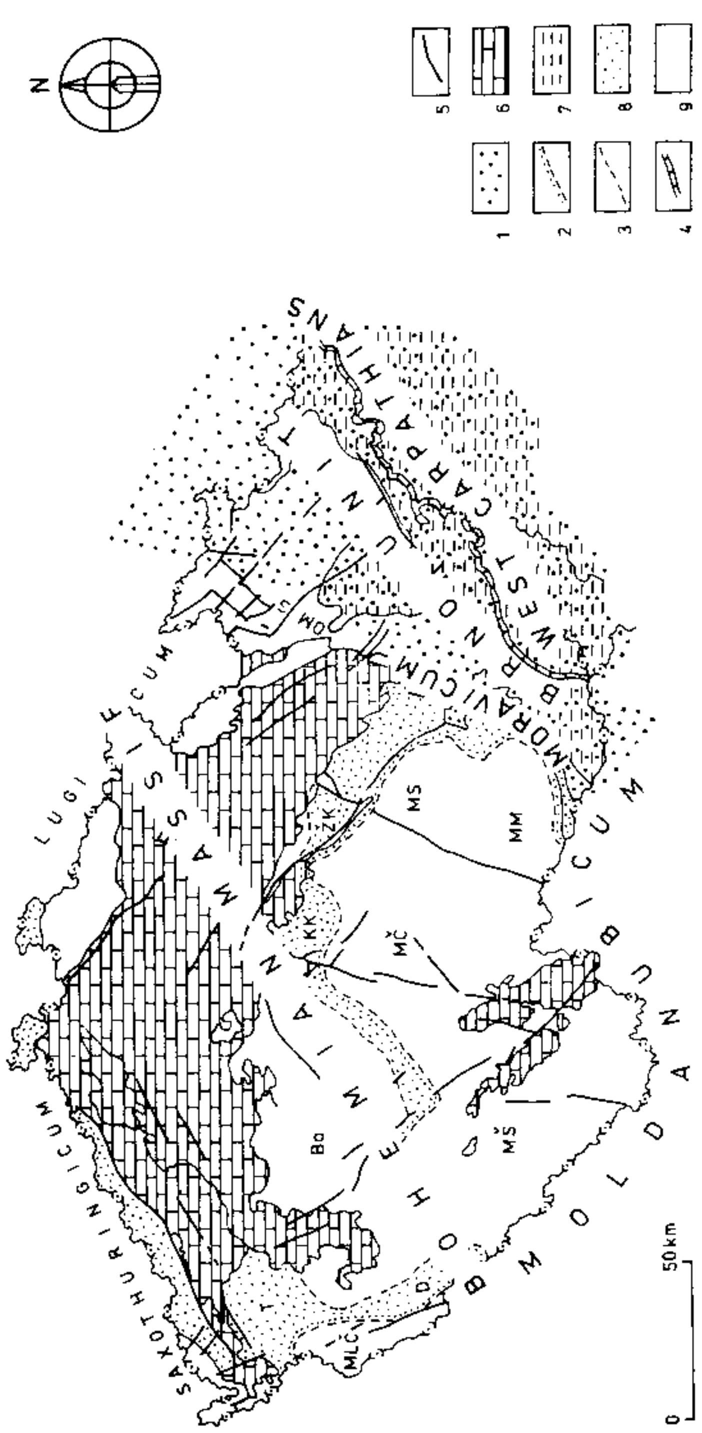
On the territory of the Czech Socialist Republic three basic units of the geological structure of Europe are represented (Fig. 2.2):

- the Bohemian Massif, which is the easternmost part of the European Hercynides (Meso-Europe), builds up Bohemia and the western half of Moravia;
- Brunovistulicum (the Brno unit), which is a part of the Precambrian basement of both the Hercynides and Alpides (Palaeo-Europe) at the eastern margin of the Bohemian Massif and in the West Carpathians, forming the south-western margin of the Ukrainian Shield;
- the West Carpathians, which belong to the Alpine-Carpathian orogenic belt (Neo-Europe).

2.1.1 The Bohemian Massif

The Bohemian Massif forms in Central Europe a block of rhombic shape, which sends two projections towards NW — the Harz and the Thüringer Wald. The surface delimitation of the Massif is in places well defined and unambiguously determinable, in places indistinct and placed more or less conventionally along the Permian—Triassic boundary. In the NW the Bohemian Massif is bounded by the marginal fault of the Thüringer Wald and the Franconian, Keilberg and Danubian faults. In the NE the fault of the middle Odra is regarded as the boundary of the Massif. In the N beyond Bohemia, on the territory of the German Democratic Republic (G.D.R.) and Poland (P.L.R.), the Bohemian Massif submerges beneath the Triassic and younger platform sediments. In the S and SE, the limitation, unless formed by faults, is defined by the boundary with the Brunovistulicum and by the boundary of the continuous Miocene filling of the Alpine and Carpathian foredeeps. Miocene sediments penetrate beyond this limit far into the Bohemian Massif through ancient valleys, and the Pliocene deposits mainly in the transverse structure of the Upper Moravian tectonic depression. The pre-platform complexes of the Bohemian Massif extend towards SW, NW and NE under the thick sedimentary cover of the West European Platform.

The Bohemian Massif is the easternmost so far known part of the Variscan (more strictly Ligurian — Moldanubian) branch of the European Hercynides (Pl. I). In all classical concepts, from the scheme of Suess (1903) to that of Aubouin (1965),



2.2 Major regional-geological units in the territory of the Czech Socialist Republic
1 — Brno unit (prevalently covered with younger sediments); 2 — boundaries of the Moldanubicum; 3 — metamorphic transitions; 4 — western boundary of the Carpathian nappes; 5 — faults; 6 — units of the platform cover; 7 — West Carpathians; 8 — metamorphosed Upper Proterozoic (T — Teplá Crystalline, D — Domažlice Crystalline, KK — Kutná Hora Crystalline, ŽK — Železné hory Crystalline, Ba — Barrandian); 9 — higher metamorphosed Proterozoic in the Moldanubicum and Lugicum (OMS — Moravo-Silesian region, MČ — Bohemian Moldanubicum, MS — Strážek part of Moldanubicum, MM — Moravian Moldanubicum, MS — Moldanubicum of Šumava, Moldanubicum of Český les). (M. Suk, orig.)

it is considered to be the central part of the Hercynian orogen with one or two wings of its divergent structure; in the mobilistic conceptions it is generally placed on the northern margin of the so-called South European continent separated from northern Europe by the ocean (Fig. 7.3).

However, many interpretations of the position of the Bohemian Massif in the geological structure of Europe are based on mistaking the Hercynian elements for the earlier, chiefly Cadomian orogenic elements.

T h e b e l t o f C a d o m i a n o r o g e n y which had consolidated the basement of the Bohemian Massif can be traced from Central Europe towards west and east (Pl. I). It extends westwards through the southern part of the Schwarzwald to the Vosges, the Massif Central français, the Armorican Massif and farther into southern England. It is presumed that it continues across the Atlantic Ocean into New Brunswick (the Avalonian—Cadomian orogenic belt). This continuation is by some authors (e.g. R a s t - G r a n t 1973) mistaken for the extension of the Hercynides which, according to predominating concepts, turn to the Iberian Peninsula (Pl. I).

In the European part Z o u b e k (1972) and Z o u b e k - V y s k o č i l (1971) differentiate two zones of the belt: the Moldanubian—Arvernian and the Barrandian—Brioverian, which are separated by a system of Precambrian deep faults forming the Perimoldanubian lineament (Fig. 2.2). According to Z o u b e k and V y s k o č i l, this dividing line within the Bohemian Massif coincides with the Moldanubian/Proterozoic boundary (i.e. the Moravian line—Labe line—Central Bohemian suture). In the opinion of other writers it corresponds to the tectonically disrupted zone of SW—NE segments, marked by doubled magnetic anomalies and anomalous development of magmatism and metallogeny (B e r n a r d 1978).

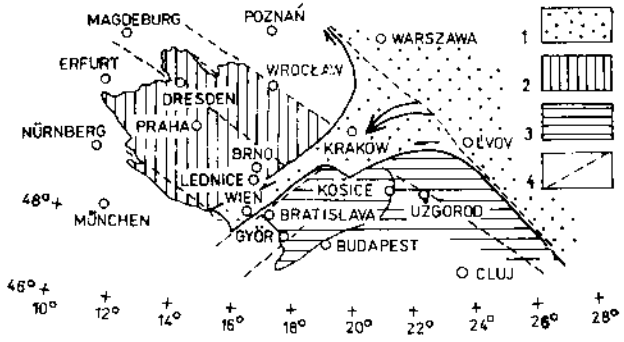
The continuation of the Cadomian orogenic belt towards E and NE is assumed by P o u b a (1970) and N e č a e v (1968). On the basis of the correlation of lithofacies development of banded iron ores in the Precambrian of the Bohemian Massif and in the western part of the Fennosarmatian platform, Pouba postulates its extension up to Minsk; N e č a e v (op. cit.) correlates the lithostratigraphic units of the Bohemian Massif with the Vendian units of the northern margin of the Ukrainian Shield.

Irrespective of the effects of the Cadomian basement and the later tectonics, the following z o n e s o f t h e H e r c y n i a n o r o g e n i c b e l t s are distinguished in the Bohemian Massif: t h e M o l d a n u b i a n z o n e, which is regarded as the central one (Stille's Alemanian threshold extending into it) and t h e S a x o t h u r i n g i a n z o n e. T h e R h e n o h e r c y n i a n z o n e a n d t h e z o n e o f H e r c y n i a n f o r e d e e p s are beyond the territory of the Czech Soc. Republic. Farther east- and south-eastwards there are the M o r a v o - S i l e s i a n z o n e (Moravicum and Silesicum in the sense of Kossmat) and t h e S u d e t i c u m. These zones probably form the basement of the Alps (Laurent 1972, Wieseneder et al. 1976), where they crop out in places (e.g. in the Helveticum — von Raumer 1976). Close analogies between the eastern margin of the Bohemian Massif and the southern margin of the Massif Central français in the Montagne Noire are in accord with the above said (Suk - Weiss 1981). The Carboniferous sediments in the Alps also show the character of the southern Inner Molasse of the Variscan branch (Krebs - Wachendorf 1973).

The late stage of the Hercynian orogeny in the Bohemian Massif is characterized by disintegration into blocks of different development (formation of intramontane depressions with terrestrial sediments, autonomous movement of blocks, different thermal character of blocks in the Permian etc.). The termination of the Hercynian development is placed in the Upper Carboniferous, in the Permian or Triassic. It is, however, indisputable that from the Late Permian (which is an important time-boundary for all European regions) the Bohemian Massif has been an Epihercynian platform rejuvenated in Saxonian times (Malkovský 1979).

2.1.2 Brunovistulicum (the Brno unit)

The crystalline basement at the eastern margin of the Bohemian Massif, east of the Moravo-Silesian tectonic zone and beneath the Carpathian foredeep and the Palaeozoic of Moravia, was formerly thought to be somewhat loosely connected with the Bohemian Massif (Zapletal 1926, Zoubek 1948), although different geological and tectonic features have been recognized. Only recently has the investigation of the deep structure (Dudek 1961, 1980, Tomšík 1972), geochronometric studies (Dudek - Melková 1975, Scharbert - Batík 1980) and interpretation of the deep structure (Beránek 1971, Roth 1977, Štelcl - Weiss 1978, Weiss 1977) shown that it is a separate geological unit, very likely belonging to the Fenno-Sarmatian Platform (Fig. 2.3). This connection has been corroborated by borings to the basement of the Upper Silesian basin both in Poland and Moravia, and evidence exists (Roth 1977) that the unit continues eastwards in the basement of the West Carpathians and links directly on the northern part of the Ukrainian Shield. In this respect our definition of the Brno unit differs from the concept of Dudek (1980), who considers the Brunovistulicum to be the south-western part of the Brno unit. A continuity of the crustal structural elements in this area lends support to this opinion. As the unit had not been reworked either by Hercynian or Alpine orogeny, it has preserved the original, late Proterozoic character. Some of its parts may have been incorporated into the Hercynian structure. Tomšík (1972), for example, noted certain analogies between the gneisses in the Brunovistulicum near Ostrava and those in the



2.3 Interpretation of the Brno unit in terms of a projection of the East European platform
1 — East European platform and Brno unit; 2 — Bohemian Massif; 3 — Alpine-Carpathian system; 4 — fault zones (J. Weiss, orig.)

Desná dome, and Jaroš - Mísař (1974, 1975) an analogy of the Tišnov Brunides in the Svratka dome. Dudek (1980) suggests that the Brno unit may continue beneath the Moravicum and Moldanubicum, which is also indicated by anomalous phenomena in the earth's crust along the eastern margin of the Bohemian Massif (Suk - Weiss 1981).

2.1.3 The Moravian sector of the West Carpathians

The West Carpathians extend to eastern Moravia with their westernmost marginal part. They comprise the Flysch Belt and the Foredeep, which forms the western part of the arc turning back from Poland to eastern Slovakia and linking on the Alpine foredeep in Austria, at the southern boundary of the Bohemian Massif. The other part is the Tertiary Vienna basin, which sends its northern projection to southern Moravia.

Many units of the Flysch Belt continue south-westwards into the Alpine region and north-eastwards into the Polish and Slovak parts of the Carpathian mountain arc.

The Waschberg sector of the Ždánice-Subsilesian unit extends in a similar development into Austria. The Subsilesian development passes to Poland where it is known as far as the drainage basin of the river Wisla. The continuation of the Subsilesian unit in the North and East Carpathians is not yet clear. From the comparative studies it appears that the Subsilesian unit, as conceived by Polish geologists, corresponds to the outer part of the Silesian unit in Moravia, which is situated in the foreland of the Baška development (Kelč unit, sensu Eliáš 1981).

The Silesian unit, especially its Godula development, continues into the Carpathians of Poland.

The Fore-Magura unit persists to the E towards the Polish part of the Carpathians.

The Magura Group is the most important unit of the Flysch Carpathians and continues north-eastwards into the Polish Carpathians.

The Rača unit of the Magura Group links in SW on the Greifenstein nappe of the Wiener Wald and passes into the Polish Flysch Carpathians in the NE. The Bystrica unit can be traced into the Polish Carpathians on the basis of the Middle Eocene solid marlstones called "marls of Łacko" in Poland. Its south-western extension into Austria is not yet clear. The Bílé Karpaty unit continues south-westwards across the basement of the Vienna basin into Austria. where it links on the Kahlenberg nappe and probably also the Laab nappe of the Wiener Wald. Its equivalent in the Orava area (NE of the Párnica sygmoid of the Klippen Belt) is the Orava-Magura-Krynica unit, which continues into Poland and the eastern part of the Slovakian Carpathians.

The Vienna basin and the Foredeep are parts of the Paratethys, which in the Oligocene and at the onset of Neogene had separated when the northern part of the Tethys was disintegrating. They belong to the extensive system of basins, which is traceable from the Rhône-river valley to western Asia. The Foredeep is directly connected with analogous structures in Austria and, on the other side, continues into Poland. The greater part of the Vienna basin spreads in Austria.

2.2 Regional geological division of the units

2.2.1 The Bohemian Massif

The regional-geological division of the Bohemian Massif is very non-uniform. The regional-geological and tectono-metamorphic units are loosely grouped to form units of a higher order, which are usually based on their position in the Hercynian orogen. For example, Stille (1951) in his classical work distinguished: the Moldanubicum (including the Barrandian and the Železné hory regions), Saxothuringicum, Lugicum, Moravo-Silesicum and Vistulicum (in the basement of the Upper Silesian basin).

Zoubek and Máška (*in* Buday et al. 1960) divided the Bohemian Massif into

a) the area of the Bohemian intermontane block, subdivided into the Moldanubian elevation (Moldanubicum), the Teplá-Barrandian region and the loosely attached Brunia block;
b) the area of intensive Hercynian tectogenesis, comprising the Krušné hory-Thüringen region, the Železné hory-West Sudetic region and the Moravo-Silesian zone.

Svoboda et al. (1966) laid great stress on regional and stratigraphic division and have differentiated:

a) the Crystalline of the Bohemian Massif which involves the Moldanubicum and the crystalline units of Kutná Hora, north-western Bohemia, the West Sudeten and of the Moravo-Silesian region (Silesicum, Moravicum and the Brno massif)
b) Algonkian and Palaeozoic of the Bohemian Massif
c) Permo-Carboniferous basins
d) Mesozoic of the Bohemian Massif
e) Tertiary of the Bohemian Massif and
f) Quaternary of the Bohemian Massif.

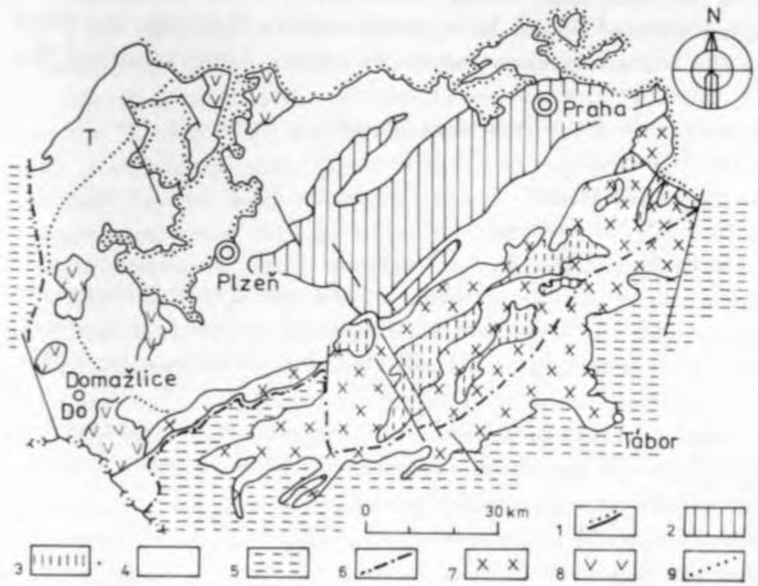
A division based implicitly on the position of the units in the Hercynian orogen, which is decisive for the Bohemian Massif, would require to distinguish:
- the Precambrian basement (viz. units affected by Cadomian or earlier tectono-metamorphic processes),
- the Palaeozoic, disturbed by Palaeozoic tectono-metamorphic processes,
- the units formed in the period of inversed tectonic regime (Upper Carboniferous, Lower Permian in the Bohemian Massif),
- the platform units (Jurassic, Upper Cretaceous and Tertiary),
- the Quaternary of the Bohemian Massif.

This division according to structural layers, however, poses a number of unsolved problems. In particular, there are difficulties in discriminating between the Precambrian and the Lower Palaeozoic in metamorphic units, and between the individual Cadomian and Hercynian units in the basement of platform sediments, as well as a lack of criteria for distinguishing between the Cadomian and pre-Cadomian units, and the impossibility to establish a uniform time limit between the Hercynian and platform units. For these reasons, we use the regional division proposed by the Commission of the Czechoslovak Academy of Sciences (Chlupáč et al. 1976), modified according to the latest investigation results and the principles given above. It is as follows:

1. Crystalline and Palaeozoic affected by Hercynian orogeny
2. Units of the period of inversed tectonic regime, i.e. the Devonian and Lower Carboniferous of Moravia. Carboniferous, Lower Permian of the Bohemian Massif
3. Platform units, viz. Lower Permian. Triassic, Jurassic and Lower Cretaceous, Upper Cretaceous and Tertiary of the Bohemian Massif
4. Quaternary of the Bohemian Massif.

The Crystalline and Palaeozoic affected by Hercynian orogeny

This group involves the units consisting of metamorphosed Precambrian and Lower Palaeozoic rock complexes with Cadomian and Hercynian plutonites (Fig. 2.4.):

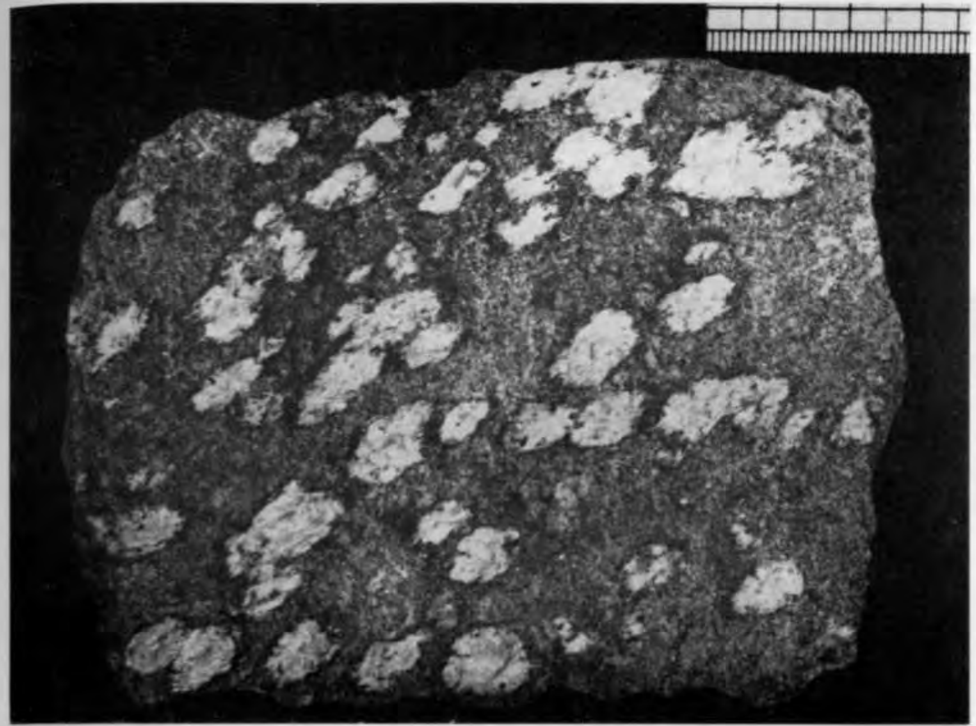


2.4 Geological units of central Bohemia
1 — Boundary of the platform cover; *2* — Barrandian Palaeozoic; *3* — Palaeozoic and Upper Proterozoic in the "Islets zone"; *4* — Upper Proterozoic in the Barrandian (T — Teplá Crystalline, Do — Domažlice Crystalline); *5* — Moldanubicum; *6* — reconstructed boundary of the Moldanubicum; 7 — Central Bohemian Pluton; *8* — magmatites of the Barrandian; *9* — metamorphic transitions (M. Suk, orig.)

The Moldanubicum

a) The Moldanubicum (= the Moldau-Danube region) forms the southern part of the Bohemian Massif built up of metamorphosed rock complexes, for the most part presumably of Precambrian age, and of large massifs of plutonic magmatites. Geographically, it includes the Českomoravská vrchovina Highland, southern Bohemia, the Šumava and Český les Mountains and, beyond Bohemian boundaries, the Bayerischer Wald and the areas of Waldviertel and Mühlviertel in Austria.

In the E the Moldanubicum borders on the Moravicum, in the S it submerges beneath the sediments of the Alpine Foredeep, in the N it contacts the Crystalline of Kutná Hora, and its western contact with the Barrandian basin is buried by the Central Bohemian Pluton. Geographically, the unit is subdivided into Moldanubicum of Český les, of Bayerischer Wald (Bavaricum), of Šumava and Mühlviertel, of Bohemia, Strážek and Moravia, and of Waldviertel.



2.5 Folded sillimanite-biotite gneiss. Varied group of Moldanubicum. Březský quarry near Tábor Photo by H. Vršťalová

The following large plutons belong to the Moldanubicum:

b) the Moldanubian Pluton in the central part of the Českomoravská vrchovina Highland, in Waldviertel and in the Šumava Mts., where it occurs as isolated massifs. It is thought to form the basement of a considerable part of Moldanubian metamorphic complexes
c) the Central Bohemian Pluton is a complex of plutonic magmatites situated S of Prague, between Příbram, Říčany, Tábor, Horažďovice and Klatovy, at the boundary between the Moldanubian and Teplá-Barrandian regions.

The Teplá-Barrandian region

It occupies the central and south-western Bohemia built up of the Palaeozoic and Proterozoic rocks of the Barrandian basin. In the Crystalline of Domažlice and Teplá and in the "Islet zone" the higher-metamorphosed units appear. In the NE the region extends into the basement of the Bohemian Cretaceous Basin.

2.6 Serpentinite steppe near Mohelno in the Jihlávka-river valley. Moldanubicum — West Moravian granulite zone Photo by J. Svoboda

a) The Barrandian basin is formed of unmetamorphosed or low-metamorphosed Proterozoic and Lower Palaeozoic rocks (Cambrian to Devonian); it was denoted by Barrande as the "système silurien du centre de la Bohême".

The Proterozoic occupies a predominant part of the basin between Kralupy nad Vltavou and Staňkov. On the basis of lithology the Dobříš, Kralovice, Kralupy, Blovice, Kleneč and Tachov sectors have been distinguished, as well as several volcanic belts, the most important of which are those of Kralocice—Rakovník, Svojšín, Stříbro—Plasy and Davle—Jílové.

The Palaeozoic sediments and volcanics of the Cambrian, Ordovician, Silurian and Devonian age are divided into lower regional-geological units such as the Příbram-Jince basin (the Brdy Cambrian, the Skryje-Týřovice Cambrian) and the Ordovician—Devonian sequence — the Prague basin.

b) The Central Bohemian "Islet Zone" consists of denudation relics of the Proterozoic and Lower Palaeozoic mantle of the Central Bohemian Pluton. It includes the Tehov, Voděrady—Zvánovice, Čerčany, Zbořený Kostelec, Netvořice—Neveklov, Sedlčany—Krásná Hora, Mirovice, Kasejovice and Rožmitál „islets" and the Jílové zone.

c) The Crystalline of Domažlice extends from the Kdyně massif near Domažlice to Bor near Tachov. In the W it is separated from the Moldanubicum by the Bohemian Quartz Lode and in the E it passes into the lower-metamorphosed zones of the Barrandian Proterozoic.

d) The Crystalline of Teplá is analogous to the Domažlice Crystalline in the north-western part and is connected with the Barrandian Proterozoic by metamorphic transitions. The Teplá block forms its eastern part and the Slavkov block and the Mariánské Lázně body occupy its western part.

e) The West Bohemian pluton is represented by discontinuous, predominantly hidden granitoid bodies in western Bohemia, which crop out at the surface in numerous isolated massifs, as e.g. the Louny, Tis, Čistá, Kladruby, Stěnovice, Bor and Stod massifs. The Sedmihoří, Hoštice and Babylon massifs have a more separate position.

The Krušné Hory-Thüringen region

It is made up of the crystalline units of western and north-western Bohemia:

a) The Smrčiny Crystalline is a part of the Saxony-Vogtland zone; the Cheb crystalline schists, the Svatava block and Dyleň mica-schists belong to it.

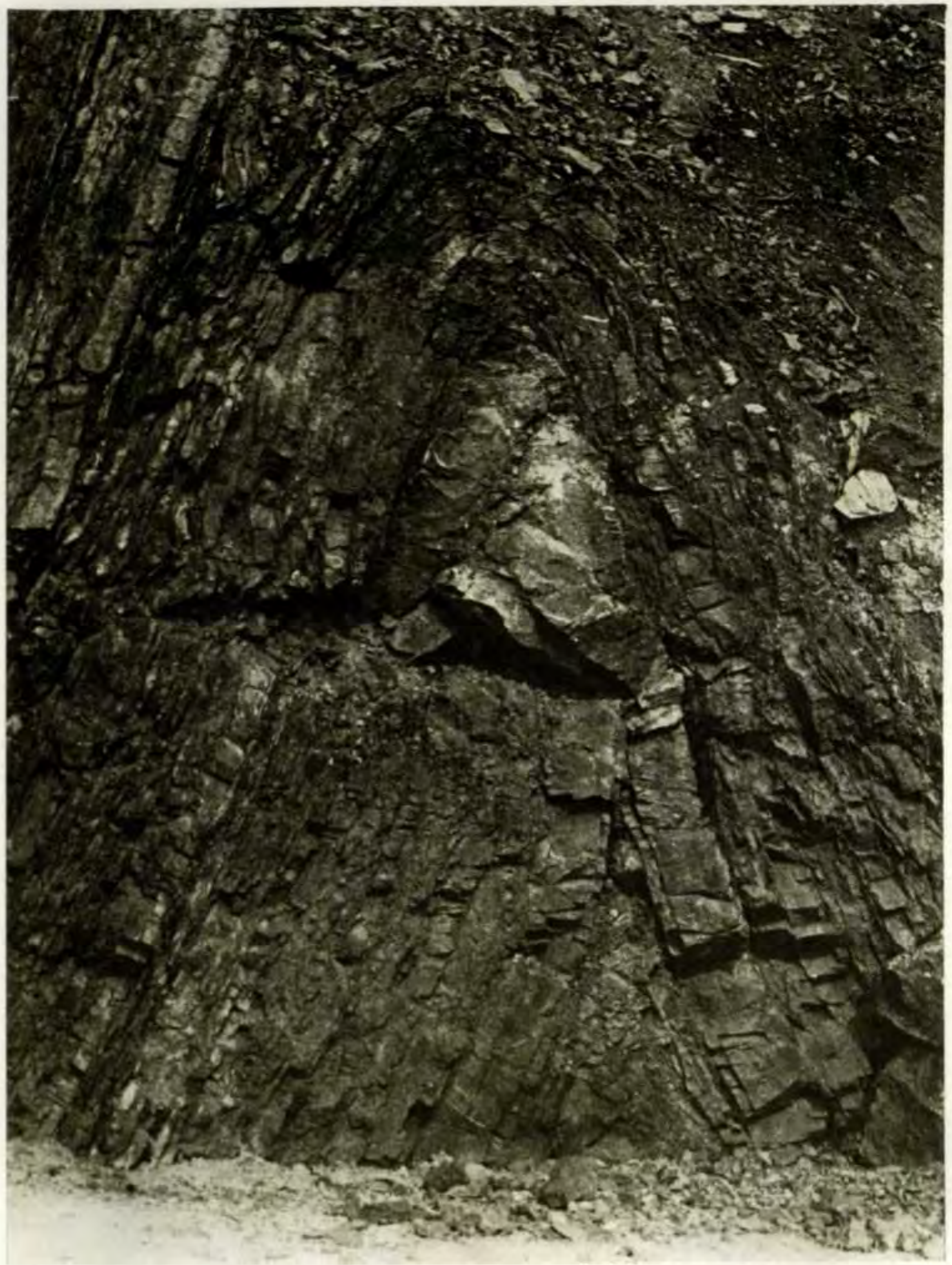
b) The Krušné hory Crystalline is bounded in the S by the Krušné hory fault, in the W by the Eibenstock massif and in the N by the Saxon depression and the Elbe Schiefergebirge. It includes the entire Krušné hory

2.7 Choustník Quartz Lode. Filling of a NE—SW trending fault in the Bohemian part of the Moldanubicum
Photo by J. Svoboda

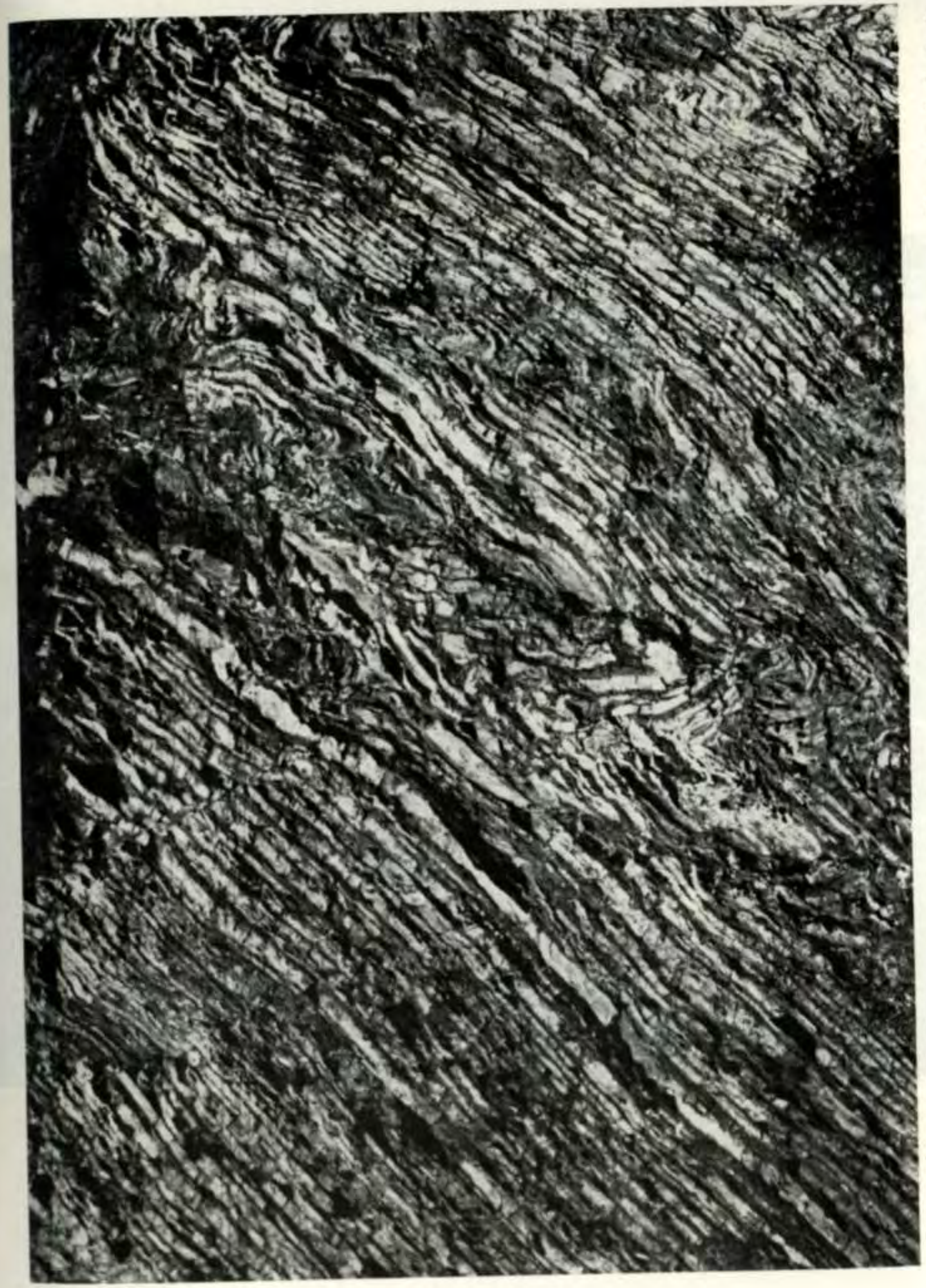
anticlinorium and isolated occurrences, e.g. in the Opárenské valley, along the river Ohře and in the České středohoří Mts.

c) The Krušné hory pluton is a complex of Hercynian intrusive rocks of granitoid composition, which penetrate the crystalline bodies of the Krušné hory and Smrčiny Mts. They form a number of domes, the highest of which are exposed at the present-day denudation level as separate massifs (e.g. Karlovy Vary, Nejdek, Smrčiny, Cínovec, Krupka and Fláje massifs). The Teplice porphyry occupies a somewhat separate position.

2.8 A chert rock west of Starý Plzenec. Upper Proterozoic of the Barrandian
Photo by J. Svoboda



2.9 Anticline in the Letná Formation (Ordovician of the Barrandian). Road-cutting near the Zbraslav bridge south of Prague Photo by J. Svoboda



2.10 Barrande's Rock. Vltava-river valley at the southern outskirts of Prague Photo by J. Svoboda

2.11 Skoupý quartzose conglomerate (Lower Devonian?). Boulders on the northern slope of Křemenice near Petrovice. The "Islets zone", Sedlčany-Krásná Hora "islet" in central Bohemia
Photo by J. Svoboda

EUROPE

1 — Alp|I, IIIA — Rhenothuringian, IV — Zone of Hercynia

The Kutná Hora-Železné hory region

It comprises the Precambrian units with the relics of the Palaeozoic mantle, which rim the Moldanubicum in the N and NE and extend beneath the sediments of the Bohemian Cretaceous Basin.

a) The Kutná Hora Crystalline (s.l.): crystalline complexes (with a predominance of orthogneiss and migmatite) at the northern margin of the Moldanubicum. It is divided into lower, geographically defined subunits, e.g. the Čáslav, Cheb or Podbořany crystalline complexes; the Ransko massif is an additional part of this unit.
b) The Chrudim Palaeozoic: a complex of Palaeozoic rocks in the Železné hory Hills and north of them (in the area of Přelouč, Heřmanův Městec and Chrudim). The Přelouč and Vápenný Podol synclines have been differentiated in it.
c) The Hlinsko zone: a complex of low-grade metamorphics of Late Proterozoic and Palaeozoic age forming a NNE—SSW trending belt at the Železné hory/Českomoravská vrchovina boundary.
d) The Svratka Crystalline: Proterozoic rocks metamorphosed in the medium to highest grade, at the NE boundary of the Moldanubicum, between the Hlinsko zone in the NW, the Moravicum in the SE and the Zábřeh Crystalline in the NE.
e) The Železné hory pluton: a complex body of plutonic magmatites in the Železné hory Hills. It consists of the Nasavrky massif (between Vápenný Podol, Skuteč and Hlinsko) and the Chvaletice massif.

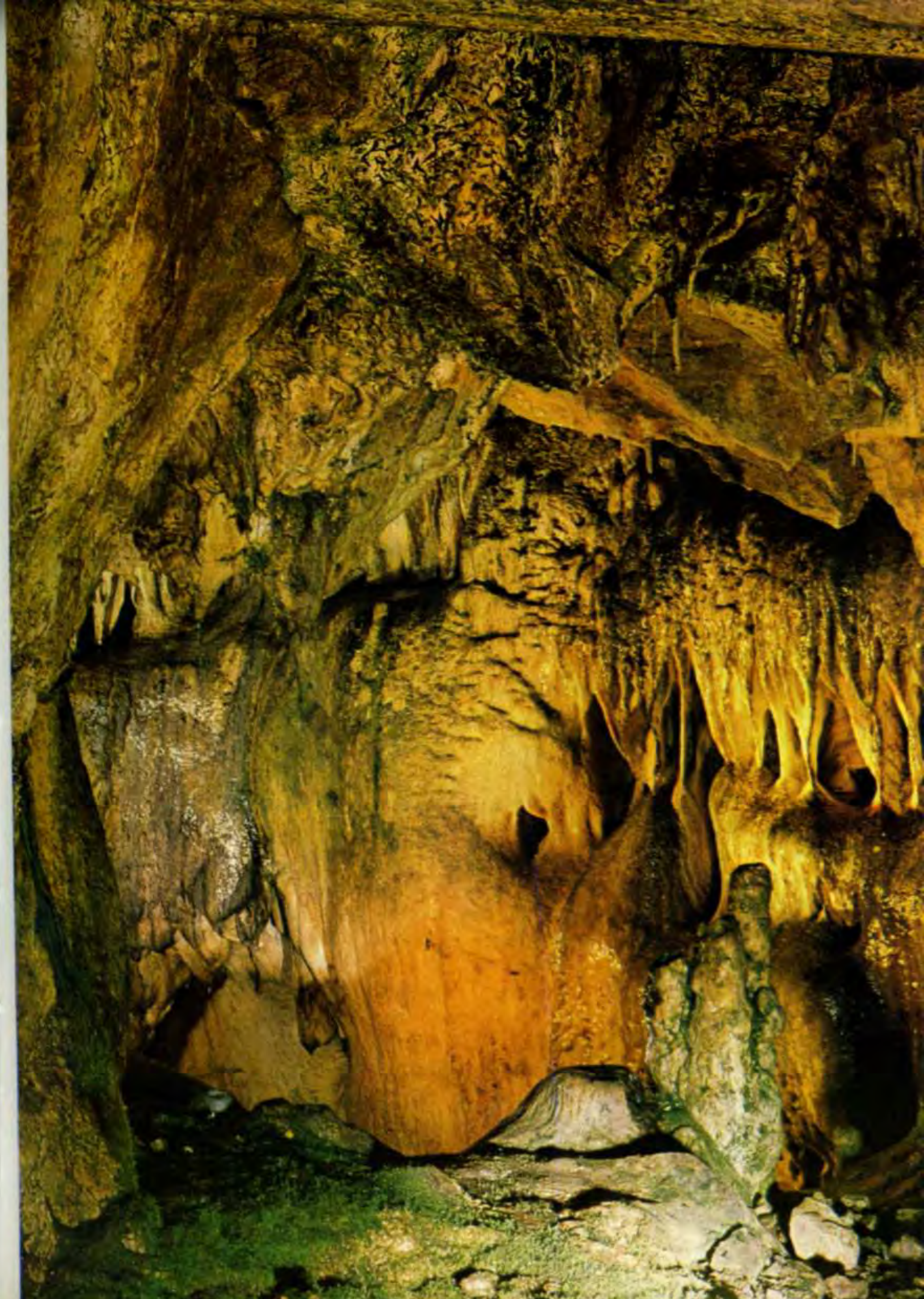
The Lusatian region (Lugicum)

This crystalline unit built up of metamorphosed Proterozoic and Palaeozoic rock complexes forms the northern margin of the Bohemian Massif east of the Labe valley as far as the Ramzová tectonic line. In the S it continues into the basement of the Bohemian Cretaceous Basin. The principal constituent parts are as follows:
a) The Krkonoše-Jizerské hory Crystalline: crystalline complexes cropping out at the surface from the Rýchory to the Ještědský hřbet Ridge, and in isolated occurrences in Zvičina, near Maršovice, etc. The unit extends into the basement of the Krkonoše-piedmont basin and of the northern part of the Bohemian Cretaceous.
b) The Orlické hory-Kłodzko Crystalline: crystalline complexes in the eastern part of the Lusatian region in the Orlické hory Mts. up to the Ramzová tectonic line.

2.12 Jeseníky Mts. View from Kouty n. Desnou Photo by B. Landisch

c) The Zábřeh Crystalline: metamorphosed rock complexes forming the southern margin of the Lusatian region in northern Moravia. It embraces metamorphic occurrences separated only at the surface by younger sediments, as for example, in the areas of Letovice, Polička and Kladky.
d) The Lusatian pluton: a complex of plutonic magmatites between Dresden and Görlitz, limited in the S and SW by the Lusatian fault and in the W by the West Lusatian reverse fault. The complex is inhomogeneous and the Jizerské hory and Krkonoše orthogneisses, the Zawidów granodiorite, the Nisa granite, Brtníky granite and others are genetically related to it.
e) The Krkonoše-Jizerské hory pluton: a uniform body of Hercynian granitoids making up the predominant part of the Jizerské hory Mts. and the Krkonoše Mts. between Liberec and Jelenia Góra in Poland.

2.13 Lipová caves. Metamorphosed Devonian (?), Hrubý Jeseník Mts. Photo by B. Landisch



The Moravo-Silesian region

The complexes of pre-Hercynian and Hercynian metamorphic and igneous rocks jointly with metamorphosed Devonian and Lower Carboniferous rocks in Moravia and Silesia make up two units:

a) the Moravicum: a belt of metamorphics bordering the eastern margin of the Moldanubicum in western Moravia, in the Dyje and Svratka Domes

b) the Silesicum: Proterozoic to evidently Devonian units of metamorphics in the Hrubý Jeseník Mts.

The units of the inversed tectonic regime

The Moravian Devonian

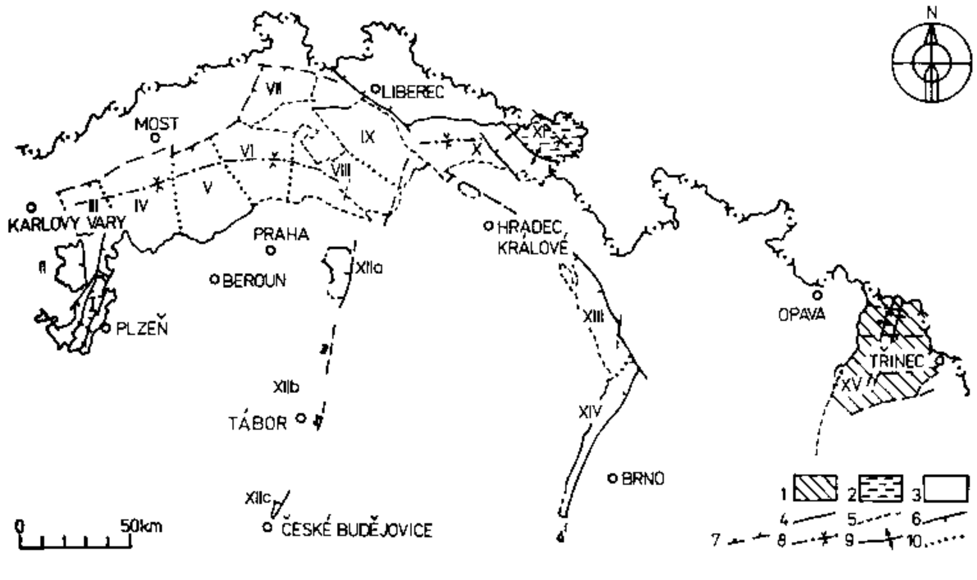
The area of the unmetamorphosed or low-metamorphosed Devonian and Lower Carboniferous of Moravia forms a separate geological unit overlying Precambrian of the Bohemian Massif and the Brunovistulicum; the occurrence of the Silurian near Stínava in the Drahanská vrchovina Upland is also annexed to it. It is divided into two large regional units: the Drahanská vrchovina Upland with the Devonian of the Moravian Karst, Devonian of the Upper Morava depression, of the Němčice and Konice-Mladeč belts, and the Nízký Jeseník Hills (the Šternberk-Horní Benešov belt, Maleník block). The Devonian of southern Moravia comprises the Devonian occurrences near Krhovice in the Boskovice Furrow and in the basement of the Carpathian foredeep. The Moravo-Silesian Carboniferous links on the Devonian.

A part of the Moravian Devonian and Lower Carboniferous is buried by the sediments of the Carpathian foredeep and by the nappes of the Outer Carpathians. The occurrences of the Lower Carboniferous are confined to the sedimentary areas of the Devonian, in which they gradually developed in places. They are discussed in the paragraph on the Devonian. In the eastern part Upper Viséan sediments are transgressive on the Frasnian limestones; they were deposited after a rather long hiatus.

The region of the Moravo-Silesian Upper Carboniferous

At the external margin of the Hercynian orogen there is the Upper Silesian Basin, which is the only Czechoslovak basin where the paralic Namurian developed gradually from the marine Lower Carboniferous.

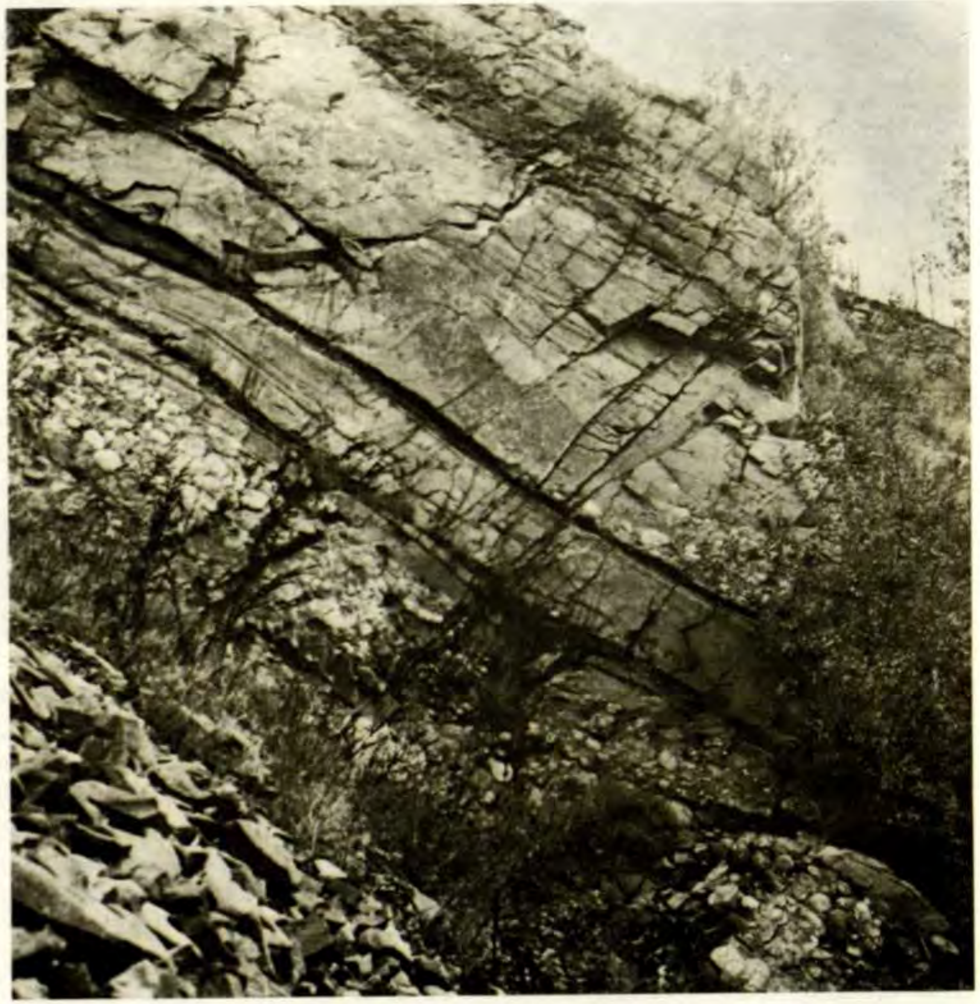
The Upper Silesian Basin is situated on the territory of Czechoslovakia and Poland, between the cities Ostrava, Kraków and Tarnowskie Góry. Sedimentation developed in three stages. In the early Namurian an intermontane



2.14 Carboniferous and Permian in the Bohemian Massif (nomenclative scheme of basins) *1* — paralic basins; *2* — transitional basins; *3* — continental sedimentation; *4* — established boundaries of Permo-Carboniferous; *5* — inferred boundaries of Permo-Carboniferous; *6* — major faults, determined; *7* — inferred faults; *8* — principal strikes of basin axes; *9* — principal strikes of structural elevations; *10* — boundaries of basins. Basins: I — Plzeň basin, II — Manětín basin, III — Žihle basin, IV — Rakovník basin, V — Kladno basin, VI — Roudnice basin, VII — Česká Kamenice depression, VIII — Mšeno basin, IX — Mnichovo Hradiště basin, X — Krkonoše-piedmont basin, XI — Bohemian part of the Lower Silesian basin; XII — Blanice Furrow. XIIa — northern part (area of Český Brod and Kostelec nad Černými Lesy), XIIb — central part (neighbourhood of Tábor and Vlašim), XIII — Orlice basin, XIV — Boskovice basin, XV — Bohemian part of the Upper Silesian basin (V. Holub - R. Tásler 1980)

depression had developed from the foredeep and this in turn in the late Namurian and Westphalian into an intramontane basin with continental sedimentation, which in the Polish part persisted until the Early Permian. The Upper Carboniferous coal-bearing deposits continue from Poland in the N and E to Czechoslovakia, extending westwards as far as the Štúr's marine band and its stratigraphic equivalents. The southern limitation of the basin is still unknown. The Kopřivnice-Třinec ridge divides the area into the Ostrava-Karviná and the Sub-Beskides basins. Structurally, the area is characterized by fold structures, in particular by linear asymmetric anticlines. The western marginal zone is the only Upper Palaeozoic area in Czechoslovakia with folded Upper Carboniferous.

The coal-bearing Upper Carboniferous is also developed in the eastern part of the Nesvačilka trough being completely hidden by the sediments of the foredeep. In this transversely bounded depression is attains a thickness of more than 1000 m.



2.15 Greywacke with thin interbeds of blackish-grey fossiliferous siltstone and thick interlayers of coarse-grained conglomerate composed prevalently of fragments of Moldanubian gneiss. In the centre, conglomerate and greywacke fill an erosion gully (comp. the drawing!). Myslejovice Formation, Moravian Lower Carboniferous, upper Viséan. Pístovice quarry
Photo by J. Dvořák

The Permo-Carboniferous region of north-eastern Bohemia

This group comprises Permo-Carboniferous basins situated in the Lusatian (Lužice) region. The western boundary of the region is represented by the Subcretaceous Maršovice-Bezděz elevation, the northern limit by the Sudetic marginal fault, and the eastern one by the Ramzová overthrust and the Moravian line (according to Suess and Stille); the Malonín horst separates the area from the Boskovice Furrow in the south.

a) The Lower Silesian Basin (synonyms: the Lower Silesian-Bohemian Basin, Intra-Sudetic Basin, Intra-Sudetic Depression, Broumov Basin and Central Sudetic Basin in Poland).

2.16 Thick-bedded greywackes with interbeds of siltstone and shale. Hradec-Kyjovice Formation (upper Viséan). E-verging overturned fold passing in the top part of exposure (upper right corner) into a fold fault (movement parallel to bed surfaces, cleavage lacking). Moravian Lower Carboniferous. Stará Ves near Bílovec, a quarry
Photo by J. Dvořák

2.17 Shale with sparse siltstone laminae. Moravice Formation (upper Viséan). Beds parallel to cleavage. Svobodné Heřmanice, abandoned quarry for roofing slate
Photo by J. Dvořák

It is filled with deposits of Lower and Upper Carboniferous, Upper and Lower Permian and Lower to Middle Triassic, and extends between the Krkonoše-Jizerské hory Crystalline in the NW, the Góry Sowie unit in the NE and the Orlické hory in the SE; in the SW it is bounded by the Hronov-Poříčí fault.

b) The Krkonoše-piedmont Basin (synonym: Permo-Carboniferous synclinorium) at the foot of the Krkonoše Mts. It is filled with deposits of the continental Carboniferous, Permian and Triassic, which extend south of the Krkonoše and Jizerské hory crystalline areas. In the east it is limited by the Hronov-Poříčí fault and in the south-west by the Lusatian fault and the Rovensko fault.

In the eastern segment two structural subunits originated: the Trutnov-Náchod depression (basin) between the Krkonoše Mts. in the NW and the Orlické hory Mts. in the SW; and the Hronov-Poříčí trough filled with Permo-Carboniferous and Upper Cretaceous deposits.

The denudation relics of Carboniferous and Permian on the Hořický hřbet Ridge and Zvičina, Upper Carboniferous near Očelice and Urbanice in the Hradec Králové area, and Permian occurrences in the Orlické hory Mts. are also ranged with the Sudetic Permo-Carboniferous. The regional assignment of the Permo-

2.18 Alternation of laminated siltstones and shales with sporadic interbeds of fine-grained greywacke. Hradec-Kyjovice Formation (base of Namurian A). Hlučín, abandoned quarry near the railway line
Photo by J. Dvořák

Carboniferous near Urbanice is not unequivocal; it can also be interpreted as a component of the Jihlava Furrow.

c) The Mnichovo Hradiště basin (synonym: Mnichovo Hradiště depression) is situated west of the Krkonoše-piedmont basin, being separated from it by the Lužice (Lusatian) fault, Rovensko fault and its continuation to the SE. The greater part of the basin is hidden beneath the sediments of the

Bohemian Cretaceous Basin (apart from the outcrops along the Lužice fault). Its south-western boundary is represented by the Maršovice-Bezděz Subcretaceous elevation and its continuation towards SE.

d) **The Orlice basin** (synonyms: Orlické hory basin, Permo-Carboniferous Furrow at the foot of the Orlické hory Mts.) embraces the sediments of the Permian (possibly also Carboniferous) and lies between the Malonín horst in the SE and Žamberk in the NW.

The region of Central Bohemian Permo-Carboniferous

The Carboniferous and Permian deposits of this region occur in central and western Bohemia (so-called Central Bohemian facies) and in the Krušné hory Mts. The Maršovice-Bezděz elevation separates this region from the Permo-Carboniferous area below the Krkonoše Mts. and the Kounice ridge separates it from the Permo-Carboniferous of the Blanice Furrow north of Český Brod.

a) **The Plzeň basin** is situated in the western neighbourhood of Plzeň. Originally it was connected with the Manětín basin. Nowadays it is separated from the latter by a Proterozoic horst and a meagre communication is maintained only between Lomnička and Dolní Bříza.

b) **The Manětín basin** lies NW of the Plzeň basin.

c) **The Radnice basin** is a system of tectonically downthrown blocks, which represent separate coal-bearing depressions (coal-bearing grabens, after L. Čepek) near Břasy-Vranov, Svatý Kříž, Vejvanov, Chomle and Skomelno.

d) **The Rakovník basin** is the central part of the original Kladno-Rakovník basin. The Nové Strašecí (Bílichov) pre-Carboniferous ridge separates it from the Kladno basin. The Kladno basin is limited in the W by the Nové Strašecí ridge of the pre-Carboniferous basement, and in the E it contacts on the Roudnice basin along the Kralupy nad Vltavou—Litoměřice line. A number of longitudinal and transverse pre-Carboniferous ridges divide the basin into several depressions, some of which contain important mineral deposits (e.g. the Kladno, Slaný and Peruc depressions).

In the east and north of the Central Bohemian Permo-Carboniferous region there are three regional structural units in the basement of the Bohemian Cretaceous Basin, viz. the Roudnice, Mšeno and Česká Kamenice basins.

e) **The Roudnice basin** adjoins the Kladno basin in the W and the Mšeno basin in the E (along the Mělník—Dubá line). Previously it was called the "confluence" (Vachtl 1965) or Labe (Holub 1970) area.

f) **The Mšeno basin** is bounded against the Roudnice basin by the Mělník—Dubá line in the W and in the E it is limited by the Maršovice-Bezděz Subcretaceous elevation and its south-eastern continuation. In the E the basin

is divided by the Luštěnice Subcretaceous ridge into the Mcely and Vlkava depressions.

g) **The Česká Kamenice basin** (syn. Česká Kamenice depression) is situated N of the Roudnice basin, being separated from it by a ridge in the crystalline basement. In the past it was wrongly regarded as a projection of the Roudnice basin. Its structural position is complicated by its being located at the intersection of Sudetic and Krušné hory tectonic directions. Some authors place it in the Krkonoše Permocarboniferous area and consider it to be the north-western continuation of the Mnichovo Hradiště basin.

To the south and west of the Permo-Carboniferous interconnected basins of central and western Bohemia there are several minor occurrences, which were originally joined with them. They were inappropriately denoted as separate basins (e.g. Němejc 1953, et seq.) or as "islets".

In the neighbourhood of the Plzeň basin there are the occurrences Merklín, Skapce, Stříbro, Letkov and Mirošov, and the Holoubkov occurrence near the Radnice basin. Genetically associated with the Rakovník basin are the Carboniferous occurrences near Žebrák (syn. Štílec basin, basin "na Štílci") In the environs of the Kladno basin there occur denudation relics „Na Lísku" near Beroun, and near Hýskov and Malé Přílepy.

h) **Permo-Carboniferous in the Krušné hory Mts.** The Permo-Carboniferous occurrences in the Krušné hory Mts. in Bohemia include the Brandov basin, occurrences near Mikulov and in the vicinity of the Teplice porphyry.

The group of Furrows

In the classical conception the "Furrows" are asymmetric basins elongated in N—S direction and filled with sediments of upper Stephanian to lower (or even upper) Autunian. The group includes the Permo-Carboniferous of the Boskovice and Blanice Furrows.

a) In **the Boskovice Furrow** the Carboniferous and Permian deposits occur between Moravský Krumlov in the S and the Malonín horst in the N, including the denudation relic near Miroslav. The Furrow, however, continues southwards to Austria, where the Permo-Carboniferous sediments occur near Zöbing.

b) In **the Blanice Furrow** isolated Carboniferous and Permian occurrences extend from České Budějovice in the S as far as the area of Český Brod in the N. Holub (1972) divides them into *a)* the northern part (occurrences near Český Brod and Kostelec nad Černými lesy, *b)* the central part — occurrences in the Vlašim area (Nesperská Lhota—Chobot, Čelivo—Milovanice, Vlastišov) and near Tábor (between Chýnov and Turovec) and *c)* the southern part near České Budějovice.

Recently, the term "Furrows" is also used for structures that do not show all features characteristic of classical Furrows. Of this type are the Jihlava Furrow (with Upper Palaeozoic sediments of the Železné hory near Kraskov and the Seč dam), the sediments assessed by boring W of Hradec Králové (Urbanice, Žižkovec), the central trough of the Plzeň basin, the Žihle basin, and the Orlice basin which, however, extends in an atypical direction of NW—SE.

The units of the platform cover

Upper Permian and Triassic

Permian sedimentation was closed during the Zechstein in the Lower Silesian Basin (so-called Pfalzian phase) and after a short interruption a new platform sedimentation started in the Early Triassic.

Triassic sediments (Scythian—Anisian) are in the Bohemian Massif represented in the German development and confined to north-eastern Bohemia (the Lower Silesian and Krkonoše-piedmont basins). They close the continental megacycle of Late Palaeozoic sedimentation.

Jurassic and Lower Cretaceous (?) in the Bohemian Massif

The Jurassic sea encroached upon the Bohemian Massif from the boreal region in the N and from the Tethys in the S. On faunal evidence the two regions were conjoined. The relics of Jurassic sediments are preserved in tectonic fragments along the Lusatian fault around Doubice near Krásná Lípa, in the Moravian Karst (Olomučany), in the area of Brno (Hády, Stránská skála, Nová Hora and Švédské valy localities). Extensive areas are covered with Jurassic deposits in the basement of the Neogene foredeep and flysch nappes from the Ždánický les (Uhřice) to the Czechoslovak—Austrian boundary and farther to the Danube valley. Towards the SE the Jurassic is traceable up to the Bulhary—Kobylí—Osvětimany line, where they have been encountered by boring.

In the basement of the Neogene and flysch sediments of the Carpathians there are also detrital sediments of the liwer Cenomanian—Senonian (boreholes Mikulov-1,2, Strachotín).

Cretaceous system in the Bohemian Massif

In the Bohemian Massif the representatives of the Cretaceous system are occurrences of the Cretaceous transgressing from the Alpine-Carpathian region, and

2.19 Transgression of the Cenomanian on Upper Carboniferous (Upper Grey Formation, Stephanian) of the central Bohemian basin. Valley of the Knoviz brook west of Kralupy, road to Velvary. Photo by J. Svoboda

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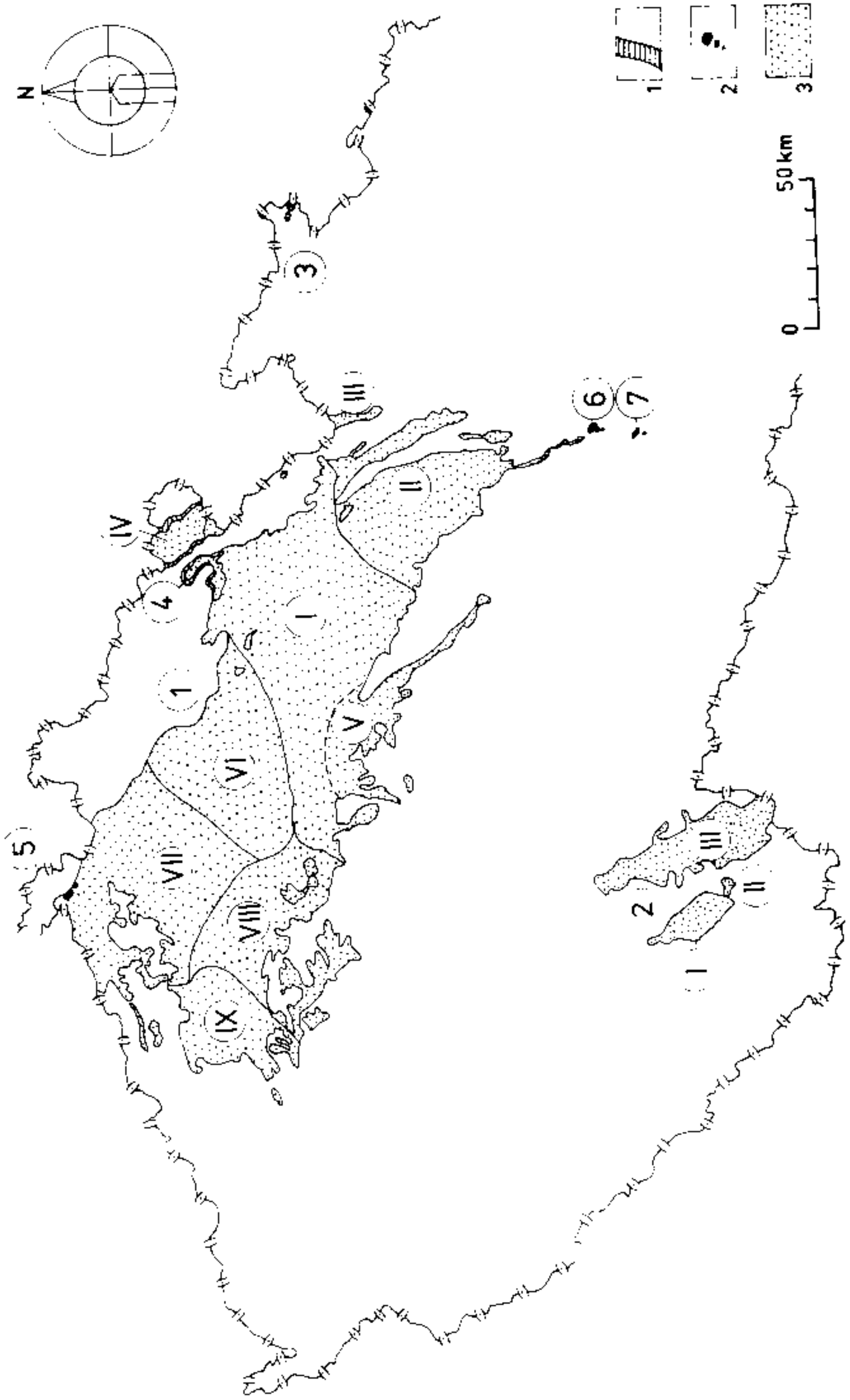
2.20 Mesozoic in the Bohemian Massif: *1* – Triassic, 2 – Jurassic, 3 – Cretaceous
Numbers in circles: 1 – Bohemian Cretaceous Basin (division according to J. Dvořák, C. Zahálka): I – Labe area, II – Orlice-Žďár area, III – Bystřice area, IV – Hejšovina area, V – Kolín area, VI – Jizera area, VII – Lužice area, VIII – Vltava-Berounka area, IX – Ohře area; 2 – Cretaceous and Tertiary in South Bohemian basins: I – Budějovice basin, II – Nová Ves basin, III – Třeboň basin; 3 – Cretaceous of Osoblaha; 4 – Triassic in Broumov area (partly in the basement of the Bohemian Cretaceous Basin); 5 – Jurassic occurrences near Krásná Lípa; 6 – Jurassic occurrences near Olomučany and Rudice; 7 – Jurassic occurrences near Brno

2.21 Upper Turonian sandstones. The Bohemian Cretaceous Basin near Jičín, Prachovské skály, viewed from Hlaholská vyhlídka
Photo by J. Svoboda



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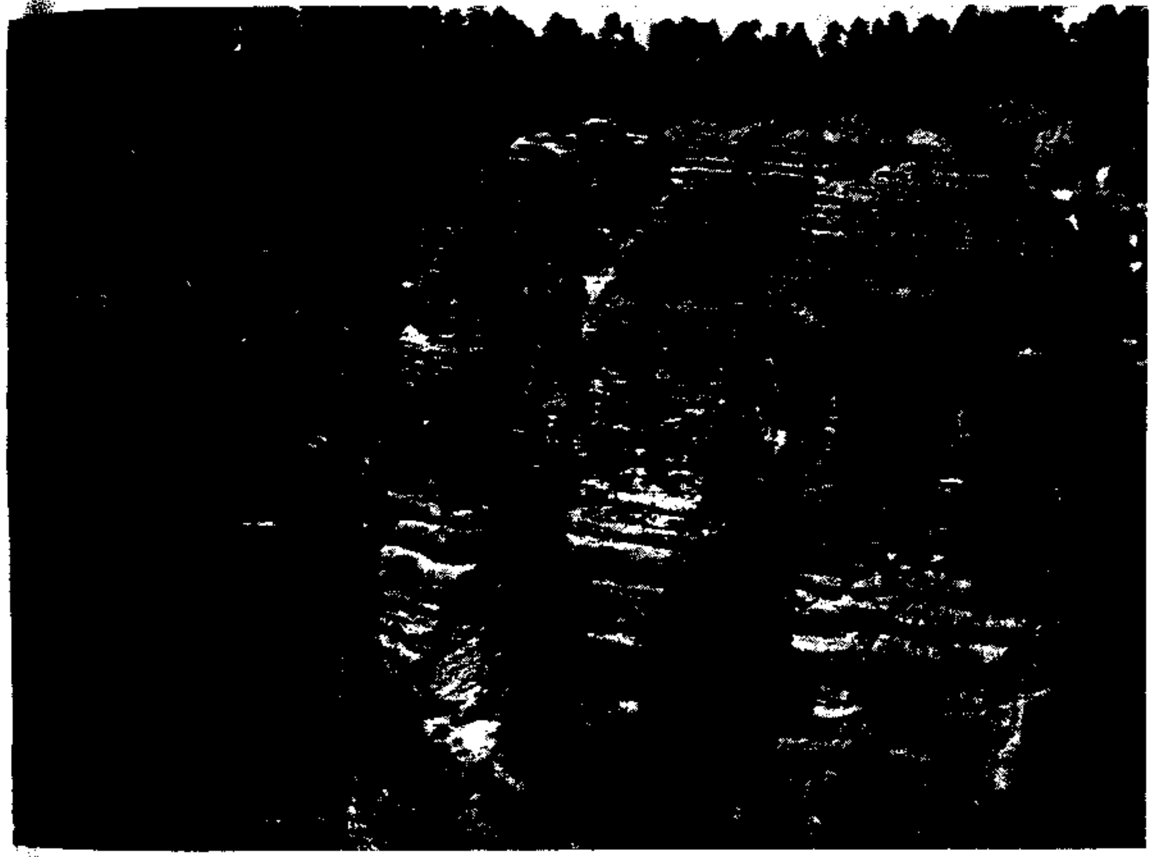

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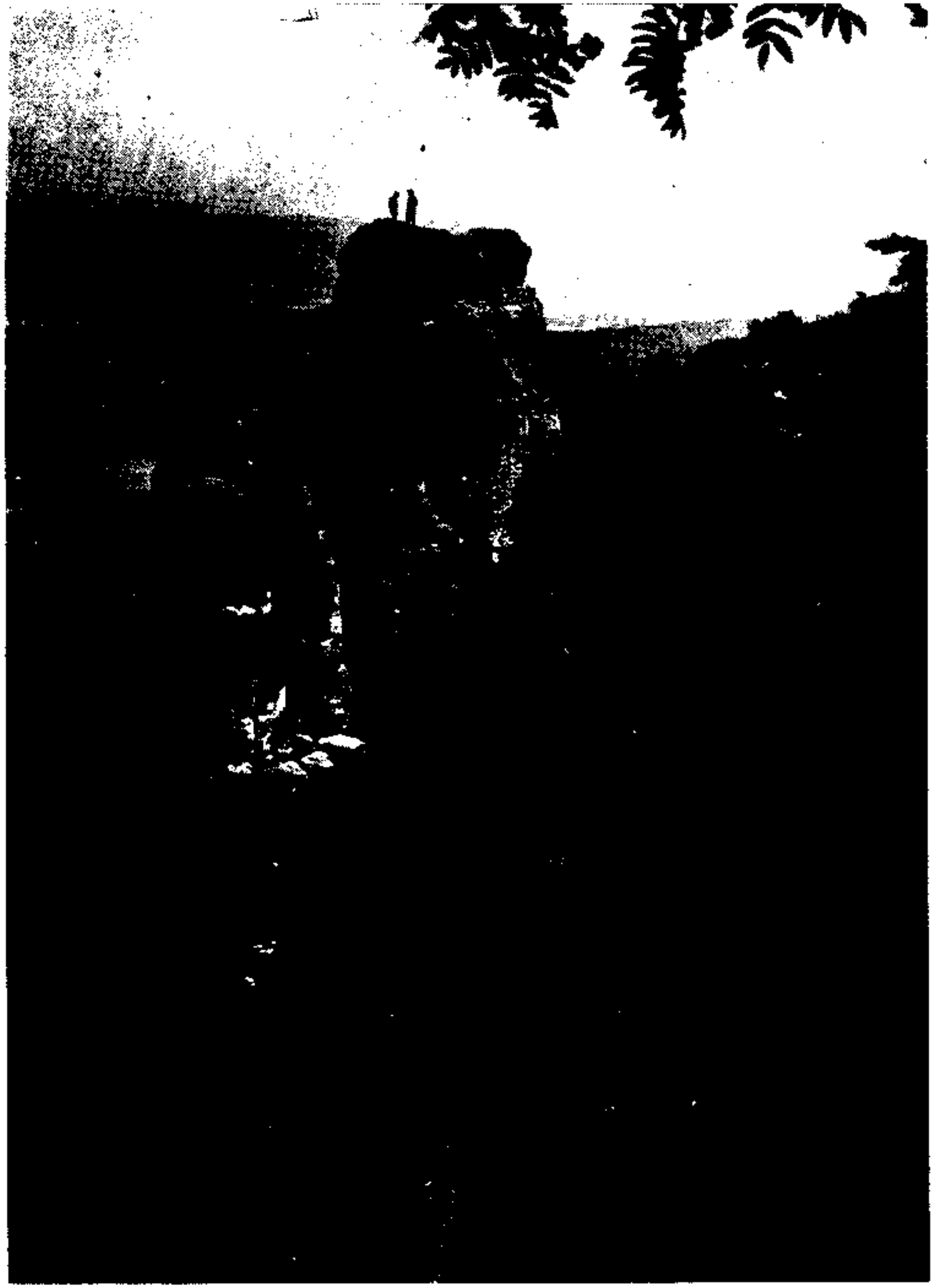


2.22 Upper Turonian sandstones, Prachovské skály, North Bohemia
Photo by J. Svoboda

occurrences in the Bohemian Cretaceous basin, in northern Moravia near Osoblaha and in the South Bohemian basins.

The Bohemian Cretaceous basin forms a uniform sedimentary area with the Saxon region. From the viewpoint of palaeogeography, in the early Late Cretaceous it was a sea connecting the Tethys and the Boreal Sea.

On the basis of facies variety Č. Zahálka (1893) and B. Zahálka (1924) differentiated in the Bohemian Cretaceous Basin the following regions:

a) Lusatian region (predominantly sandy development)
b) Jizera region (predominantly calcareous sandstones)
c) Labe region (dominantly marly-clayey sediments)
d) Hejšovina region (predominantly sandstones)
e) Bystřice region (prevalently clayey sandstones)
f) Orlice-Žďár region (prevalently calcareous sandstones)
g) Kolín region (partly littoral reef limestones)
h) Vltava-Berounka region (predominantly marly-sandy sediments)
i) Ohře region (marly-clayey development).

During the Cenomanian and late Turonian the Boreal sea also ingressed the area of northern Moravia. The occurrence of Turonian—Cenomanian sediments has been proved in the Osoblaha area near Slezské Pavlovice (Skácel 1970), but the extent of the Cretaceous beds beneath the lower Badenian in the Osoblaha area is not known.

In southern Bohemia the Cretaceous sediments fill the major part of the České Budějovice basin and the southern part of the Třeboň basin. They are also preserved in denudation relics near Nová Ves, Stráž nad Nežárkou, Kardašova Řečice and Turovec.

Tertiary of the Bohemian Massif

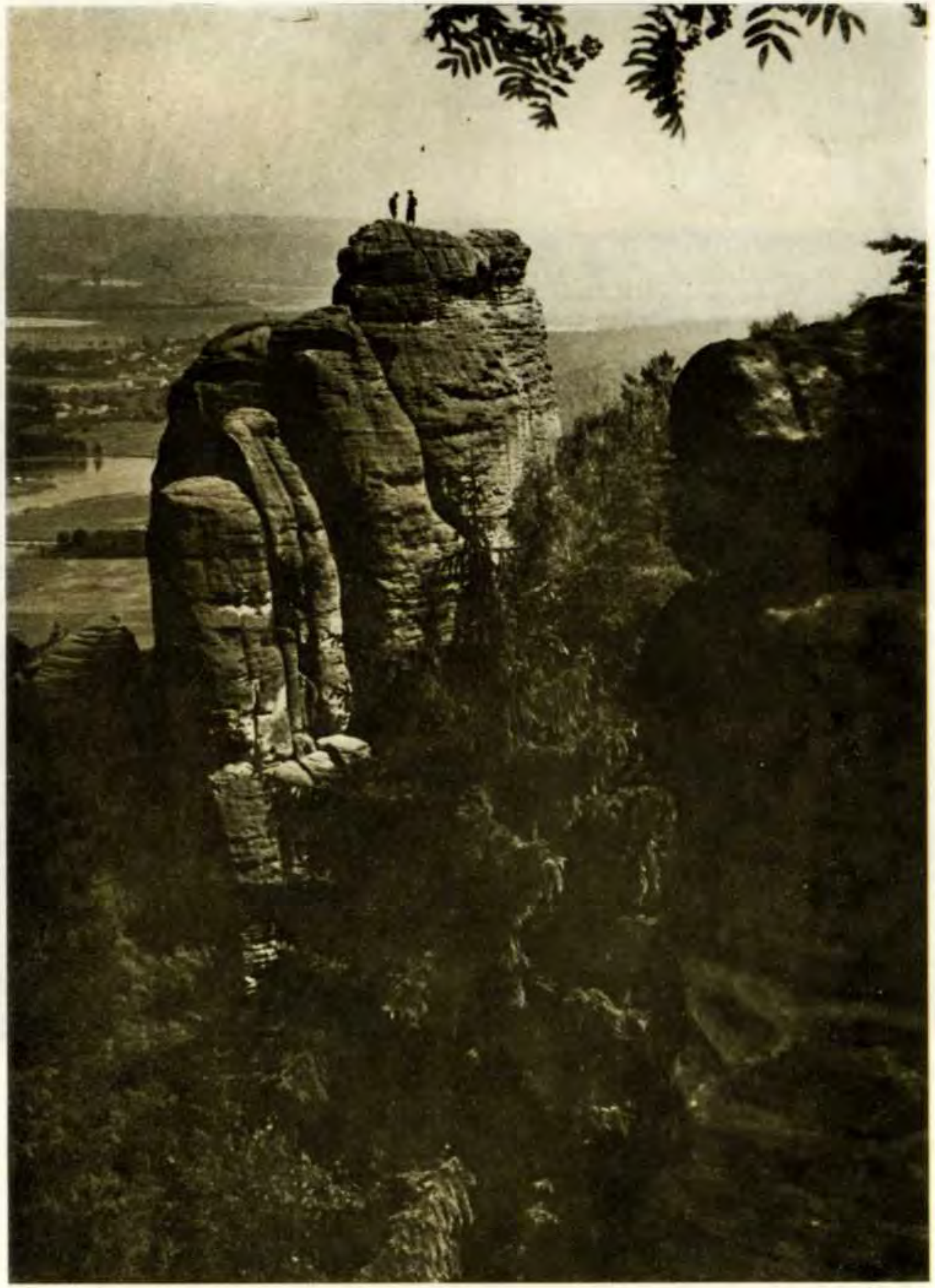
The Tertiary of the Bohemian Massif is represented by Palaeogene sediments and Neogene sedimentary and neovolcanic rocks.

a) Tertiary of north-western Bohemia. At the foot of the Krušné hory Mts. there are three Neogene limnic basins differing in stratigraphy and lithology:

— The Cheb basin in the extreme west is separated from the Sokolov basin by a crystalline ridge near Chlum nad Ohří. The occurrences in the Fed. Rep. of Germany are linked on it;

— The Sokolov basin extends from this crystalline ridge up to the neovolcanics of the Doupovské hory Mts.;

— The North Bohemian basin is located between the Krušné hory, Doupovské hory and České středohoří mountain ranges.



2.22 Upper Turonian sandstones, Prachovské skály, North Bohemia
Photo by J. Svoboda

occurrences in the Bohemian Cretaceous basin, in northern Moravia near Osoblaha and in the South Bohemian basins.

The Bohemian Cretaceous basin forms a uniform sedimentary area with the Saxon region. From the viewpoint of palaeogeography, in the early Late Cretaceous it was a sea connecting the Tethys and the Boreal Sea.

On the basis of facies variety Č. Zahálka (1893) and B. Zahálka (1924) differentiated in the Bohemian Cretaceous Basin the following regions:

a) Lusatian region (predominantly sandy development)
b) Jizera region (predominantly calcareous sandstones)
c) Labe region (dominantly marly-clayey sediments)
d) Hejšovina region (predominantly sandstones)
e) Bystřice region (prevalently clayey sandstones)
f) Orlice-Žďár region (prevalently calcareous sandstones)
g) Kolín region (partly littoral reef limestones)
h) Vltava-Berounka region (predominantly marly-sandy sediments)
i) Ohře region (marly-clayey development).

During the Cenomanian and late Turonian the Boreal sea also ingressed the area of northern Moravia. The occurrence of Turonian—Cenomanian sediments has been proved in the Osoblaha area near Slezské Pavlovice (Skácel 1970), but the extent of the Cretaceous beds beneath the lower Badenian in the Osoblaha area is not known.

In southern Bohemia the Cretaceous sediments fill the major part of the České Budějovice basin and the southern part of the Třeboň basin. They are also preserved in denudation relics near Nová Ves, Stráž nad Nežárkou, Kardašova Řečice and Turovec.

Tertiary of the Bohemian Massif

The Tertiary of the Bohemian Massif is represented by Palaeogene sediments and Neogene sedimentary and neovolcanic rocks.

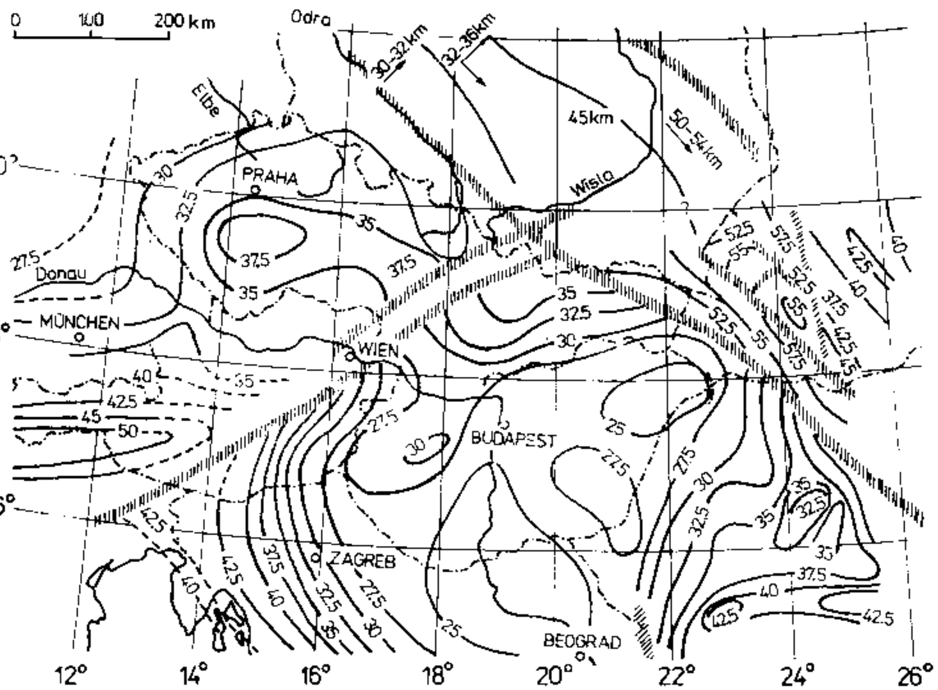
a) Tertiary of north-western Bohemia. At the foot of the Krušné hory Mts. there are three Neogene limnic basins differing in stratigraphy and lithology:

— The Cheb basin in the extreme west is separated from the Sokolov basin by a crystalline ridge near Chlum nad Ohří. The occurrences in the Fed. Rep. of Germany are linked on it;

— The Sokolov basin extends from this crystalline ridge up to the neovolcanics of the Doupovské hory Mts.;

— The North Bohemian basin is located between the Krušné hory, Doupovské hory and České středohoří mountain ranges.

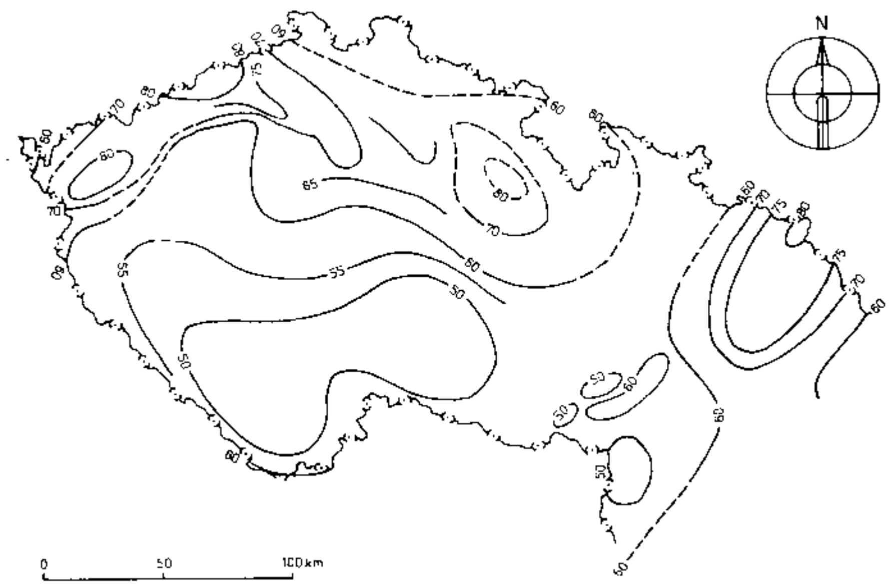
magmatism. This relationship was interpreted by changes in the thickness of the earth's crust in the axial part of the European Hercynides, i.e. the increase in the crust thickness in this (Moldanubian) zone from the Vosges and Schwarz-



2.34 Thicknesses of the earth's crust in Central Europe (A. Zátopek - B. Beránek 1980). Numerals give the thickness of the earth's crust in km

wald (22—25 km) into the Moldanubicum in the Bohemian Massif (40 km). The anomalous thickness of the crust might be alternatively explained as due to the subduction of the adjacent units beneath the Moldanubicum, for example, of the Brunovistulicum beneath Moravicum, as presumed by Fuchs (1976). The geological situation also indicates that during the Hercynian orogeny the Moldanubicum might have collided with the ancient Brunovistulicum crystalline complex, which possibility was already admitted by Stille (1951). The uplift of the Moldanubicum and subsidence of the Brunovistulicum towards the end of the Hercynian orogeny (Dvořák 1980) is in agreement with this assumption, as well as the overthrust and repeated compression of Precambrian rocks in the Moravo-Silesian zone (Mísař 1963) and termination of the Hercynian orogenic zones in this area.

According to Čermák (1980), the values of heat flow change concurrently with the change of the crust thickness at the mantle/crust boundary. In the Moldanubicum, in places of the greatest crust thickness the heat-flow values are



2.35 Heat flow in the territory of the Czech Soc. Rep. (according to V. Čermák 1980, modified and simplified). Numerals give the values of heat flow in mWm^{-2}

21—23 mWm^{-2} (which correspond to temperatures of 500—600 °C at the M-discontinuity), in the northern part 27 mWm^{-2}, and 30 mWm^{-2} at the eastern margin of the Bohemian Massif.

In the surficial parts the lowest heat-flow values are in NE Bohemia (Bohemian Cretaceous Basin, the Jeseníky Mts. about 22 mWm^{-2}), in the Moldanubicum and the Barrandian (about 50 mWm^{-2}). Increased values have been established in the eastern part of the Krušné hory Mts. and in the Teplice area (as high as 160 mWm^{-2}) and around Ostrava (about 100 mWm^{-2}). These anomalies are obviously associated with the processes in the earth's crust.

2.3.2 Characteristics of the earth's crust structure in the Bohemian Massif

The data on the deep structure of the earth's crust in the Bohemian Massif are derived from the deep seismic sounding (B e r á n e k - D u d e k 1980, B e r á n e k - S u k - W e i s s 1980), from the interpretation of gravimetric data (B u d a y et al. 1969, A d a m et al. 1979), I b r m a j e r 1978, B l í ž k o v s k ý et al. 1981) and some results of airborne magnetic mapping (M a n 1966).

I n t h e g r a v i t y f i e l d of the Bohemian Massif the elements of SW—NE direction are most prominent (I b r m a j e r 1978). These zones alternate within the whole Bohemian Massif, having the NE—SW trend and widths of several tens to one hundred km (Fig. 2.36). The zones with positive anomalies, as were delimited by B u d a y et al. (1969, correspond geologically to the Saxothuringicum, Proterozoic, Barrandian and the E. part of the Moldanubicum with the Nízký Jeseník Hills. The zones with negative anomalie comprise the Krušné hory Mts., the western part of the Moldanubicum, the basement of the central part of the Bohemian Cretaceous, and the Orlické hory Mts. The differences in the gravity pattern are explained either by different thicknesses of the volcano-sedimentary formations (B u d a y et al. 1969), by differences in the thickness of the basalt layer (R ö h l i c h - Š ť o v í č k o v á 1968), or by the absence of the granite layer in the positively anomalous zones (Z o u b e k 1967). In any case, the type of these zones is associated mainly with the structure of the crust and not with its thickness (i.e. with the course of M-discontinuity), because the correlation between the thickness of the earth's crust and the regional gravity anomalies cannot be sought for in the subdivision of the Bohemian Massif (B e r á n e k - I b r m a j e r 1976, V y s k o č i l P. 1972). These heterogeneities seem to be explained most appropriately by the structure of the granite layer, as is also evidenced by seismic data, particularly by the distribution of the velocities of seismic waves. The thicknesses of that part of the crust in which the wave velocities do not exceed 6 km s^{-1} are 16 km in the western part of the Moldanubicum, 8 km in the Krušné hory Mts., 4—5 km in the positively anomalous zones at the eastern margin of the Bohemian Massif (Moravian block after W e i s s 1977), and 5—6 km in the Teplá-Barrandian zone. Negative gravity anomalies thus correspond to greater thicknesses of metamorphosed, migmatized and granitized rocks in the western part of the Moldanubicum and the Krušné hory region, for which the low wave velocities are characteristic. In contrast, in the Teplá-Barrandian zone predominate metamorphosed volcano-sedimentary formations distinguished by higher densities and velocities of seismic waves.

The configuration of the regional gravity anomalies is also controlled by the thickness of the basalt layer or, in general, by the occurrence of zones with wave

2.36 Gravity anomalies in the Czech Soc. Rep. (J. Ibrmajer - M. Blížkovský, orig.). Residual gravity anomalies in dots, regional gravity anomalies after Griffin, centred to 8 15 km
1 — positive anomalous fields; 2 — negative anomalous fields

velocities of above 7.5 km.s⁻¹ in the deeper parts of the earth's crust. The configuration of the gravity field in the Bohemian Massif, however, is too diversified for the effects of individual zones to be distinguished.

This influence is doubtless involved at the eastern margin of the Moldanubicum and in the Moravicum, where the basalt layer approaches to the earth's surface. The occurrence of numerous bodies of basic and ultrabasic rocks at the eastern margin of the Moldanubicum provides additional evidence. The situation in this area is analogous to that in the Ivrea zone (W e i s s 1977) and corresponds to the subduction of the Brunovistulicum beneath the Moldanubicum.

The changes in the thickness of the basalt layer are also demonstrable in the Šumava region in the SW of the Bohemian Massif. The uplift of the basalt layer towards the earth's surface was in this part connected with the general upheaval of the southern part of the Bohemian Massif during the Hercynian orogeny and the inclination of the block of the Bohemian Massif to the N (NNE), which is substantiated geologically (D u d e k - S u k 1965).

The increasing depth character towards the S is demonstrable in the whole southern and western parts of the Bohemian Massif despite the departures caused by fault tectonics. It is particularly marked in the Barrandian, at the boundary with Domažlice crystalline complex, where it is manifested by the increase in metamorphic grade and a gradual approaching of heavier rocks towards the surface along the seismic profile in the Krušné hory Mts., and in the Central Bohemian and Moldanubian Plutons. From the dips of lineation, the geometry of the distribution of the relics of cover deposits, and the changes in the breadth of zones of metamorphism and migmatization, the depth difference between the northern and southern margins of the Moldanubicum can be estimated at ca. 15 km. This value agrees fairly well with the data on the uplift of the basalt layer.

Also in this case the uplift was associated with the origin of major tectonic lines (Jáchymov zone, zone of the Bavarian Quartz Lode) and with the concentration of ultrabasite occurrences in the South Bohemian granulite zone. We assume that the fundamental properties of the crust in the area of the Bohemian Massif formed as early as in Precambrian times. The concentration of metavolcanics, and basic and ultrabasic igneous rocks (zones of granulites, amphibolites, ultrabasites and orthogneisses in southern Bohemia) really indicates the existence of a Precambrian rift zone in this area (Z e m a n J. 1979), which only during Hercynian orogeny and uplift of the southern part was separated from its basement.

According to B u d a y et al. (1969) and I b r m a j e r (1978), there are four characterictic regions in the gravity pattern of the Bohemian Massif, the foundations of which lie in the deep structure of the earth's crust. In the map of regional anomalies (Fig. 2.36) the regions are arranged from W to E as follows:

1. Extensive gravity low passing along the NW frontier of Bohemia, which corresponds to the Krušné hory and Krkonoše-Jizerské hory blocks;
2. Positive anomalous zone, which extends from the Český les Mts. across the Tepelská vysočina Upland and the Barrandian synclinorium into the area of the Bohemian Cretaceous and the crystalline complex at the foot of the Krkonoše Mts., and further eastwards into the Inner Sudetic basin. This gravity elevation is for the most part occupied by the Teplá-Barrandian block;
3. The region of negative gravity values covering the area built up of the Moldanubicum, the Central Bohemian Pluton and Central Moldanubian massif, the Svratka anticline, the Orlické hory-Kłodzko Dome and the western part of the Hrubý Jeseník Mts. A distinctive feature of this region is an intricate relationship between the upper and deep geological structure;
4. The eastern part of the Bohemian Massif is the region of positive gravity values. It comprises the eastern part of the Moldanubicum, the Moravicum, the Brno massif, the Drahanská vrchovina Upland, the Nízký Jeseník Hills and part of the massif in the basement of the Carpathian foredeep and of the flysch nappes of the West Carpathians.

Extensive negative gravity zones geologically represent elevations originated towards the end of the Proterozoic. Palaeozoic complexes occur here to a very limited extent and are for the most part affected by Hercynian regional metamorphism. Positive anomalous gravity zones are distinctive of the depression areas (Saxothuringicum, the Proterozoic of the Barrandian, and the eastern part of the Moldanubicum with the Nízký Jeseník Hills). In these areas the Palaeozoic is mostly unmetamorphosed and a preponderant part of volcanic formations is concentrated in them or along their boundaries, from magmatites metamorphosed in the Precambrian crystalline complexes to the youngest Tertiary and Quaternary neovolcanics.

K l o m í n s k ý - D u d e k (1978) and B e r n a r d (1978) have proved that the areas of these two types differ in plutonism and mineralization. In the positive anomalous gravity zones there is an absolute majority of occurrences of tonalitic rocks, of five-element mineralization, sulphides of gold and antimony and most of the mercury occurrences. In the negative anomalous zones granites with Au mineralization in quartz veins predominate, and the occurrences of tungsten, tin and Pb+Zn and Ag+Cu ores as well. The granite plutons in these zones are of large extent also in the basement of crystalline schists (the Krušné hory Mts. and the western part of the Moldanubicum). The boundaries of the zones of a different geological and gravity pattern are usually interpreted as the limitation of blocks. This, however, is not identical with the fault boundaries at the surface, which are very often considered erroneously to be principal indication of a deeper block structure of the crust (e.g. the Přibyslav zone, Blanice Furrow). Thus, for example, in the zone of the Central Bohemian Suture the gravity boundary between the negative anomalous block of the western Moldanubicum and positive anomalous Barrandian is not identical either with the Klatovy fault and its extension to Mníšek pod Brdy, or with the western margin of the Central Bohemian Pluton between Říčany and Rožmitál pod Třemšínem, but runs in the mantle of the Pluton between Písek and the river Sázava (i.e. is broadly identical with the "zone of intrusive tectonics" of Z e l e n k a 1929, initiated in the Precambrian). Also the boundary between the positive anomalous Teplá-Barrandian zone and the Krušné hory gravity low is not defined by the Ohře fault zone. An analogous discord is observable at the Bohemian Massif/ Carpathian boundary.

The region of negative anomalies of the Krušné hory Mts. and the Krkonoše-Jizerské hory massif is bounded by an expressive gravity gradient and is divided into four isolated lows (Fig. 2.36). B u d a y et al. (1969) explain these gravity depressions as due to light granitoid massifs. which crop out at the surface or come near to the surface.

The most striking is the anomaly in the area of Karlovy Vary, which is produced by a body of leucocratic granitoids. whose thickness is estimated at 10 km at least. Two partial depressions issue from this anomaly towards W and SW, respectively. On introducing corrections for gravitational effects of the Neogene sediments of the Cheb and Sokolov basins (B l í ž k o v s k ý et al. 1981) it became evident that these local depressions are closely connected with the large gravity low near Karlovy Vary.

The gravity depression in the map of Bouguer anomalies with the centre near Duchcov appears substantially less pronouncedly in a stripped gravity map, which permits to presume the influence of a deeper lying volcano-plutonic centre.

The negative gravity anomaly in the area of Stráž pod Ralskem is a very distinct structure. B l í ž k o v s k ý et al. (1981) interpreted it quantitatively using a model of rotation ellipsoid, and they assume that beneath the Cretaceous sediments there is a body of light granitic rocks with the gravity point at a depth of about 6 km. which might be connected with the Krkonoše-Jizerské hory pluton.

East of the Lusatian fault, the Krkonoše-Jizerské hory massif represents a gravity low. With regard to the circumstance that in the western part of the massif, the gravity field is less marked in the map of residual anomalies than in the E. the conception of a slabby form of the pluton and of its root zone located in the eastern part appears more reasonable.

The gravity field in the positive anomalous zones of the Teplá-Barrandian block and at the foot of the Krkonoše Mts. is diversified, showing a discrete zonal structure.

At the western end, in the area of the Mariánské Lázně metabasite complex there is a marked gravity high. A sharp gradient in the northern and north-western parts indicates a density boundary between the granitoid complex in

the NW and the metamorphosed Upper Proterozoic complexes containing layers of basic magmatites. in the SE. The idea that this gravity structure reflects the effects coming from a greater depth is supported by the opinion of C h á b (1973) that an ophiolite complex with relics of the oceanic crust exists in this area. In the north-eastern continuation of this gravity elevation the isolines bend distinctly towards the E. evidently due to the effect of the Jáchymov fault.

Major accumulations of basic bodies are also indicated by gravity anomalies in the central part of the Doupovské hory Mts. and NE of Žatec. The extension of this positive gravity zone trends W—E within the area covered with Cretaceous sediments. The idea put forward by B u d a y et al. (1969) that it may be accounted for by Proterozoic rocks with strongly developed spilite-keratophyre volcanism. was supported by a detailed analysis of the basement of the Cretaceous sequences (C h a l o u p s k ý 1973).

Gravity elevations associated with basic volcanism also occur in the Permo-Carboniferous area at the foot of the Krkonoše Mts. and in the Broumov projection.

Another parallel zone of positive gravity anomalies extends from the basic Kdyně complex through Plzeň and Kralupy nad Vltavou to the basement of the Cretaceous N of Benátky nad Jizerou. It is linked up with the Proterozoic spilite belt, in which there are large accumulations of basic volcanites and the presence of subvolcanites should be postulated.

A prominent positive anomaly between Domažlice. Stod, Přeštice and Nýrsko is produced by the Kdyně basic complex. The local gravity elevation NW of this massif corresponds to the Poběžovice basic massif. The analysis of the gravity pattern and of the radiometric data has revealed that the West Bohemian Pluton is divisible into two parts (I b r m a j e r 1978). The more basic part of Proterozoic age occupies the areas of positive anomalies (Kdyně. Poběžovice and Stod massif and some minor stocks) and the more acid Hercynian part is connected with negative gravity anomalies (Babylon. Kladruby, Bor and Štěnovice massifs).

The isolated anomaly near Slaný and the western part of the gravity elevation near Kralupy can be accounted for by the presence of extensive complexes of spilite-keratophyre volcanism. In the eastern part basic intrusive rocks of the Neratovice massif in the basement of the Permo-Carboniferous are thought to contribute to the gravity effect (B l í ž k o v s k ý et al. 1981).

The third belt of a positive anomalous zone, extending approx. along the line connecting Příbram with the lower course of the river Sázava, is explained by B u d a y - D u d e k - I b r m a j e r (1969) as due to the influence of the metabasites of the Jílové Zone and the adjacent Netvořice-Neveklov metamorphic "islet". Besides metabasites, the effects of numerous gabbroid bodies enclosed in the pluton and the presence of another source at depth are emphasized (M o t t l o v á - S u k 1970 and M í s a ř et al. 1972).

A prominent zone of positive gravity anomalies trending NW-SE, i.e. parallel to the Labe line and the Lusatian fault, extends from the area of Poděbrady to the SE and occupies both the Železné hory area and the Nasavrky massif. The course of the isolines and a marked gravity gradient corresponds to the Železné hory fault zone. The Dlouhá mez tectonic zone is accompanied by intrusive bodies of basic rocks, which are shown in the gravity map as local highs as, for example, the isometric anomaly above the Ransko massif. B l í ž k o v s k ý et al. (1981) assume that the largest body on this line will occur at the site of maximum elevation E of Čáslav. The zones of positive gravity anomalies of the Teplá-Barrandian block and of the region at the foot of the Krušné hory Mts. are separated from each other by the zones of negative anomalies. The zone running broadly along the Bor—Louny tie-line is essentially caused by acid granitoids of the West Bohemian Pluton (I b r m a j e r 1978), and intensified by the effect of Permo-Carboniferous sediments in the Manětín basin. The gravity elevation NE of the Manětín basin is evidently controlled by the Jáchymov fault, along which the north-eastern block with the granitoids of the Čistá massif has been uplifted.

The more easterly depression zone is composed of two isolated lows NW and SE of Plzeň of a negative gravity anomaly at the site of the Palaeozoic Barrandian syncline. The first two anomalies are due to the Permo-Carboniferous sediments of the Plzeň basin and the presence of the Štěnovice granitoid massif. The third zone, after B u d a y et al. (1969), corresponds to the acid volcanites and alleged subvolcanic bodies of the Křivoklát-Rokycany zone. T o m e k (1978) explains the origin of the negative gravity anomaly above the Palaeozoic Barrandian basin as due to highly contrasting densities of the Upper Proterozoic.

The third belt traceable in the gravity pattern of the Bohemian Massif is an area of negative gravity values. In contrast to the two previous areas, the gravity elements are not arranged in a belt but are distributed rather randomly. The south-western part is more extensive and bounded by prominent gradients in NW, S and E. These gradients indicate the fault zone of the Central Bohemian suture at the north-western margin of the Central Bohemian Pluton adjacent to the Algonkian, and the prominent fault zone at the eastern margin of the Central Moldanubian Massif, which trends towards the Ransko massif and the Hlinsko zone in the Železné hory Hills.

In the negative gravity field of the Moldanubicum, the manifestations of granitic rocks in the gravity pattern are the most pronounced but they are not uniform (M o t t l o v á - S u k 1970). Some types, e.g. the Mrákotín or Freistadt granites, produce a marked negative density boundary against the Moldanubian mantle, whereas the Rastenberg type and partly the Weinsberg type almost do not differ from the Moldanubian pararocks in density (E l i á š - U h m a n n 1968).

The most marked gravity lows of the area discussed occur in the south-eastern part of the Central Bohemian Pluton, above the central massif of the Českomoravská vrchovina Highland, whence they extend southwards into the Třeboň basin and the Novohradské hory area; in the northern part of the Central Bohemian Pluton there is a very striking low above the light granites of the Říčany body. This anomaly is separated from the remaining part of the Central Bohemian Pluton by a sharp gravity gradient, which is evidently a manifestation of the Sázava fault zone. I b r m a j e r (1978) interprets it in terms of a vast granitoid pluton buried at depth. This interpretation is supported by a detailed analysis of O r e l (1975); in his opinion the existence of a large granitoid body is also demonstrated by the occurrences of pegmatite and ore mineralization arranged concentrically around this anomaly. From the overall configuration of the gravity field in the Moldanubicum I b r m a j e r (1978) infers that the Říčany granite and the alleged granitoid body are not genetically associated with the Central Bohemian Pluton and that they should be ranged to the central massif of the Českomoravská vrchovina Highland.

In the north-eastern part of the area of negative anomalies the most prominent gravity low occurs in the Orlické hory-Kłodzko Dome. This negative anomaly, which extends to Poland, is associated with the migmatites and orthogneisses of the Gieraltów type, or with the light granites in the core of the Dome.

Granitoid bodies near Žulová and Šumperk produce local lows as well as the NNW—SSW trending zone corresponding to migmatites and orthogneisses of the Keprník Dome. The Staré Město mica-schist zone with abundant occurrences of basic and ultrabasic rocks produces a slightly positive anomaly.

A pronounced gravity gradient at the eastern margin of the Keprník Dome is obviously caused by the deeper structure of the crystalline complex, because the surface sequences on either side of it show a similar petrographical character (I b r m a j e r 1978).

The area of positive gravity values can be divided into two parts by a negative zone in the area of the Upper Morava depression. To the south-west of the Upper Morava depression the most marked gravity elements are represented by two elevations with peaks near Svitavy and S of Brno. Both anomalies are elongated broadly into the N—S direction, being bounded by sharp gradients. They distinguish the ancient fault zone in the structure of the Bohemian Massif, which had been used as a pathway for the intrusions and effusions of basic and ultrabasic magmas.

Č u t a - M í s a ř - V á l e k (1964) interpreted the Svitavy anomaly as due to the gravity effect of basic rocks and estimated the width of the body at 10 km. B u d a y et al. (1969) explain this elevation as a manifestation of basic and ultrabasic rocks of the Letovice crystalline complex. B l í ž k o v s k ý et al. (1981) quantitatively interpreted this structure using a model of three prisms with a width of 5—9 km for difference density +0.21 g cm^{-3}. The lower edge of the disturbing body with a density of ca. 3.00 g cm^{-3}, i.e. complex of rocks with predominating basites, has a base at a depth of 8.5 km; the upper prism reaches to 0.35 km below the surface.

The positive gravity anomaly, associated with the basic zone of the Brno massif (B u d a y et al. 1969), links up on the Svitavy elevation after an interruption within the area of the Boskovice Furrow. Its continuation of SE direction was emphasized by introducing gravity corrections for sediments of the foredeep. B l í ž k o v s k ý et al. (1981) explain the anomaly as due to the effect of a disturbing body with a difference density +0.13 g cm^{-3} relative to the adjacent rocks. The base of the body is estimated at a depth of 12 km, and the upper edge approaches to the surface.

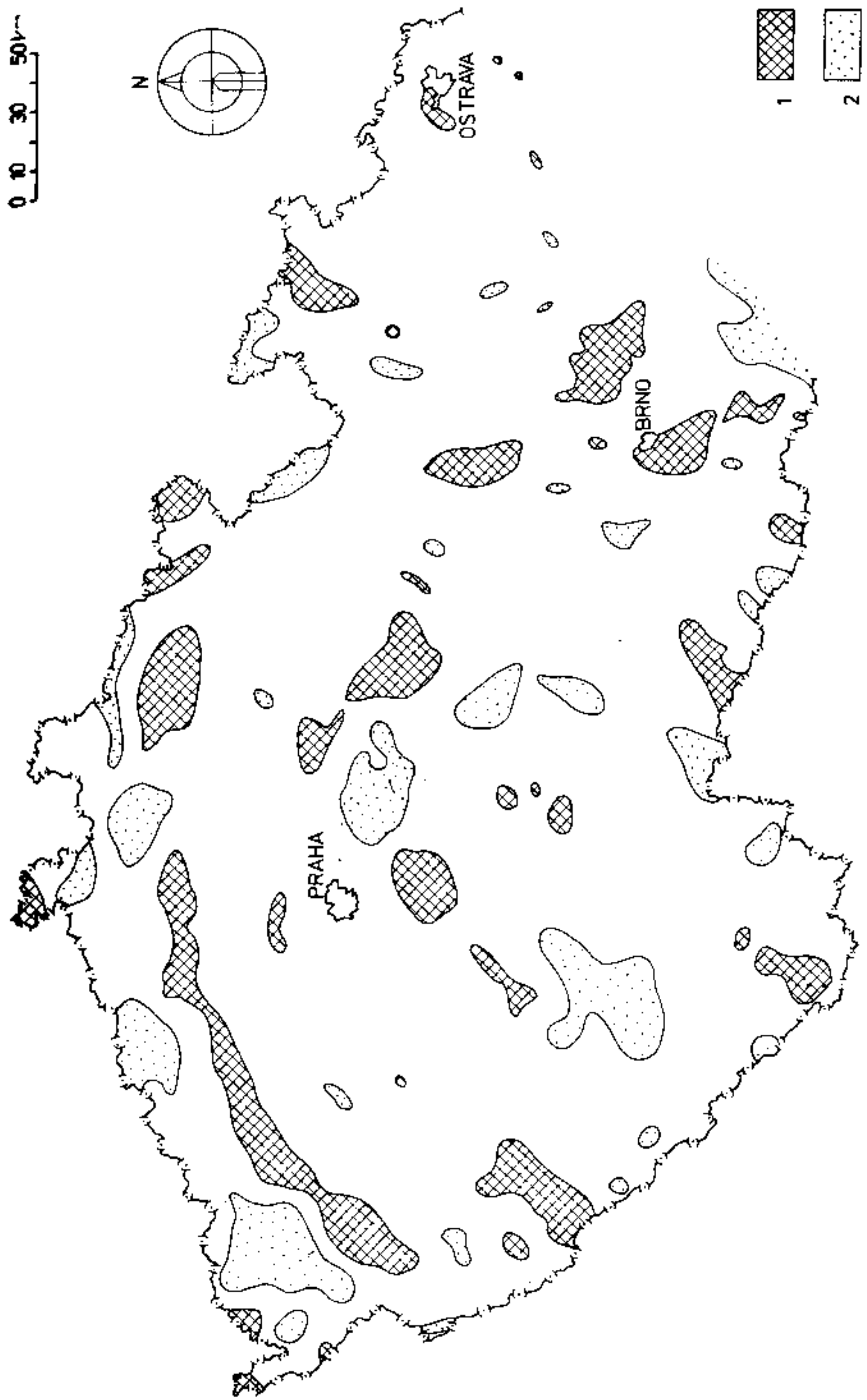
The Moldanubian part of the area of positive anomaly shows a configuration of the gravity field broadly corresponding to the homogeneous petrographic character of the rocks. Light granitoid plutonites are not represented in this area even in the deeper parts of the crust and therefore the total gravity effect is here induced obviously by an elevation of the upper mantle and a reduced thickness of the crust (I b r m a j e r 1978). The relatively negative gravity anomalies are caused by the rocks of the Moravicum as in the Svratka and Dyje Domes so in the protrusion of the Dyje massif.

To the north-east of the Svitavy and Brno gravity elevations, in the residual map there is an extensive positive anomaly above the relatively heavier Palaeozoic rocks of the Drahanská vysočina Highland and the Nízký Jeseník Hills and the rock complex of the eastern part of the Silesicum. The area of the Upper Morava depression remained in the stripped gravity map a depression (B l í ž k o v s k ý et al. 1981) also after corrections for the effects of Tertiary sediments. The contacts between the Palaeozoic and its basement show themselves as a broad belt of gravity gradients SW and NE of the depression axis; this is obviously connected with its tectonic limitation, i.e. a NW—SE trending fault zone, which is traceable from the Bohemian part of the Lower Silesian basin to the Central Carpathians.

The gravity depression zone in the Carpathian foredeep indicates light granitic rocks in the basement of the Neogene, because the thickness of sediments in this area is not great enough to produce a negative anomaly.

T h e c o u r s e o f a n o m a l i e s o f t h e m a g n e t i c f i e l d in the Bohemian Massif agrees to a certain extent with the gravity picture: there is considerable agreement between the segments positively and negatively disturbed with analogous gravity undulations (Fig. 2.37). On the territory of the Czech Socialist Republic the magnetic field is distinguished by the following prominent features:

a) zone of positive anomalies which borders the Litoměřice fault in the south and continues eastwards bending arcuately across the area at the foot of the Krkonoše Mts. into the Orlické hory Mts. This zone illustrates the course of the



2.37 Map of significant magnetic anomalies in the Czech Soc. Rep. (compiled from aeromagnetic map of O. Man 1966 and map of J. Bernard et al. 1982)
1 — Principal positive magnetic anomalies (+8 . 10^{-5} m . s^{-2} and more); 2 — principal negative magnetic anomalies (—8 and less)

Hercynian orogenic belt. It is probably produced by Precambrian magmatic rocks (P o u b a 1970), which reach to great depth of the geological structure (M a š í n 1966);

b) zone of prominent doubled anomalies (the westerly negative, the more easterly positive) can be followed in sectors interrupted by transverse faults (Kdyně—Plzeň, Blatná—Sázava, Golčův Jeníkov—Vysoké Mýto and Zábřeh—Jeseník) across the Bohemian Massif, from its south-eastern part. These belts indicate the shifting of the more northerly blocks eastwards along the Jáchymov, Sázava and Labe lineaments and the faults of the Upper Morava depression (Fig. 7.7). The zone of doubled anomalies is traceable both north-eastwards to Poland (P o u b a 1970) and south-westwards from Augsburg to the Schwarzwald, in the basement of the Jurassic (A n g e n h e i s t e r 1974). It indicates the course of the zone of basic and associated acid magmatites (in the Precambrian of the Bohemian Massif it comprises the Kdyně massif and Zinkovy spilite belt, the Jílové and Kozí hory zones, basites of the Železné hory Hills, in the western part of the Moravian zone and in the Silesicum), and its extension in the European Variscides into the Massif Central français and into the basement of the Russian Platform. It is a zone of specific volcanism (J a k e š 1978), which originated during the formation of the Cadomian geosyncline and persisted until the Palaeozoic (geanticline of the Brdy Hills, H a v l í č e k V. 1971);

c) buried bodies of basic rocks caused the development of the marked positive N—S trending zone between Ústí nad Orlicí, Svitavy (so-called Svitavy anomaly), Brno and Židlochovice. Its southern part was induced by the basic zone of the Brno massif and its northern continuation, running obliquely to the geological structure, has not yet been satisfactorily cleared up;

d) elongated positive-anomaly zones in the crystalline units, e. g. in the Moldanubicum between Tábor and Pacov and between Červená Řečice and Havlíčkův Brod, are controlled by the primary composition of the rocks and by the conditions of the metamorphic formation of magnetite (Z e m á n e k 1967, Š a l a n s k ý 1967). Z o u b e k (1975) inferred from their absence in the low-metamorphosed Upper Proterozoic of the Barrandian the principal difference between the Proterozoic and Moldanubicum. The cause of this phenomenon, however, is only the metamorphic grade, when under oxidation conditions secondary magnetite is formed in Fe-rich rocks, in cordierite gneisses, but also in skarns and erlans (S u k 1964) and lower-metamorphosed units of the Kaplice unit (Š a l a n s k ý 1967). In some cases the zones may be indicators of the lava flows and help in discriminating between the amphibolites derived from lavas (with magnetite) and from tuffs and tuffites (with Fe-sulphides — V e j n a r 1971).

In the Českomoravská vrchovina Highland and in southern Bohemia the Varied Group contains layers of magnetite-bearing quartzite and itabirite. The course of the primary stratification in these high-metamorphosed units can be

followed along these layers. Similar rocks are described by P o u b a (1970) from the Desná Dome. According to Pouba, the Fe accumulations form in the Precambrian of the Bohemian Massif a belt, which can be followed in the proximity of the above zone of basic volcanites across the Massif up to the southern branch of the Karelides, where such rocks appear in the progressively older units.

Very marked anomalies of a small areal extent indicate the stocks of neovolcanites in the Nízký Jeseník Hills, part of which is not yet uncovered by denudation (G r u n t o r á d 1977), or serpentinized ultrabasites (e.g. in the Moldanubicum in the Tábor area).

2.3.3 Geological structure of the buried parts of the Bohemian Massif

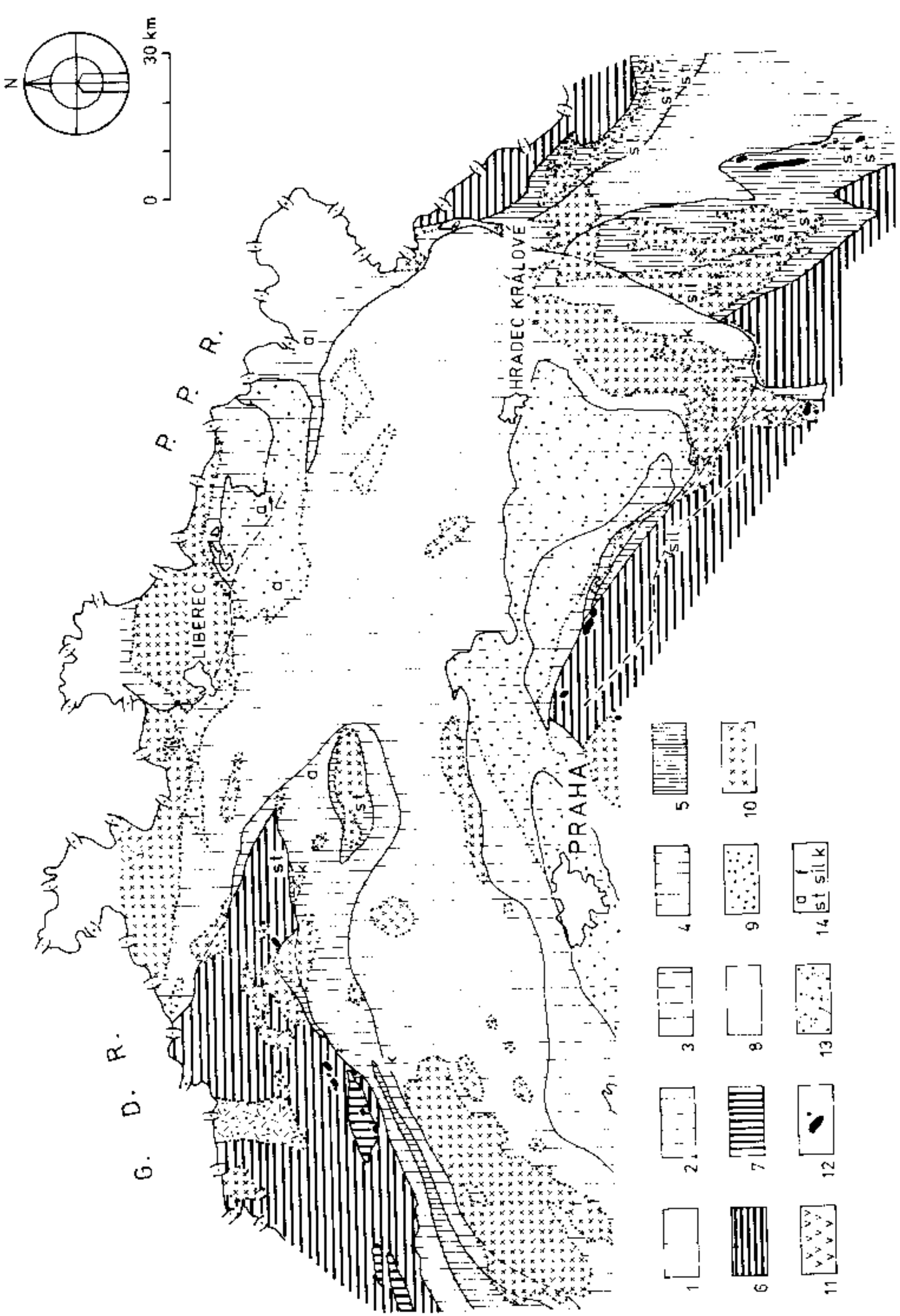
About one third of the Bohemian Massif is covered with sediments of the platform cover and of the western marginal part of the Carpathians.

The most important and largest segment is covered with the Bohemian Cretaceous sediments. According to V a c h t l (1965) and M a l k o v s k ý et al. (1974) t h e b a s e m e n t o f t h e C r e t a c e o u s consists prevalently of the Precambrian units: in the west and north it is the low-metamorphosed Upper Proterozoic of the Barrandian, whose metamorphic zones are linked up with the crystalline complexes of the Krušné hory, Krkonoše and Orlické hory Mts. In the east the basement is formed of the Proterozoic of Zábřeh and Svratka, affected by medium-grade metamorphism.

In the Proterozoic there are the following plutons of large extent:

— the Louny pluton situated between Čistá, Rakovník and Louny in the valley of the river Ohře; it is elongated in the NE—SW direction, parallel to the structure of the Proterozoic;
— the Neratovice pluton, elongated in the ENE—WSW direction;
— the Lusation pluton extends to the south as far as the Lusatian fault, a prominent WNW-trending line, which also forms the southern boundary of the Krkonoše pluton;
— along the southern limit of the Krušné hory crystalline complex there are minor occurrences of diorite, gabbro, hornblendite and pyroxenite;
— the Nasavrky pluton extends in the basement of the Cretaceous far to the north, into the area to the east of Hradec Králové;
— near Svitavy, crushed ultrabasites form the continuation of the Letovice crystalline complex in the basement of the Cretaceous.

The Lower Palaeozoic is preserved in discontinuous relics, which are remnants of a vast a sedimentary basin. The Lower Palaeozoic of the Barrandian (chiefly



Ordovician) reaches up to Městec Králové and the Palaeozoic of the Železné hory Hills (Cambrian and Ordovician) to Hradec Králové and Pardubice. Isolated occurrences are on Zvičina, in the Vyhnanice ridge and in the Devonian near Jítrava and Jablonné v Podještědí. This occurrence indiciates a connection of the Ještěd area with the Elbe Schiefergebirge. The metamorphosed Lower Palaeozoic of the Krkonoše Mts. continues up to the axis of the Permo-Carboniferous basin at the foot of this mountain range, and there are probably other occurrences, not quite conclusively indicated, in the basement of the Upper Palaeozoic. The Upper Palaeozoic is represented in a continuous basin between Žatec and Broumov (Fig. 2.38), from which the Orlice basin was separated by denudation. Of a very small extent is the Permo-Carboniferous in the continuation of the Blanice Furrow and near Třebechovice pod Orebem.

The morphology of the basin floor is controlled by two fault systems. According to Chaloupský (*in* Malkovský et al. 1974), the NW—SE direction is of primary importance; it is followed by the Rovensko fault, the Lusatian fault and several minor dislocations, and the Přibyslav zone and other NNE faults also turn into this direction. The NE—SW fault system governs the western part of the basin. The Litoměřice fault and the conjugate faults reach as far as Chrastava, Hrádek nad Nisou and Harrachov.

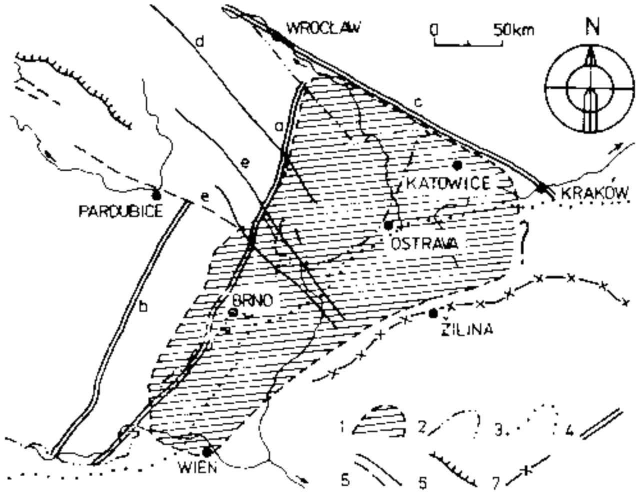
The crystalline complex of the Krušné hory extends southwards in the basement of the North Bohemian brown-coal basin and other minor basins. According to Kopecký L. - Sattran (1966) and Poubová (1963) metamorphism rises at first (granulites and ultrabasites are abundant), but south of the Litoměřice fault it decreases abruptly, passing through a sequence of narrow zones into the Barrandian Proterozoic (Chaloupský *in* Malkovský et al. 1974, Fig. 2.38).

The extraordinary importance of faults of the Jáchymov system follows from the knowledge of the basement of the South Bohemian basins (Malecha et al. 1965, Kadlec et al. 1978). They induced the origin of the Budějovice basin and of the southern part of the Třeboň basin and the morphology of their floor in the Pištín and Stropnice troughs. The study of the basement has confirmed that the Lišov granulite is connected with the

2.38 Metamorphic structure in the basement of the Bohemian Cretaceous Basin (J. Chaloupský 1976, modified by J. Cháb - M. Suk 1977)
1 — Unmetamorphosed folded rocks; *2* — rocks affected by very low metamorphism; *3* — rocks of greenschist facies, dominantly of quartz-albite-chlorite subfacies; *4* — rocks of greenschist facies, mainly of quartz-albite-epidote-biotite (to almandine) subfacies; *5* — metamorphism of garnet and staurolite zones; *6* — metamorphism of garnet to sillimanite zone; *7* — granulite to granulitic gneiss; *8* — Precambrian; *9* — Early Palaeozoic; *10* — granite to quartz diorite; *11* — diorite, gabbro; *12* — ultrabasites; *13* — quartz porphyry; *14* — regions of albitization, fenitization, occurrences of staurolite and sillimanite

granulite near Holná and Nová Včelnice, the Ševětín granodiorite with the Klenov massif and that the Lhotice Permo-Carboniferous is an isolated occurrence.

The negative gravity anomaly in the basement of the Lower Palaeozoic in the Barrandian was explained by the presence of a granite body (Buday et al. 1969). However, a detail analysis (Tomek



2.39 Distribution of the Brunovistulicum in Moravia, modified according to A. Dudek, 1980

1 — Brunovistulicum; *2* — marginal parts of the Bohemian Massif; *3* — boundary of the Carpathian flysch; *4* — main lineaments; *a* — Moravo-Silesian lineament, *b* — Přibyslav zone, *c* — Odra lineament, *d* — marginal Sudetic fault, *e* — Haná fault zone; *5* — other faults; *6* — Lusatian fault; *7* — Outer Klippen belt

1978) and seismic survey have shown that rather the effect of the thickness of Lower Palaeozoic sediments is here involved; in the axis of the Barrandian basin the thickness attains 6000 m. Seismic data demonstrated a very stable structure of the Upper Proterozoic with a marked rising of wave velocity (i.e. of density and metamorphic grade) from the Barrandian to the Domažlice crystalline complex. The structure is disturbed only in the area of the Jáchymov zone. In the geophysical pattern a striking discordance appears between the Lower Palaeozoic basin with ENE-trending axis and the Upper Proterozoic structure showing NE trend in general.

The eastern margin of the Bohemian Massif in Moravia is covered with Permo-Carboniferous sediments of the eastern margin of the European Hercynides and with deposits of the Alpine-Carpathian foredeep. The thickness of the Palaeozoic attains up to 2000 m and that of the foredeep sediments in the east is as much as 8000 m.

The crystalline basement is formed by the Brunovistulicum (the Brno unit). According to Dudek (1980) the Brunovistulicum is limited in the NE by the Odra lineament, in the SW by buried faults south of the line Wien—Krems, and in the SE by the deep fault against the West Carpathian block. The western margin of the unit extends up to the Šumperk-Jeseník zone and the Boskovice Furrow, and on the basis of geophysical indication its extension to the west can be postulated in the basement of the Moldanubicum. The crystalline complex of the Brunovistulicum is built up of plutonic rocks (Brno pluton s.l.) and crystalline schists of Cadomian age (550—650 Ma). Dudek divides the Brunovistulicum into the North Moravian, Central Moravian and South Moravian blocks, bounded prevalently by NW—SE trending faults (Fig. 2.39). Štelcl-Weiss (1978) and Beránek-Weiss (1979) assume consistently with Roth (1978) that the Brunovistulicum extends to the basement of the Carpathians through a continuous succession of zones of rising intensity of metamorphism.

Palaeozoic sedimentation in this area began in the Silurian (an isolated occurrence near Stínava provides evidence of the migration of sedimentation into this area). The major transgression, however, is of Devonian and Early Carboniferous age.

The Devonian in the basement of the Carboniferous of the Nízký Jeseník Hills and the Drahanská vrchovina Upland displays a highly varied development. In the western part of the Nízký Jeseník and in the centre of the Drahanská vrchovina Upland (around Konice) it is predominantly pelitic, and accompanied by initial volcanism, but limestone sedimentation concentrated to volcanic elevations is here also developed. The uppermost member of this sequence reaches to the Lower Carboniferous and is characterized by an abundance of radiolarites. In contrast, the marginal parts of the basin flooded by the sea only during the Middle Devonian are distinguished by up to 1200 m thick carbonate sediments (Dvořák 1980). The lower part (up to 1000 m thick) consists of a reef complex s.l. The terrestrial facies of violet colour ("Old Red"), which SSE of Brno attains a thickness of 1500 m, is its time equivalent (Skoček 1980). The reef limestones were deposited during a slow transgression, which proceeded to all directions, chiefly south- and eastwards, where it covered a large area with sediments of a great thickness.

The sea began to retreat from the region already in the late Frasnian but mainly during the Famennian and Tournaisian, and sequences of impure nodular limestone and dark bioclastic limestone were laid down. In other places, particularly in the south (in the Brno area), the transgression still persisted at that time and pure reef limestones sedimented in the sea (Zukalová 1976).

In the latest Devonian flysch sedimentation started in the "Zwischengebirge" (median mass) and gradually pushed out other formations from the basin towards the east and south. This process came to an end during the late

Viséan. At that time early marine molasse was deposited in the environs of Brno. It is a more than 3000 m thick complex of coarse-grained conglomerates, which grade laterally into greywackes and laminated shales similar to varvites.

The development of the basement of the Mesozoic and Tertiary SE of Brno (D v o ř á k 1973b, 1978, A d á m e k et al. 1980) was more complicated. The thicknesses and facies of sediments were strongly influenced by differing subsidence of the blocks along ancient faults of NW—SE strike. The basin closed brachysynclinally in the south.

The thick complex of terrestrial clastic sediments of the "Old Red" facies was flooded by the sea during the Givetian, and at the south-eastern margin at about the Givetian—Frasnian boundary. The lower, dark-coloured and partly dolomitic part of the reef complex reaches high into the Frasnian, and the light-coloured part of the reef limestones up to the Famennian. The reef-forming organisms disappear during the Famennian (A d á m e k et al. 1980). In the Tournaisian and early and middle Viséan the sedimentation was for the most part interrupted. When the sea re-invaded the area, dark-grey bioclastic limestones with foraminifers, corals and brachiopods of the group Gigantoproductus sedimented. During the latest Viséan a complex of conglomerates accumulated in the synsedimentarily sinking Nesvačilka block in the west. The conglomerates above 1000 m in thickness pass eastwards into greywackes and shales. South of the Nesvačilka block the thickness of the upper Viséan does not exceed a few tens of metres. In the eastern part of the Nesvačilka trough (and in the more southerly blocks) a more than 1000 m thick Namurian A complex of terrestrial coal-bearing molasse was deposited. The molasse complex closes here the Palaeozoic sedimentation.

Stratigraphic development of the units

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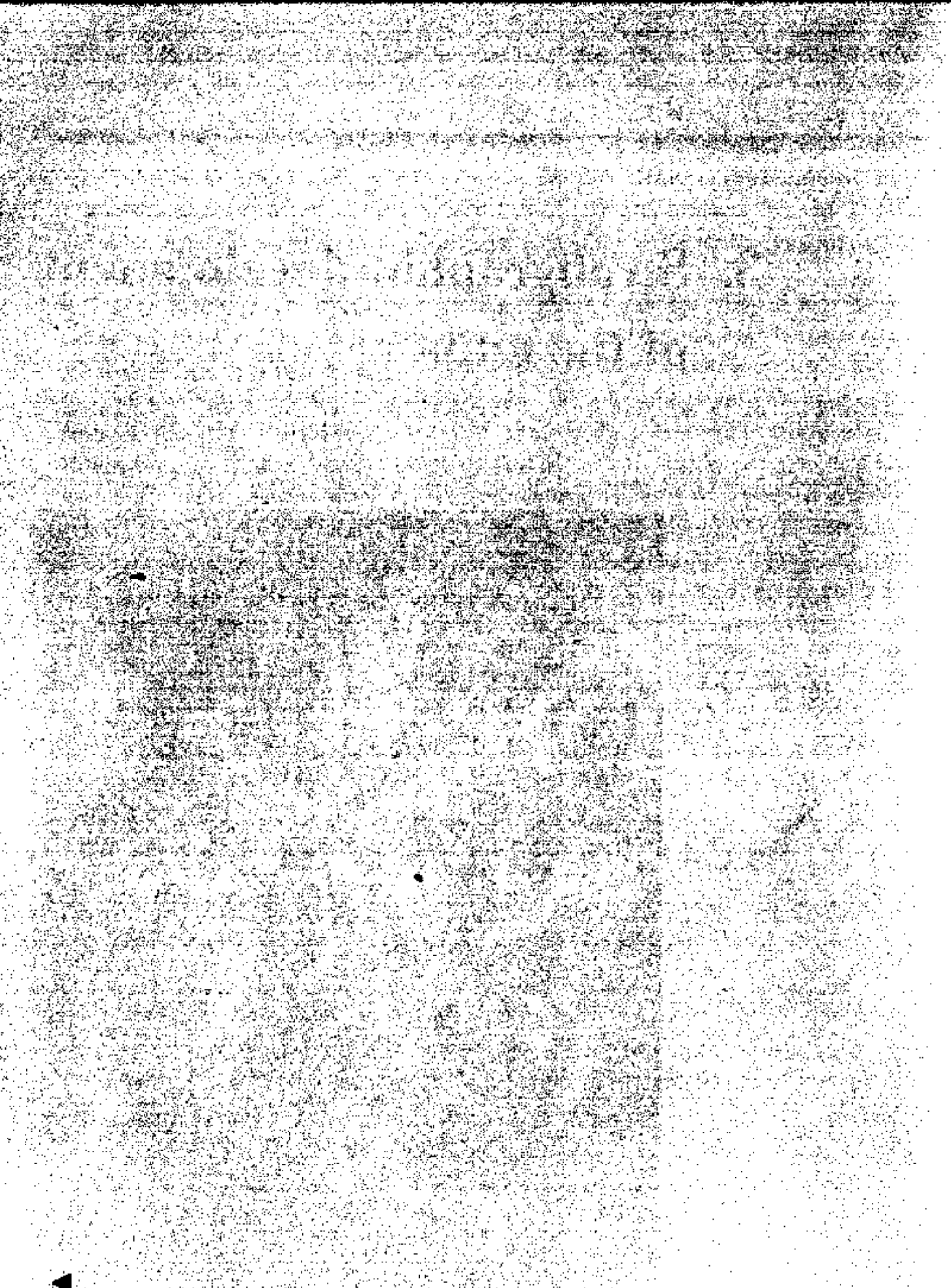
3. Stratigraphic development of the units



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3.1 *Ellipsocephalus* Hoffi (Schlotheim). Middle Cambrian, Jince Formation. Koníček near Jince
Photo by B. Landisch

3.1 Units of the Bohemian Massif

3.1.1 Precambrian

Pre-Cadomian units

The age and stratigraphic classification of the Precambrian, universally metamorphic units are among basic problems of the geology of the Bohemian Massif. The problem does not concern only the stratigraphic division of the units, as also their correlation in the individual units is controversial.

In the Czechoslovak part of the Bohemian Massif no units older than Upper Proterozoic of the Barrandian have been proved satisfactorily. These sediments contain fairly abundant minerals, and to a small extent, also fragments of deep magmatites and metamorphites (Fiala 1948, 1980, Bernardová 1966, Cháb - Pelc 1973, Cháb - Bernardová 1968, Kodymová 1977, Jakeš et al. 1979) providing evidence of the existence of earlier complex units in the source area of the Proterozoic sediments. The alleged units have not yet been localized; most authors favour the opinion of Watznauer (1968) that the crystalline material had been supplied by the Scandinavian Shield. The results of radiometric studies of sedimentogenic zircons from the rocks of Central Europe also indicate the existence of the material of this derivation.

Several units of the Bohemian Massif are thought to have been folded in pre-Cadomian times, as e.g. parts of the Barrandian Proterozoic (Pertold 1964) and the Proterozoic of the Železné hory Hills (Urban 1972), Moldanubicum (Beneš 1964) and the Orlické hory crystalline complex (Faist 1976). However, unconformities that would substantiate the existence of pre-Cadomian folding are inconclusive and many objections have been raised to this interpretation. The oldest demonstrable unconformity (Fiala - Svoboda 1956) is in the Železné hory Hills separating the "Post-ore" division from the Eocambrian (see Table 3.1). The most likely area of the occurrence of pre-Cadomian elements is thought to be the Brunovistulicum, whose Proterozoic age is evidenced by the transgression of the Devonian and numerous radiometric age data. They correspond to Late Proterozoic (550—620 Ma, Scharbert - Batík 1980) and sporadically in the Dyje massif, even higher age (Dudek - Melková 1975), which is comparable with the Middle Proterozoic of the Fennosarmatian Shield also on the basis of lithofacies.

Approximate stratigraphic correlation of Precambrian and Lower Palaeozoic in metamorphic units of the central part of the Bohemian Massif

Table 3.1

			Moldanubicum				Barrandian	Železné hory			Krušné hory		Krkonoše
				Chaloupský 1978, Zoubek 1976	Vejnar 1966, Losert 1967, Suk 1974	Stejskal 1925, Thiele 1976, Matura 1976, Zoubek 1946	Röhlich 1965, Cháb 1978	Svoboda-Fiala 1956, Svoboda et al. 1966	Vachtl 1962	Urban 1972	Skvor 1975	Lorenz 1979	Chaloupský 1981
PALAEOZOIC	345 Ma	Devonian					Ordovician-Devonian group of the Barrandian	Skoupý Conglomerate					Jítrava Group
		Silurian				Varied Group ?		Podol Limestone Míčov Beds	Mrákotín Beds		Gräfenthal Group (phyllite of Rehefeld, Vápenice)	Gräfenthal Group	
		Ordovician						Lipoltice Beds	Hlinsko-Rychmburk Group	Black quartzite and shales	Phycodes Group	Schwarzburg Group	Poniklá Group
		Cambrian			?		Cambrian molasse sediments	Senice Beds		metagreywacke, phyllite, quartzite	Boží Dar (= Frauenbach) Group Jáchymov Group Klínovec Group	Thumer Gr. Jáchymov Group Klínovec Group	Radčice Group
PROTEROZOIC	570 Ma	upper	Brioverian Supergroup		Monotonous Group Volcanogenic Group (incl. "Malín Series") Monotonous Group	Monotonous Group	Lečice Beds Dobříš (Stěchovice) Group Davle Group Blovice (Blovice-Teplá) Group Monotonous-volcano-flysch Group	Litošice Conglomerate Eocambrian Post-ore Fm. Ore Fm. Pre-ore Fm. Monotonous Fm.	Vítanov Group	Litošice Conglomerate, group of banded schists and volcanites group of graphitic schists, spilite hornfels group	Přísečnice Group (volcanogen.) Upper Grey Gneiss	Niederschlager Group Přísečnice Group Group of the eastern Krušné hory	Machnín Group
	900 Ma	middle	Moldanubian Supergroup	Flysch (Kaplice) Group Varied (Český Krumlov) Group							Lower Grey Gneiss		Velká Úpa Group
	1600 Ma	lower		Monotonous (Želiv) Group						Podhořany Group			

Table 3.1 (*continued*)

			Orlické hory		Jeseníky	Moravicum
			Opletal - Domečka 1976	Fajst 1976	Examples of assignment	Misař et al., Jeneček - Dudek 1976
PALAEOZOIC	345 Ma	Devonian			Andělská hora Formation, Vrbno Group (p.p.) (lower part of Branná series) ?	Závist-Květnice Group
		Silurian				
		Ordovician				
		Cambrian				
PROTEROZOIC	570 Ma	upper	Upper Nové Město Group Lower Nové Město Group Upper Stronie Group Lower Stronie Group	Zábřeh Group s.l.	Vrbno Group (p.p.) Staré Město Group Keprník and Desná Gneiss	Bílý potok Group. Vranov-Olešnice Group Vratěnín Group Podhradí Group Monotonous (Nedvědice) Group
	900 Ma	middle		Stronie Group Śnieżnik Group		
	1600 Ma	lower				

Cadomian units

Moldanubicum

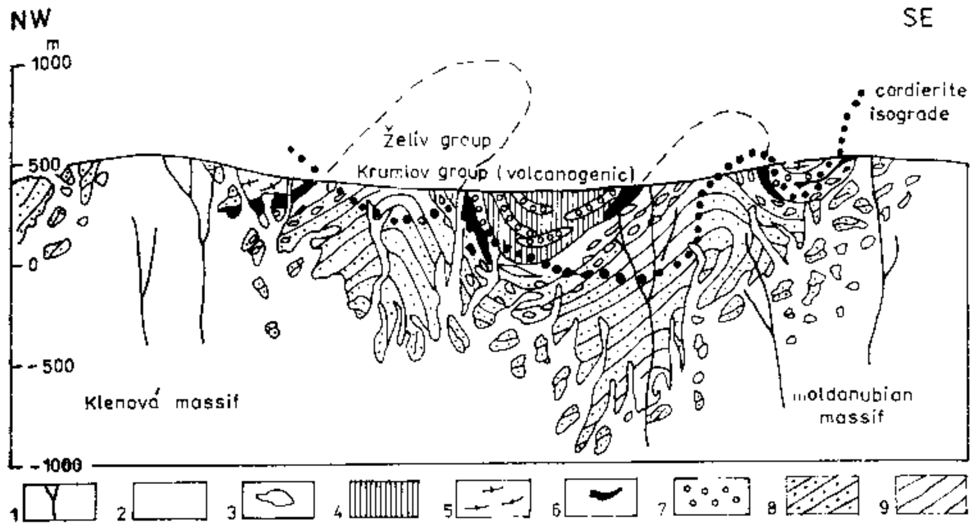
In recent years, the evidence given for the presence of Lower Palaeozoic rocks in the Moldanubicum is steadily increasing (Thiele 1971, Andrusov - Černá 1978, Paeltová 1980, Konzalová 1980), which is also supported by interpretation of most geochronometric data (e.g. Losert et al. 1977, Gorochov et al. 1977). On the other hand, the opinions on the Early Proterozoic to Archean age of this unit are also strongly defended (Zoubek 1974, 1976, Chaloupský 1977, 1978). They are based chiefly on palaeogeographic considerations (e.g. assumed arcuate arrangement of the Proterozoic about the Moldanubian nucleus) or tectonic conditions. Some authors (Vejnar 1968, 1971, Suk 1974, Losert 1967) derive their theory on the Cadomian age of the predominant part of the Moldanubicum from the analogies of lithology and the transitions of the Moldanubian rocks into Upper Proterozoic sequences which, however, are not proved conclusively. Correspondingly, the assignment of the units of Moldanubian type in the West European Hercynides, e.g. in the Schwarzwald, Vosges, Massif Central français and the Armorican Massif, also varies.

There are two principal stratigraphic units in the Moldanubicum (Table 3.2). The Monotonous Želiv Group is regarded as older and the Varied Český Krumlov Group generally lies in the upper part of the sequence, but it is questionable whether it consists of one or more horizons (marked lithofacies differences are e.g. between the Sušice—Votice and Krumlov belts). Another disputable question is the stratigraphic position of the rocks differing in metamorphic grade. Although a transition of the layers of the Varied Group into the Kaplice and Chýnov Mica-schists and cordierite migmatites can be demonstrated (Zikmund 1971, Pletánek - Suk 1976), the mica-schists are considered to be a younger (flyschoid) unit. Thiele (1976) and Blümel - Schreyer (1976) date them even as Early Palaeozoic and the cordierite gneiss to be older (Arapov et al. 1965). The alternation of schistose and greywackeous layers, on which the lithological interpretation of the Kaplice Mica-schists as a younger "flyschoid" unit is based, has also been found in some parts of the zones of sillimanite-biotite gneiss and cordierite migmatite (Pletánek - Suk 1976). The circumstances are still more complicated by the possibility that some parts of the Moldanubicum are tectonically reworked in such a degree that the differences between the Varied and Monotonous Groups have been effaced (Vrána 1977). Usually, however, the fundamental structure can be well recognized according to the course of interlayers: Kodym (*in* Svoboda et al. 1966) even believes the continuous course of the Varied Group to be evidence of its stratigraphic homogeneity.

Table 3.2
Lithostratigraphic division of the Moldanubicum (V. Zoubek 1980, simplified)

Group	Complex / Formation	Rocks	Lithology	Thickness	Metamorphism
Upper Moldanubian Group ("Varied Group") "Český Krumlov Group" M_2	flysch complex M_2^3 Kaplice Formation	metapelites and metagreywackes	mica-schists with predominantly abundant quartzite layers	2000 m (?) (overlying rocks not preserved)	lower amphibolite f. (Ky-staur. sbf.)
	organogenic complex M_2^2 Krumlov Formation		gneisses crystalline limestones, calc-silicate rocks, graphitic beds metabasites and scarce ultrabasites	100—1000 m	predominantly higher amphibolite f. (sillim.-K-feldspar) to hornblende-granulite facies subordinately lower amphibolite f. (Ky-staur. sbf.)
	leptynitic complex M_2^1 Kleť Formation	rhyolites to ultrabasites	ultrabasites pyroxene granulites amphibolites light-coloured leptynites	50—2000 m	
Lower Moldanubian Group ("Monotonous Group") "Želiv Group" M_1	undivided	metapelites, metagreywackes	gneisses with more frequent metabasite and quartzite layers; gneisses with rare intercalations of other rocks	3000 m (basement unknown)	

The position of granulites and leptynites is likewise controversial. They are regarded either as a separate stratigraphic horizon at the boundary between the Varied and Monotonous Groups (Jenček - Vajner 1968, Losert 1967)



3.2 Relationship between the Moldanubian lithostratigraphic units and metamorphic isograds in the mantle of the pluton near Jindřichův Hradec (J. Zoubek - M. Suk 1974)
1 — Dyke rocks; *2* — Moldanubian pluton; *3* — sedimentogenic interbeds in paragneiss of the Varied Group; *4* — granulite and granulitic gneiss; *5* — leucocratic gneiss; *6* — amphibolite and serpentinite; *7* — porphyroblastic biotite paragneiss; *8* — biotite- and sillimanite-biotite paragneiss of the Monotonous Group; *9* — migmatized cordierite-biotite paragneiss

or as a component of the Varied (volcanogenic) Group (Zoubek 1951, Veselá 1967, Pletánek - Suk 1976). In other conceptions, these horizons are indications either of volcanic zones (Mísař et al. 1974), of palaeosutures (Behr 1978) or ancient lineaments (Zeman J. 1979).

The granulites and utrabasites associated with them are often thought to be allogenic elements derived directly from the deeper zones of the primordial crust, or in-folded parts of older units (Zwart 1969, Thiele 1971).

Zoubek (1974, 1980) and Chaloupský (1977, 1978) apply the term Moldanubicum to denote all Precambrian units of higher-grade metamorphism and with granulites as typical rocks; they date them as Middle Proterozoic. It is rather a compromising concept trying to put into harmony the interpretation of the Moldanubicum as a unit predating the Barrandian Proterozoic with the fact that some lithologically well-defined belts are traceable from the Moldanubicum into the adjacent units.

Similarly as in the Barrandian Proterozoic, the Moldanubian metaconglomerates contain pebbles of rhyolite and rare basic magmatites indicating the supply from the differentiated sialic crust (N ě m e c 1979, V r á n a 1982).

M o r a v i c u m

In the Moravicum, the Proterozoic age is ascribed to the varied units — t h e V r a n o v - O l e š n i c e G r o u p (Outer phyllites), t h e B í l ý p o t o k G r o u p (Inner phyllites) and t h e V r a t ě n í n G r o u p — and t h e m o n o t o n o u s P o d h r a d s k á G r o u p and N e d v ě d i c e G r o u p (previously called the Mica-schists zone and placed in the Moldanubicum). The Nedvědice Group is at many places connected by transitions with the Vranov-Olešnice Group and is related with it more closely than with the Moldanubicum. The varied units are allegedly of the same age but their stratigraphic assignment is not uniform; they are regarded as Proterozoic mainly by the Czech authors who correlate them with the Proterozoic of the Kutná Hora Crystalline. This opinion has been supported by a high radiometric age (800 Ma) of the Bíteš Gneiss, which penetrates them (S c h a r b e r t 1977). The re-location of the newly defined Vratěnín and Podhradí Groups from the Moldanubicum into the Moravicum (J e n č e k - D u d e k 1971) was substantiated by the higher content and smaller thickness of interlayers, by the metamorphic grade and the character of orthogneisses more similar to those of the Moravicum. The Austrian authors, however, regard them still as retrograde metamorphosed Moldanubicum. Of the same age is probably also the upper part of the stratigraphic succession in the Silesicum, where a sequence of mica-schists to gneisses with graphite, limestone, amphibolite and quartzite develops gradually from the underlying monotonous micaschist-phyllites to gneisses. The varied interlayers had been cumulated in the Velké Vrbno Dome, where K v ě t o ň (1951) distinguished the lower clastic complex the graphitic complex and the upper clastic complex; consistently with the views then accepted, he placed the last one in the Ordovician to Silurian.

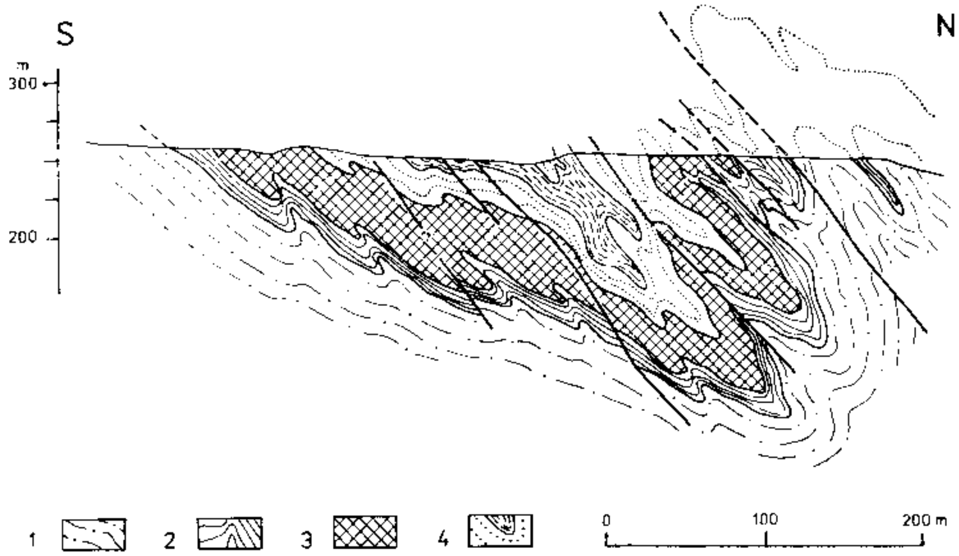
U p p e r P r o t e r o z o i c o f t h e B a r r a n d i a n

The Barrandian Precambrian is placed unanimously in the Upper Proterozoic on the basis of rather scarce biostratigraphic records (e.g. K o n z a l o v á 1978) and radiometric data (analogy with the Brioverian of the West European Hercynides). Microfossils in its latest part indicate a relationship to the Cambrian. A break in sedimentation, which is known to have occurred in the Železné hory area, has not been assessed in the Barrandian basin.

The Proterozoic sediments are of the eugeosynclinal type, attaining a thickness of about 8000 m. Recent investigations of R ö h l i c h - Š ť o v í č k o v á (1968) and J a k e š et al. (1979) indicate that the Proterozoic sediments for the most part set on the oceanic crust.

According to H o l u b e c (1966) sedimentation was of a cyclic character and the sequence involves the following principal rock types:

1. clastic, broadly homogeneous rocks (greywackes, shales, siltstones),
2. rocks showing rhythmic sedimentation. The rhythms of mm-order compose cycles of ca. 100 m thickness. The amount of siltstones varies between 10 and 50 per cent,
3. rocks with pseudogalls, intraformational breccia and conglomerate. They were produced by turbid sedimentation and redeposition, subaqueous slumping and the like, and are often in association with the products of basic volcanism. Conglomerates, occurring chiefly in the southern limb of the Barrandian are intraformational and contain pebbles of allogenic material,
4. productss of submarine basic volcanism, and the genetically indirectly associated lydites, silicified rocks, graphitoid shales±pyritic and calcified rocks to impure limestones. Graphitoid shales were formed by quiescent sapropelitic sedimentation, often before the onset of younger cycles.



3.3 Schematic section through the Upper Proterozoic in the Železné hory Hills, according to J. Svoboda, 1965
Pre-ore division: *1* — argillaceous shales and greywackes; *2* — graphitic shales and pyrite-bearing quartzites. Ore division: *3* — a layer of Mn and Fe ores with Mn carbonates. Post-ore division: *4* — graphitic shales with a layer of quartzitic shales

Table 3.3

Survey of stratigraphic schemes for the Upper Proterozoic of the Barrandian (M. Suk, original)

Kettner - Kodym 1919	Svoboda - Fiala 1955	Máška - Zoubek 1961	Röhlich 1961, 1965	Holubec 1966 (approx. paralellization)	Zoubek V. 1976	Chaloupský 1978	Cháb 1978	Mašek - Zoubek J. 1980
Post-spilitic stage		Post-spilitic complex	Štěchovice series	Upper Nižbor series	upper Brioverian series B_2	[Brioverian: upper] rhythmites with shales +greywackes upper banded phyllites	Dobříš Group (Series)	Štěchovice Group
				Lower Nižbor series				
		Lečice Beds					Lečice Member	
Complex with silicites b 2	Post-ore Formation	[spilite complex] Zbiroh Fm. (with silicites)	Davle series	Zvíkovec series	[lower Brioverian series] Post-ore Formation B_1^c	[Brioverian: middle] phyllites with graph. shales+calc-silicate rocks	Davle Group ("Series")	Kralupy-Zbraslav Group
Spilitic stage b		[spilite complex] Kamenec Fm. (with graph. quartzite and carbonates)						
	Ore Formation							
Complex with spilites b 1	Pre-ore Formation	[spilite complex] Hromnice Fm. (pyrite-bearing clay slates)			[lower Brioverian series] Ore Formation B_1^b	[Brioverian: lower] spilites		
Pre-spilitic stage	Monotonous Formation	Pre-spilitic complex	Blovice series	Upper Rabštejn series	[lower Brioverian series] Pre-ore Formation B_1^a	[Brioverian: lower] slates and greywackes	Blovice-Teplá Group ("Series")	
				Lower Rabštejn series				
Kralovice area	Železné hory	Plzeň area Kralovice area	Vltava-river valley	Plzeň area Kralovice			Vltava-river valley, Kralovice area	Vltava-river valley, Kralovice, Blovice areas

Within the whole area, H o l u b e c (l.c.) established seven megacycles, which differ in both the average composition and the thickness of the individual layers. Volcanic effusions recurred and their material is present in most of the cycles (see Table 3.3). H o l u b e c (1966) also discriminated two sedimentary developments: the West Bohemian, corresponding to a shallower sedimentary area with sediments less differentiated in facies development and containing a higher proportion of greywackes, and the Central Bohemian, with more varied sediments deposited in agitated environment. The boundary between the two developments runs approximately along a deep fault.

C h á b - P e l c (1973), C h á b (1978) and M a š e k - Z o u b e k (1980) and other authors deny the possibility of delimiting the extent of the megacycles in space and propose a simple stratigraphic division of the Barrandian Upper Proterozoic (Table 3.3). In any case, however, the younger unit with rhythmites of the flysch type (Štěchovice Group) corresponding to the previous "Postspilitic Group" (possibly to Eocambrian of S v o b o d a et al. 1966) is unanimously separated from the stratal sequence formed by cyclic sedimentation.

In the "Islets Zone" only fragments of metamorphosed Proterozoic have been preserved; they correspond stratigraphically to the rocks of the southern limb of the Barrandian. Some occurrences with lenses of limestone, which may be of Palaeozoic age, have been grouped with them. A metaconglomerate found E of Ondřejov (V r á n a - C h á b 1981) contains pebbles derived from the near metatonalite. In case the assumption of the Proterozoic age of this conglomerate were correct, the basement of the Upper Proterozoic sediments would be verified here.

In the Železné hory Hills the stratal sequence is known in greater detail, in the Železné hory crystalline area, in particular (Table 3.3). An unconformity is there proved beneath the uppermost Proterozoic and Subcambrian. According to S v o b o d a - F i a l a (1957), this division contains glaciomarine and glaciofluvial deposits and is not necessarily equivalent to the youngest part of the Barrandian Proterozoic.

The Vitanov Formation in the southern part of the Hlinsko zone (V a c h t l 1971) is formed of metapelites and quartzites, and in the upper part there are basic and less abundant acid volcanites. It corresponds most likely to the Upper Proterozoic.

The Krušné hory region

The opinions on the age of the units of the Krušné hory region are also not uniform. The oldest part of the stratal sequence, so called "the Lower monotonous complex" (L o r e n z - H o t h 1964) is often correlated with the Spilitic Group of the Barrandian. Š k v o r (1975) pointed out the differences in the lithology of the two units (deficiency of volcanites and the predominantly greywackeous character of the rocks of the Krušné hory area), and considered that the older units might be lacking and the entire Krušné hory crystalline complex might be correlated with the Postspilitic Group of the Barrandian.

The upper metagreywacke complex (Přísečnice Group) is usually regarded as equivalent to the Postspilitic Group on account of the content of conglomerates. However, it resembles rather the Spilitic Group in the overall development, and especially in containing basic volcanites.

These units are often thought to be separated by an unconformity associated with folding and metamorphism, which would correspond to the Železné hory phase. The unconformity, however, has not been substantiated structurally; the differences in metamorphism can be explained as due to a high resistance of greywackes to kneading and thus also to metamorphism. The conglomerates contain only non-metamorphosed pebbles of granitoids, greywacke, quartzite, porphyrites and basalt.

The overlying varied sequence including the Jáchymov, Klínovec and Arzberg Groups is usually placed in the Cambrian but some authors dated it as Proterozoic (S t e t t n e r 1974). The presence of an unconformity at the base of this unit is questionable.

The eastern part of the Bohemian Massif

The Proterozoic rocks in the eastern part of the Bohemian Massif are a continuation of the Barrandian Proterozoic on the one side and of the Proterozoic units of the Moravicum on the other side. Exceptional are the migmatized gneisses and orthogneissic rocks of the Desná and Keprník Domes which, according to some authors may correspond even to earlier structural stages. In the Upper Proterozoic of their mantle M í s a ř (1963) distinguished a schistose facies, which he regarded as earlier. This occupies an extensive area, cropping out at the surface mainly in high-grade metamorphosed units of the Lugicum (Velká Úpa Group in the Krkonoše Mts.) (Table 3.1), Stronie Group in the Orlické hory-Kłodzko Dome, and a greater part of the Svratka anticline). Crystalline limestones in various stratigraphic positions, interlayers of other rocks and varying proportion of metavolcanites occur sporadically. Granulites that are also present probably correspond stratigraphically to those of the Moldanubicum.

The greywacke facies, which is thought to be younger, develops gradually from the schistose facies, and builds up the Zábřeh unit and its equivalents (Polička and Letovice crystalline complexes). It contains basic volcanic rocks.

The varied neritic facies with limestones, graphite and amphibolites is of a substantially lesser extent, being developed chiefly in the south-eastern part of the Lugicum, in the Moravicum and Silesicum. It originated only under appropriate sedimentary conditions and is coeval rather with the greywacke facies (Mísař 1963).

Similarly as in the Moravicum, the mantle of the Proterozoic is formed of palaeontologically evidenced Lower Palaeozoic — the Devonian. Its extent, however, cannot be determined precisely because of metamorphic alterations.

The Krkonoše-Orlické hory region

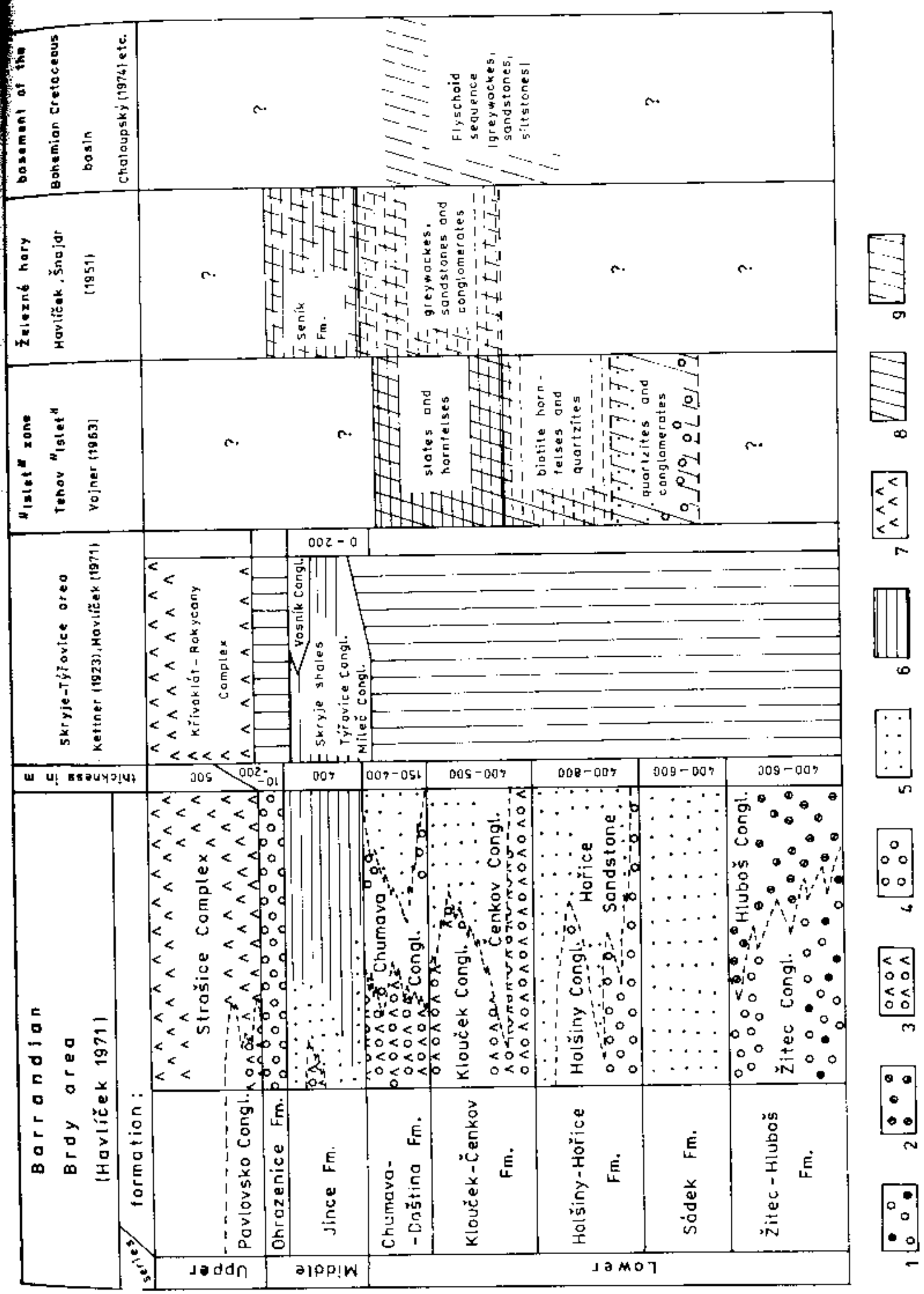
The stratigraphic classification of the Krkonoše-Orlické hory crystalline complex is far from being uniform. The Proterozoic units are particularly difficult to distinguish from those of Early Palaeozoic age. Chaloupský (1979, 1981) proposed the following stratigraphic units to be established in the crystalline complex of this region:

— the Velká Úpa Group — a monotonous sequence of mica-schists and phyllites, enclosing a more varied complex of mica-schists with interlayers of calc-silicate rocks, amphibolite, quartzite and graphitic schists. It is dated as Middle Proterozoic (equivalent to the Varied Group of the Moldanubian complex), and developed typically in the Krkonoše Mts., e.g. in the valley of the river Úpa, between Obří důl and Velká Úpa;

— the Machnín Group is a monotonous sequence of metagreywackes and phyllites with layers of metadiabase. It corresponds to the Upper Proterozoic of the Barrandian and is developed typically in the northern part of the Ještěd area;

— the Radčice Group in the Železný Brod area (J. Chaloupský also assigns to it the Železný Brod volcanic complex) is a varied sequence of phyllites with interlayers of metalydite, green-schists and metadiabase layers. It has been correlated with rock complexes within the range of Upper Proterozoic—Lower Ordovician; in lithofacies it shows relations to the Upper Proterozoic of the Barrandian and the Železné hory Hills. A typical development of this unit is near Železný Brod.

In addition, J. Chaloupský defined in the Krkonoše-Jizerské hory crystalline complex also Lower Palaeozoic Poniklá Group (inferred Ordovician and palaeontologically evidenced Silurian) and the Jítrava Group (Late Devonian age evidenved Koliha 1929, Chlupáč 1979).



3.4 Stratigraphic scheme of the Cambrian in the Bohemian Massif (I. Chlupáč, orig.)
1 — polymictic greyish-green conglomerates; *2* — polymictic reddish conglomerates; *3* — greyish-green and red conglomerates with tuffaceous admixture; *4* — whitish-grey quartzose conglomerates; *5* — greywackes and sandstones; *6* — clayey and silty shales; *7* — porphyries; *8* — metamorphosed rocks; *9* — rocks affected by subsurface alterations

In the Orlické hory Mts. there are the Stronie and Nové Město Groups, which Opletal places in the Middle or Upper Proterozoic (Table 3.1) and Fajst (1976) in the Middle Proterozoic: the latter author assumes the Late Proterozoic age for the Zábřeh Group s.l. (i.e. the Zábřeh, Staré Město and Nové Město Groups — Table 3.1) and its separation from the above units by the "Orlice" unconformity.

3.1.2 Lower Palaeozoic

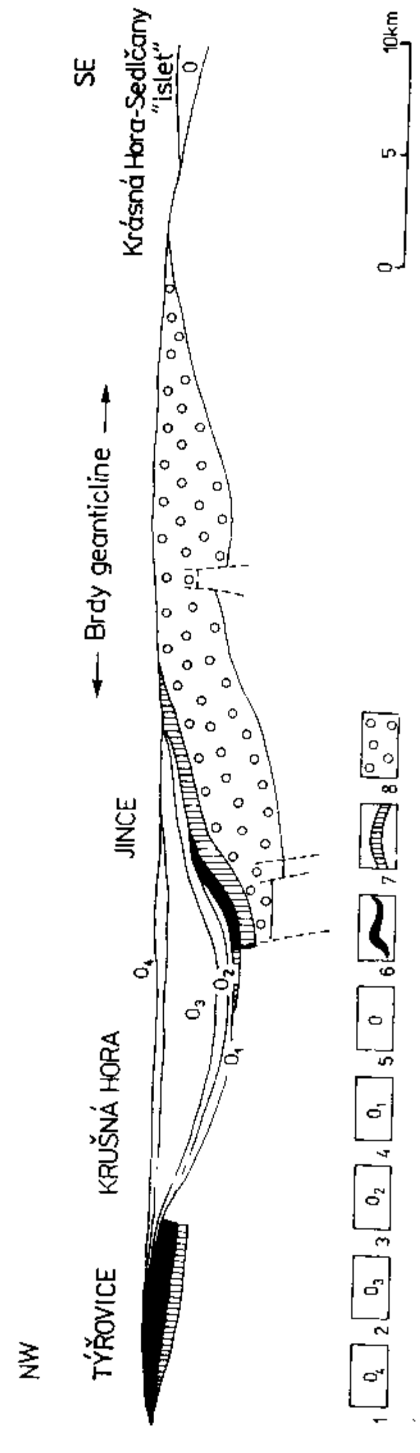
Cambrian

The principal occurrences of the Cambrian are in the Barrandian and palaeontologically evidenced Cambrian is also known from the Železné hory; the remaining occurrences are ranged to the Cambrian with reservation, chiefly on the basis of lithological analogies and correlation with other areas.

In the Barrandian, the principal Cambrian sedimentary area (the Příbram-Jince basin, Havlíček V. 1981) was situated south of and eccentrically to the sedimentary area of the younger systems. The Cambrian deposits crop out at the surface in the extensive Brdy area and the Skryje-Týřovice area of a smaller extent. In both of them the Cambrian lies on the Proterozoic complexes with a clear-cut angular unconformity.

The Brdy Cambrian, whose lower part is classed with the Lower Cambrian is formed of thick accumulations of clastic sediments (combination of conglomerate and sandstone facies, higher up with a portion of volcanic material). As a whole, the sequence consists predominantly of continental sediments (Kukal 1971a). A prominent member is the Žitec Conglomerate, the pebble material of which contains Proterozoic rocks, granitoids and subordinate metamorphites (metaquartzites, mica-schist, rare orthogneiss, etc.). Organic remains have been found in the Lower Cambrian only in the shale interlayers of the Hořice Sandstone, which yielded remains of the merostoms (arthropod *Kodymirus vagans*, which is the oldest faunal fossil found in Czechoslovakia, its biotope being doubtless a limnic or lagoonal environment). The Middle Cambrian represented by the Jince Formation is richly fossiliferous; the marine, predominantly trilobite faunas permit a zonal division and correlation with other areas as well. They provide evidence for the palaeo-zoogeographic assignment of the unit to the Mediterranean subprovince. The gradual decrease in faunal content in the upper part of the Jince Formation documents a proceeding freshening of the basin, which preceded the retreat of the sea (Upper Cambrian is no more evidenced palaeontologically).

In the Skryje-Týřovice area the marine transgression over the Proterozoic basement is dated as early Middle Cambrian; the Skryje Shales



3.5 Relationship between the Cambrian and Ordovician sedimentary areas in the Barrandian. Presumed state towards the end of the Ordovician, after V. Havlíček, 1981
1 — Ashgillian; *2* — Caradocian; *3* — Llanvirnian and Llandoverian; *4* — Tremadocian and Arenigian; *5* — Ordovician, undivided; *6* — Křivoklát-Rokycany and Strašice volcanic complexes; *7* — Jince and Ohrazenice Formations; *8* — Žitec-Hluboš and Chumava-Baština Formations

3.6 *Kodymirus vagans* Chlupáč et Havlíček, merostomate arthropod from the Lower Cambrian of Brdy (Barrandian), the oldest macrofossil of Czechoslovakia. Reconstruction, natural size
Photo archive ÚÚG, Praha

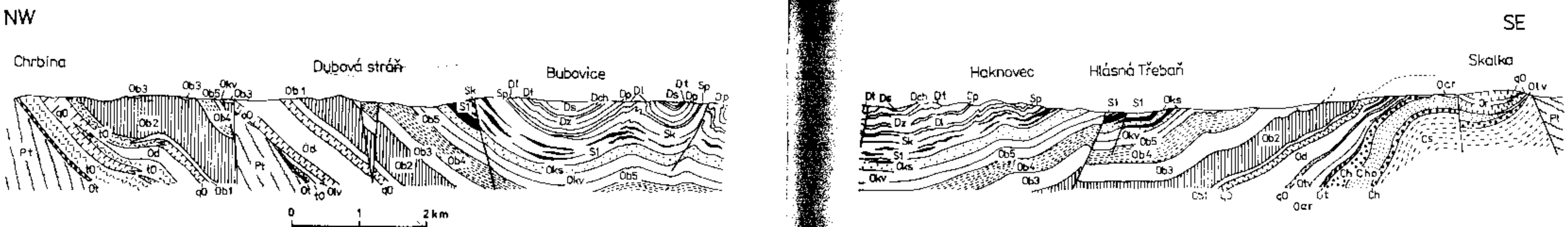
3.7 Trilobite *Paradoxides gracilis* (Boeck) from the Middle Cambrian of Brdy, Jince Formation. Vystrkov near Jince, Barrandian. ×2
Photo by H. Vrifalová

3.8 *Trochocystites bohemicus* Barrande, echinoderm of *Carpoidea* class, from the Middle Cambrian of the Skryje-Týřovice area. Skryje. ×2
Photo by V. Turek

rich in fossils are demonstrably equivalent to the lower part of the Jince Formation (for summarizing reports on the Cambrian see Havlíček V. 1971, Kukal 1971a).

In the period of the Upper Cambrian the Barrandian was the site of intensive volcanic activity, as is attested by thick effusions of andesite, dacite, rhyolite and subordinate basalt, accompanied by pyroclastic deposits (the Křivoklát-Rokycany and Strašice complexes). Radiometric age data on these volcanites (474±5 Ma, Vidal et al. 1975) probably indicate a long time interval of volcanic activity.

In the Železné hory area the clastic sediments are placed in the Lower Cambrian, but only Middle Cambrian is evidenced palaeontologically, showing faunal relations with the Skryje-Týřovice Cambrian (Havlíček V. - Šnajdr 1951). The Cambrian rocks were affected by a low-grade metamorphism.



3.9 Geological section of the north-eastern part of the Barrandian (V. Havlíček 1981) Pt — Proterozoic, Cs — Sádek Member, Ch — Holšín Conglomerate, Cho — Hořice Sandstones, Ot — Třenice and Milín Formations, Oar — Klabava Formation, Olv — Šárka Formation, tO — basalt tuffs, Od — black shales of Klabava Formation, qO — quartzose sandstones of Dobrotivá and Libeň Formations, Obl — black shales of Libeň Formation, Ob2 — Letná Form., Ob3 — Vinice Form., Sl — Liteň Form., Sk — Kopanina Form., Ob4 — Zahořany Form., Ob5 — Bohdalec Form., Okv — Králův Dvůr Form., Oks — Kosov Form., Sp — Přídolí Form., Dl — Lochkov Form., Dt — Třebotov Form., Ds — Srbsko Form. Silurian basalts — in *black*

The presence of the Cambrian is also assumed in the "Islets zone", in the Tehov "islet" (contact hornfels, quartzite, etc., Vajner 1963), the Sedlčany-Krásná Hora "islet" (Havlíček V. - Šnajdr 1955), and in the basement of the Bohemian Cretaceous Basin (boreholes in the areas of Trutnov, Poděbrady and elsewhere). The Cambrian is probably also represented in the metamorphic rocks of the Krušné hory Mts. (the Arzberg Group and the lower part of the Klínovec Group) but its presence is only based on the correlation with the Saxon-Thüringen region, where it is evidenced palaeontologically. In the Bohemian part of the Lusation region the Cambrian may occur in the Krkonoše-Jizerské hory crystalline complex, e.g. some older sequences with carbonates, but there is no evidence available as yet.

Ordovician

The Ordovician is best known in the Barrandian but is also evidenced palaeontologically in the basement of the Bohemian Cretaceous Basin and in the Železné hory Hills. As concerns the metamorphosed units, it is represented in the "Islets zone" and in the Krušné hory and Lusatian regions.

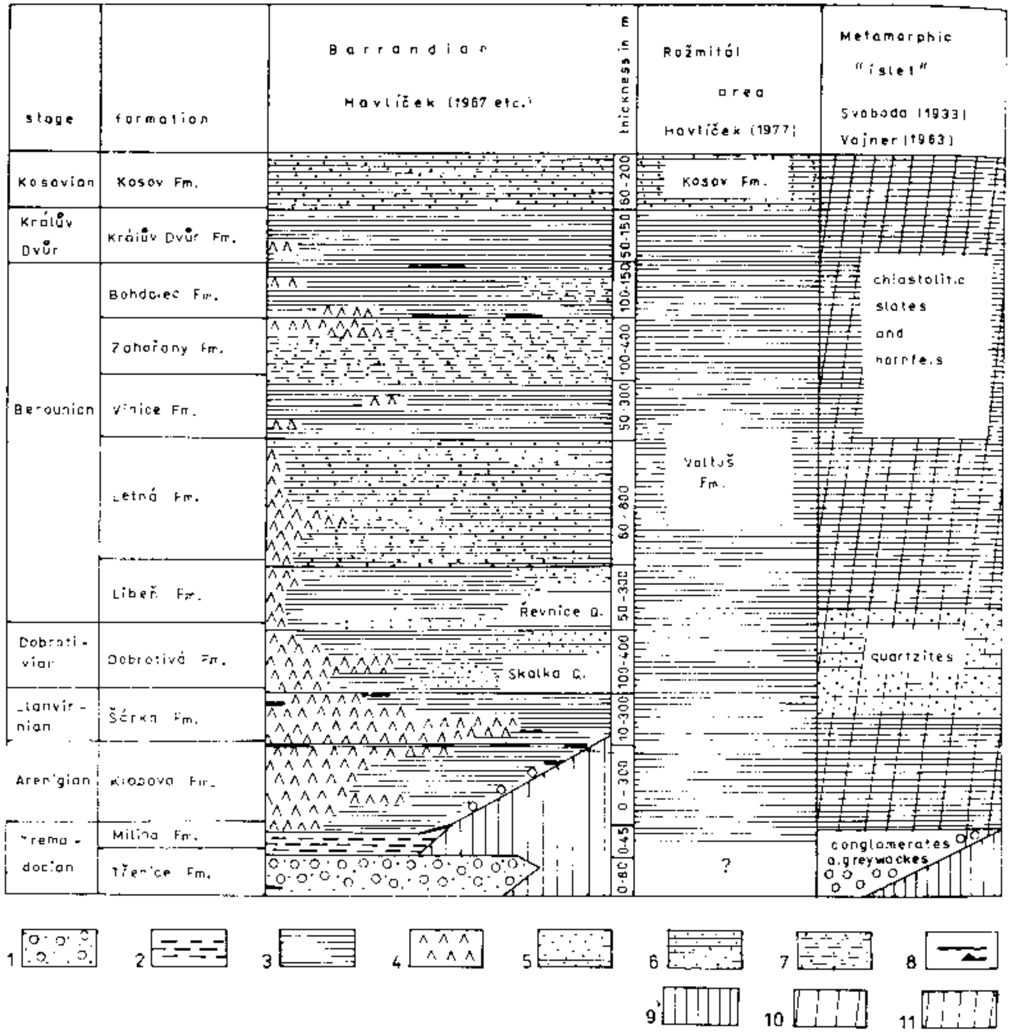
Ordovician in the Barrandian

In the Barrandian the Ordovician sedimentation was concentrated in the tectonically founded basin, elongated in NE—SW direction and showing the maximum subsidence in the axial part (Prague basin in the sense of Havlíček V. 1981). The Lower Ordovician lies transgressively on the Proterozoic or Cambrian; sedimentation began in the Tremadocian and continued until the deposition of the boundary Ordovician—Silurian beds. The facies development is distinguished by combined shallow-water sandy and deeper-water shaly facies. In the Arenig and lower Berounian there are frequent basaltoid volcanics (mainly the Komárov complex), and in the near-shore lagoonal environment favourable conditions for sedimentation of oolitic Fe-ores existed locally. Rich faunas with a predominance of benthic forms (esp. trilobites and brachiopods) belong to the cool-water Ordovician Mediterranean Province, and they make possible a detailed biostratigraphic classification. The stages of the Upper Ordovician as proposed by Havlíček V. - Marek (1973) can be applied to the entire Mediterranean region. For the summary reports on the Barrandian Ordovician see Havlíček V. (1981, 1982), Havlíček - Vaněk (1966, biostratigraphy), Kukal 1963 (lithology) and Fiala 1971b (volcanites).

Other occurrences of the Ordovician

The Ordovician sediments extend from the Barrandian eastwards into the basement of the Bohemian Cretaceous Basin (they have been proved by boring in the vicinity of Poděbrady, Pardubice and west of Hradec Králové — Klein 1978). They crop out at the surface in the northern part of the Železné hory area, where the Tremadocian and Berounian were evidenced palaeontologically (Prantl - Růžička 1941, Havlíček V. - Šnajdr 1951). In these occurrences the Ordovician displays a monotonous shale development with a sole, rather conspicuous quartzite member.

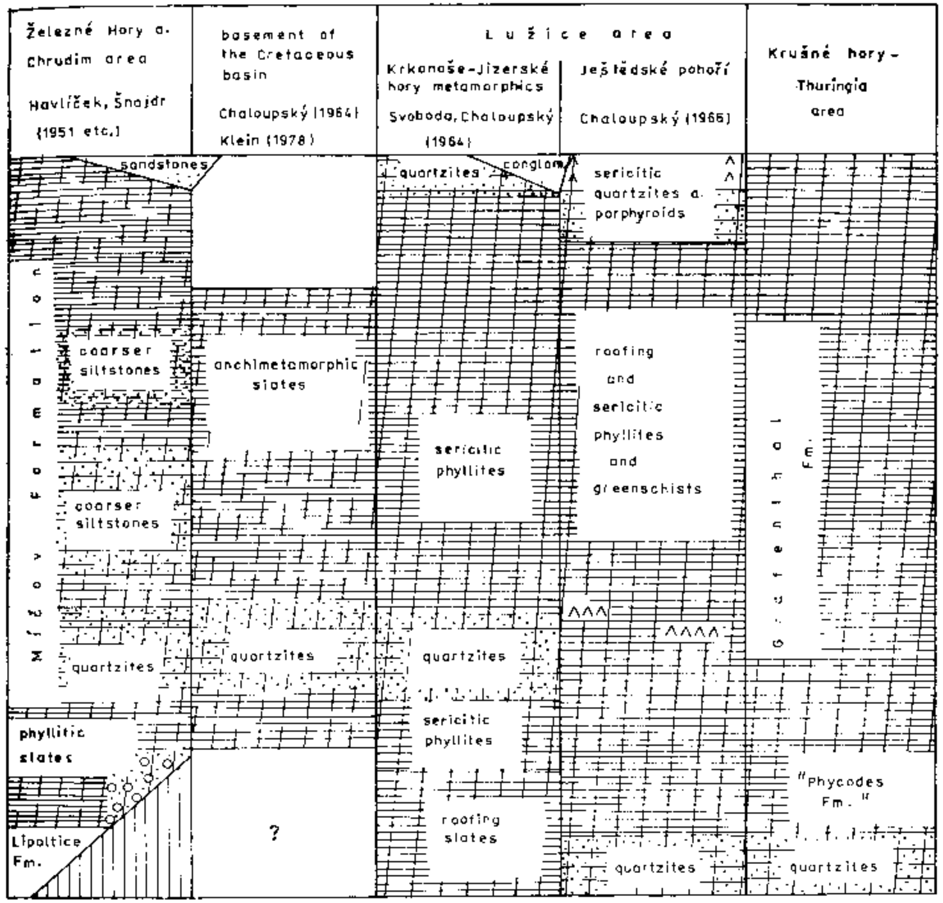
In the "Islets zone" the sequences of prevailingly chiastolite and cordierite slates with one major layer of metaquartzite are ranged to the Ordovician on the basis of superposition (Svoboda 1933, Vajner 1963). The correlation



with the Barrandian is also facilitated by the chiefly shale development of the Ordovician in the Rožmitál area, where Arenigian and Berounian have been established on palaeontological evidence (H a v l í č e k V. 1977).

In the metamorphic complex of the Krušné hory Mts. the rocks of the so-called "P h y l l i t e G r o u p" in the areas of Aš and Kraslice are thought to be of Ordovician age. The complex comprises quartzitic rocks and the overlying phyllites and mica-schists, which may be the metamorphosed equivalents of t h e F r a u e n b a c h, P h y c o d e s a n d G r ä f e n t h a l F o r m a t i o n s of the Saxo-Thüringen region (Š k v o r 1975).

In the Lusatian region the determination of Ordovician deposits is questionable because of an absolute lack of fossils. According to K o d y m O. sen. and



3.10 Stratigraphic scheme of the Ordovician in the Czech Soc. Rep. (I. Chlupáč, orig.) *1* — conglomerates and sandstones; *2* — cherts; *3* — siltstones and claystones; *4* — volcanic rocks; *5* — quartzites; *6* — greywackes and alternation of siltstones and sandstones; *7* — siltstones; *8* — Fe-ores; *9* — stratigraphic breaks; *10* — metamorphosed rocks; *11* — rocks affected by subsurface alterations

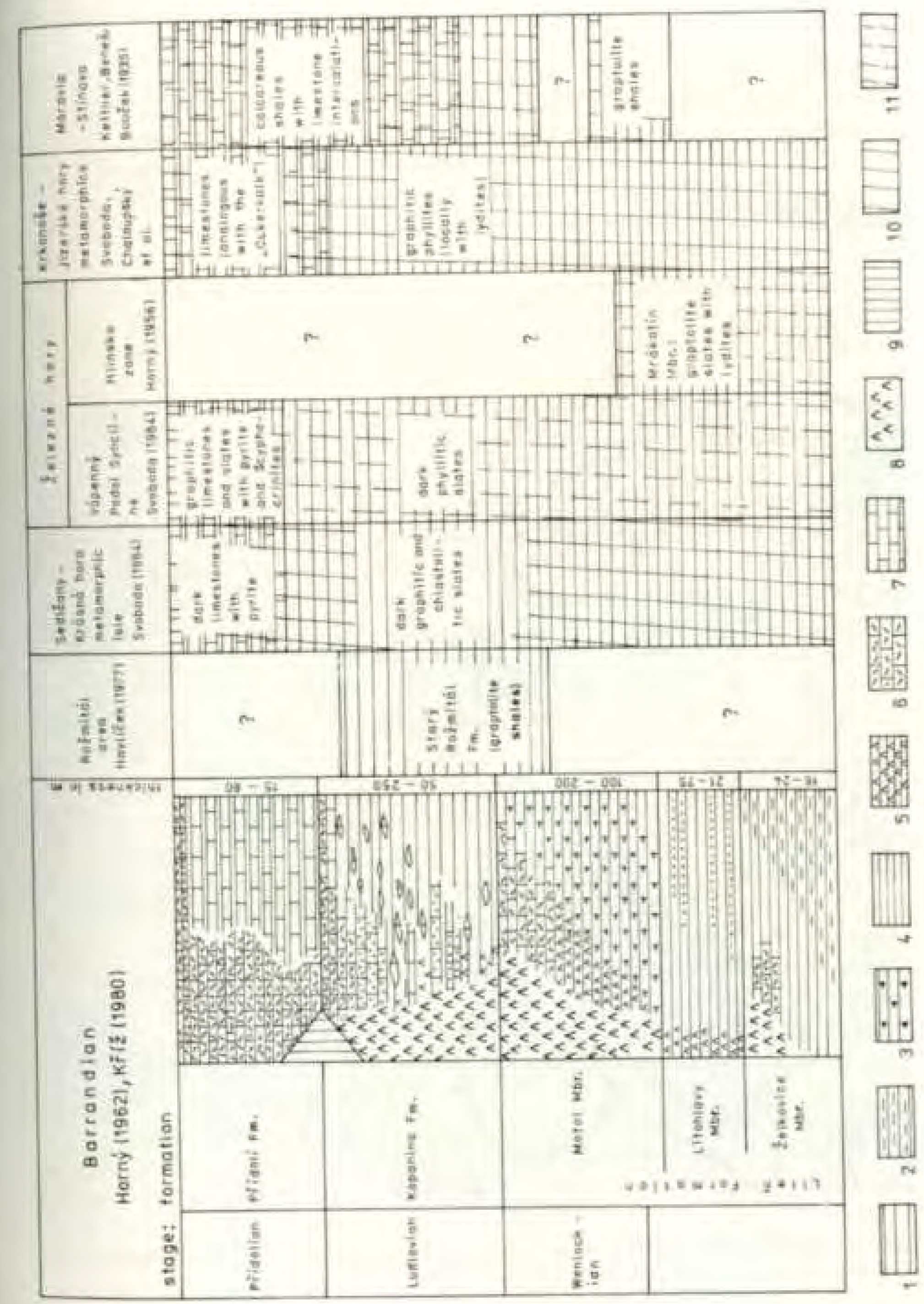
S v o b o d a (1948), in the Krkonoše-Jizerské hory crystalline complex the sequences of sericite phyllites with metaquartzites and possibly also the roofing slates from Železný Brod can be classed as Ordovician. Worthy of attention are metaconglomerates from Rokytnice nad Jizerou, which contain pebbles of granitoids and older metamorphosed rocks (C h a l o u p s k ý 1963). In the Ještěd crystalline complex C h a l o u p s k ý (1966) allocated to the Ordovician the sequence of quartzitic phyllites, in the upper layers mainly sericite phyllites with subordinate interlayers of limestone and metaconglomerate, overlain by quartzites. According to the new stratigraphic classification proposed by C h a -

3.11 Concretions from the Šárka Formation with brachiopod *Eurthisina moesta minor* Havlíček (Ordovician of the Barrandian). Praha - Vokovice, ×1.52 Photo by H. Vršťalová

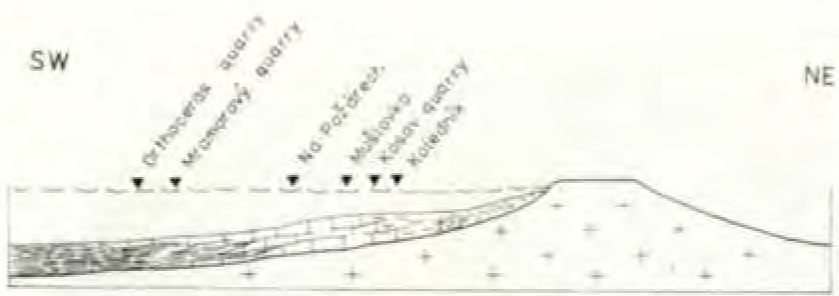
loupský (Tab. 3.1.), the alleged Ordovician sequences are assigned to the upper part of the Radčice and Poniklá Groups.

Silurian

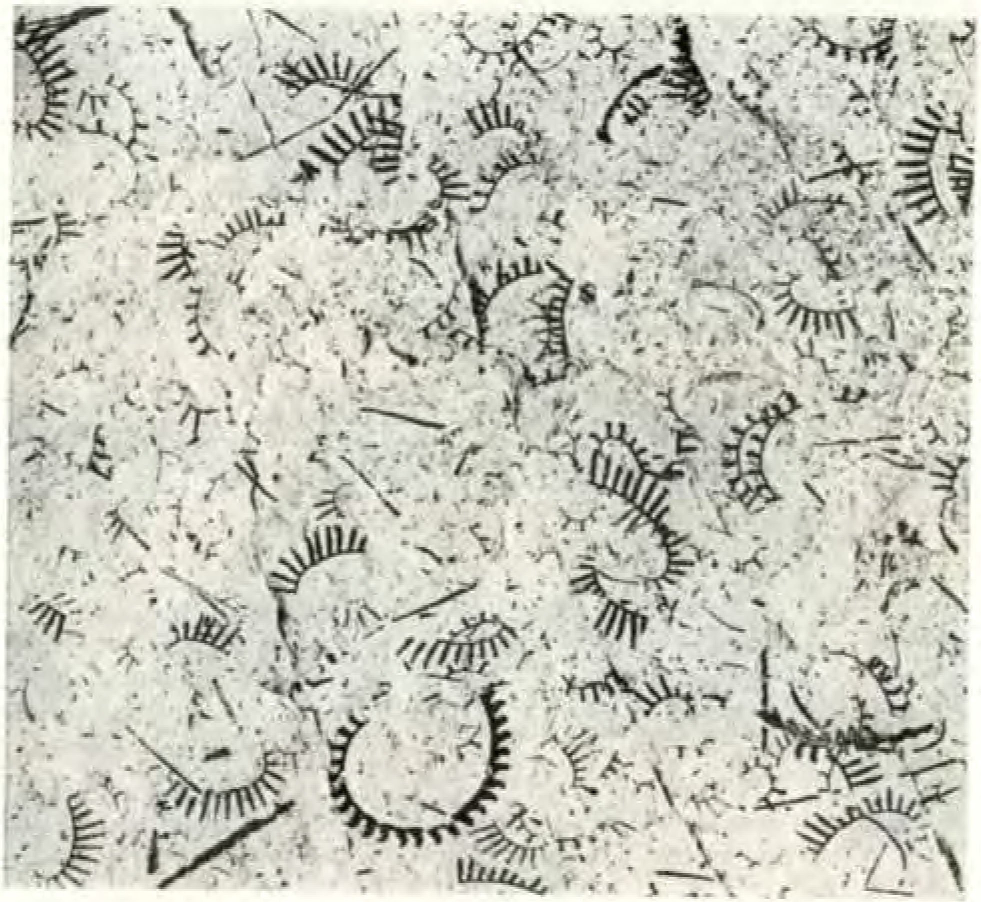
The most carefully studied and richest in palaeontological finds is the Silurian of the Barrandian. Other palaeontologically evidenced occurrences are in the Železné hory area, the "Islet zone", the Hlinsko zone, and in the Moravo-Silesian and Lusatian regions. The presence of the Silurian may be inferred in some other metamorphosed units.



3.12 Stratigraphic scheme of the Silurian in the Czech Soc. Rep.
1 — shales (in general); *2* — shales with microcrystalline silicites; *3* — calcareous shales with limestone concretions; *4* — alternating black shales and greenish claystones; *5* — tuffaceous shales; *6* — bioclastic limestones (biosparites, biomicrites); *7* — micritic limestones and limestones in general; *8* — volcanic rocks; *9* — stratigraphic breaks; *10* — metamorphosed rocks; *11* — rocks affected by subsurface alterations



3.13 Distribution of the Kopanina Formation (upper part) in NE—SW direction (R. Horný 1962). Bioclastic limestones on a volcanic slope pass into brachiopod limestones, cephalopod limestones and graptolite shales towards south-west



3.14 Light-coloured graptolite shale with graptolite of *Rastrites* and *Demirastrites* genera from the Liteň Formation, Bohemian Silurian. Barrandian, Tmaň. ×2
Photo by B. Matoulková

Silurian in the Barrandian

The principal occurrences of the Silurian in the Barrandian are concentrated between Prague and Zdice, in the central Silurian—Devonian synclinorium. Silurian deposits lie conformably on the uppermost Ordovician. The facies of black graptolite shales, which predominates in the Lower Silurian, is in the Upper Silurian gradually replaced by limestone facies. Sedimentation was strongly affected by submarine basic volcanism culminating in the upper Wenlockian and lower Ludlovian. Accumulations of volcanites, mainly in the north-western limb, gave rise to volcanic elevations surrounded by various shallow-water organogenic and bioclastic facies. Carbonate sedimentation continued uninterrupted from the Late Silurian till the Devonian. The Barrandian Silurian is very rich in benthic, planktonic and nektonic forms. On the basis of graptolites 41 zones (more than in the classical British Silurian) have been discriminated, and conodonts, trilobites and other groups permit other detailed divisions. The development of fauna reflecting the gradual increase in temperature during the Silurian period, went on without interferences also in the latest Silurian. It is the uppermost Silurian in itself which makes the Barrandian a classical region on the world scale and the Přídolian Stage is of international validity. For summary information on the Silurian see Horný (1962), Bouček (1953), Fiala (1970 — volcanites), Kříž et al. (1983).

Other occurrences of the Silurian

In the Chrudim Palaeozoic of the Železné hory area the Silurian is known only from the central part of the Vápenný Podol syncline. The phyllitic graptolite slates with fauna of Llandovery and Wenlockian age are overlain by graphitic limestones and shales with *Scyphocrinites*, which undoubtedly represent the Přídolian (Jahn 1898, Goldbachová-Svoboda 1930).

In the Hlinsko zone the Silurian is represented by the Mrákotín Formation: Llandoverian and Wenlockian low-metamorphosed graptolite slates with silicites (Horný 1956). The stratigraphic position of the higher layers (mainly Rychmburk Greywackes) is questionable, although their Palaeozoic age has been demonstrated reliably by micropalaeontological finds (Konzalová-Vachtl 1976).

In the "Islets zone", the graphitic chiastolitic slates and the overlying erlans and dark limestones, developed chiefly in the Sedlčany-Krásná Hora "islet" are placed in the Silurian (Svoboda 1933, 1956, Chlupáč 1981a). Their dating is based on new finds of graptolites (Chlupáč, in press). The opinion on the distribution of the Silurian has been supported by the find of typical graptolite slates of Wenlockian and Ludlovian age in the Rožmitál environs,

3.15 Trilobite *Cromus beaumonti* (Barrande) from the Kopanina Formation of the Bohemian Silurian. Zadní Kopanina, Barrandian. ×3
Photo by V. Turek

3.16 Crown of crinoid *Scyphocrinites elegans* (Zenker) from the Přídolí Formation of the Bohemian Silurian. Barrandian, Karlštejn; natural size
Photo by H. Vršťalová

which lies nearer to the metamorphic "islets" than to the Barrandian Silurian proper (Havlíček 1977) and by the graptolite-bearing slates at Bělčice in the Mirovice islet (Storch et al., in press).

In the Lusatian region, the Silurian has been assessed in the peripheral part of the Krkonoše-Jizerské hory crystalline complex around Železný Brod and in the Ještědský hřbet range. It is represented by graphitic phyllites with lydite (containing identifiable lower Ludlovian graptolite fauna at Poniklá — Horný 1964) and the overlying limestones, which can be correlated with the Ockerkalk Limestone of the Saxon-Thüringen region (they very likely contain Scyphocrinites from the Ještěd ridge, Chlupáč 1963).

The only occurrence of the Silurian in the Moravo-Silesian region is at Stínava in the Drahanská vrchovina Upland. In a tectonically isolated block, slightly altered graptolite shales of Llandoverian and Wenlockian age pass upwards into calcareous shales with limestone interlayers; their age ranges from the Ludlovian possibly up to the Přídolian (Kettner - Remeš 1935, Bouček 1935). The presence of the Silurian in other metamorphosed units is purely hypothetical (e.g. in the Silesicum or Moravicum).

Devonian

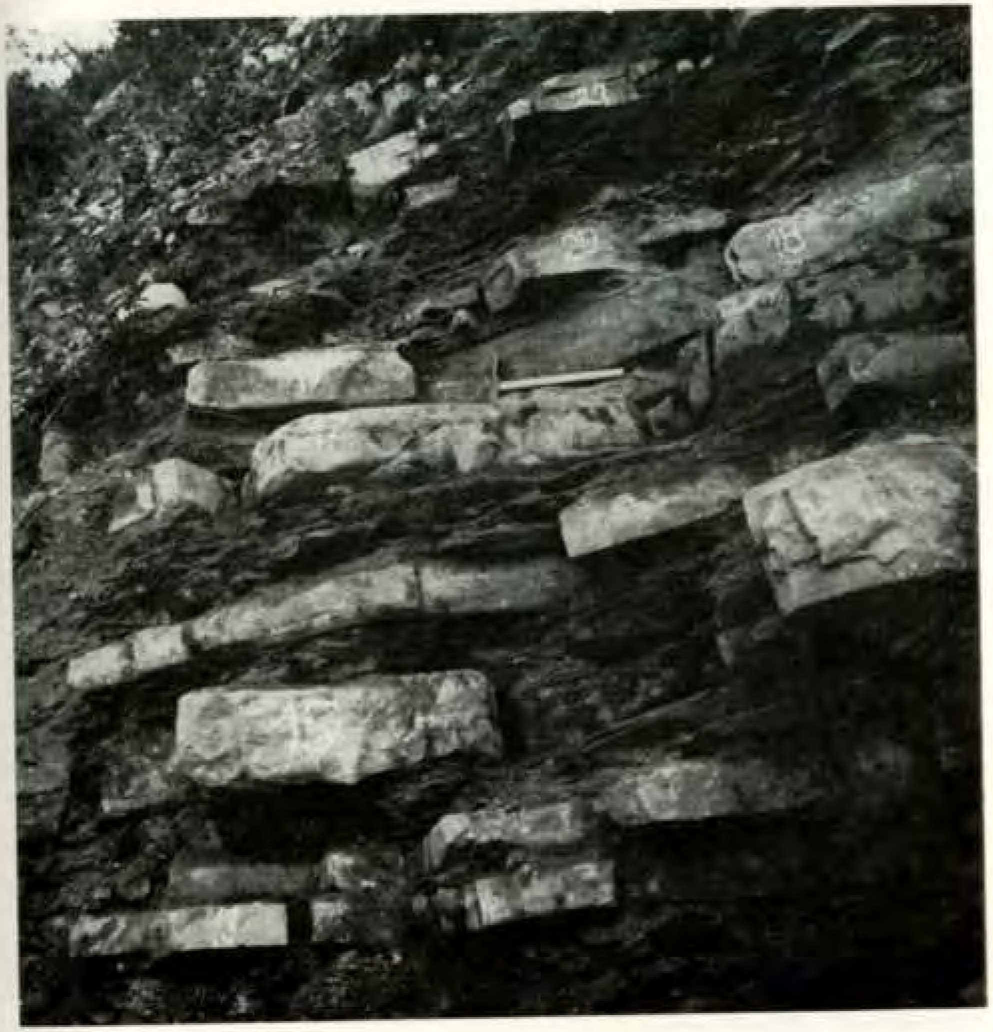
Of primary international significance is the Devonian in the Barrandian basin, but the Devonian of the Moravo-Silesian region is of a much larger areal extent. Minor occurrences are known in the "Islets zone", in the Železné hory Hills and in the Lusatian region.

Devonian in the Barrandian

The Devonian forms the central part of the Barrandian synclinorium between Prague and Zdice, making up the area of the Bohemian Karst. It rests conformably on the Silurian and the greater part of the sequence consists of limestone facies. Very characteristic are the combinations of shallow-water bioclastic (in the Pragian also reef) facies with the deeper-water facies of fine-grained micritic limestones, which were deposited in a substantially more quiescent environment. Shale facies are subordinate and sandy facies are confined to the uppermost member of the sequence — the Roblín Member (Givetian), the last to be deposited before the regression of the sea from central Bohemia.

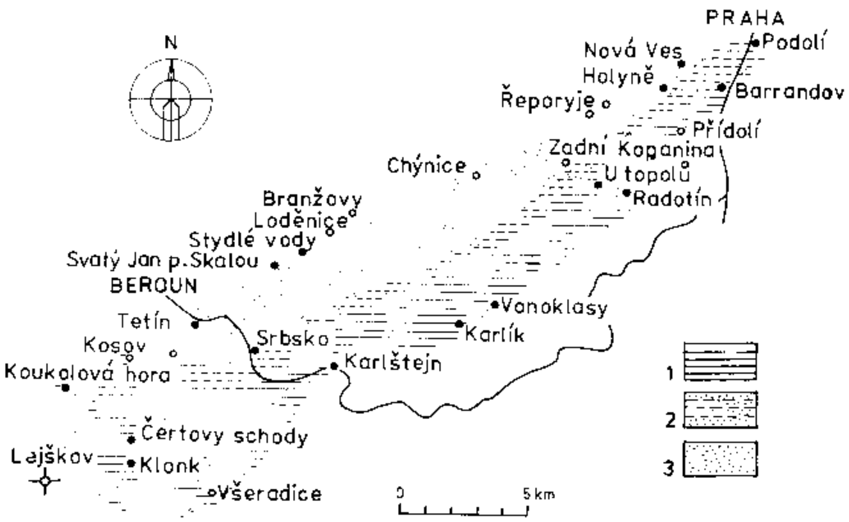
The Devonian in the Barrandian is a classical occurrence of the world-scale. It contains pelagic and reef faunas very rich in species of the so-called Bohemian type; they are characteristic representatives of the associations of the warm

3.17 International stratotype of the Silurian—Devonian boundary — Klonk near Suchomasty in the Barrandian, west of Prague. Total view, in the foreground monument designating the stratotype
Photo by B. Matoulková



3.18 Detail of the exposure of Silurian—Devonian boundary inside bed no. 3.17
Photo by B. Matoulková

climatic zone in an environment out of reach of a direct influence of the continent (e.g. the famous fauna of the Koněprusy reef complex is one of the richest Devonian associations in the world). The abundant occurrence of zonal fossils, chiefly tentaculites, conodonts, trilobites, graptolites, and of goniatites beginning with the Zlichovian, makes possible a highly detailed biostratigraphic subdivision. Uninterrupted carbonate sedimentation and development of faunas from the Silurian to the Lower Devonian was the reason why t h e w o r l d s t r a t o t y p e o f t h e S i l u r i a n/D e v o n i a n b o u ndary has been chosen in the Barrandian (Klonk near Suchomasty, see Chlupáč et al. 1972, McLaren 1977), and the units established in the Barrandian became a basis for the stage subdivision of the Lower Devonian in pelagic development on the world scale (Lochkovian, Pragian, Zlichovian etc., see Chlupáč 1976). Recently, the international parastratotype of the Lower/Middle Devonian boundary has also been chosen in the Barrandian (Chlupáč 1982). For summary information see Chlupáč (1968, 1981b, et al. 1979).



3.19 Lithofacies map of Silurian—Devonian boundary beds in the Barrandian (I. Chlupáč et al. 1972). Interval of upper Přídolian—lower Lochkovian
1 — platy limestones with shale interbeds; *2* — upper Přídolian in platy limestone facies, lower Lochkovian in pure carbonate facies; *3* — pure carbonate facies (crinoid and brachiopod ls)

Other Devonian occurrences in Bohemia

Additionally to the central part of the Barrandian, Devonian has been demonstrated in the Rožmitál area, where clastic development is predominating (Havlíček V. 1977). The late Lower Devonian also contains tentaculite shales. Worthy of mentioning are the Bezděkov Conglomerates, whose lenticular bodies consist, besides other rock material, of pebbles of contact-metamorphosed rocks, granitoids and rare orthogneiss (Fediuk 1959).

In the "Islets zone", in the mantle of the Central Bohemian Pluton, the Devonian is evidently represented mainly by light-coloured crystalline limestones (partly probably of reef origin, with crinoid remains) and the overlying cordierite hornfelses, quartzites and monomictic Skoupý Conglomerates; these are developed typically in the Sedlčany-Krásná Hora "islet" (Svoboda 1933, Chlupáč 1981a).

The light-coloured Podol Limestone forming the core of the Vápenný Podol syncline in the Železné hory area are very likely equivalent to the Devonian limestones of the "Islets zone". Their Devonian age follows from the superposition on the palaeontologically evidenced Přidolian with *Scyphocrinites*.

In the basement of the Bohemian Cretaceous Basin the Upper Devonian (Famennian) limestones have been found in the Nepasice borehole E of Hradec Králové. The carbonate sedimentation (bioclastic at the base and grey and reddish micritic limestones higher up) extends from the uppermost Devonian to the Early Carboniferous without interruption, and the development is similar to the southern part of the Moravian Karst, in particular (Chlupáč - Zikmundová 1976). The finds of pebbles of Lower Devonian limestones bearing faunas of Pragian age in the Permian encountered by the borehole Zdětín S of Mladá Boleslav, suggests a larger original extent of the Barrandian-type Devonian beneath the Cretaceous (Zikmundová - Holub 1965).

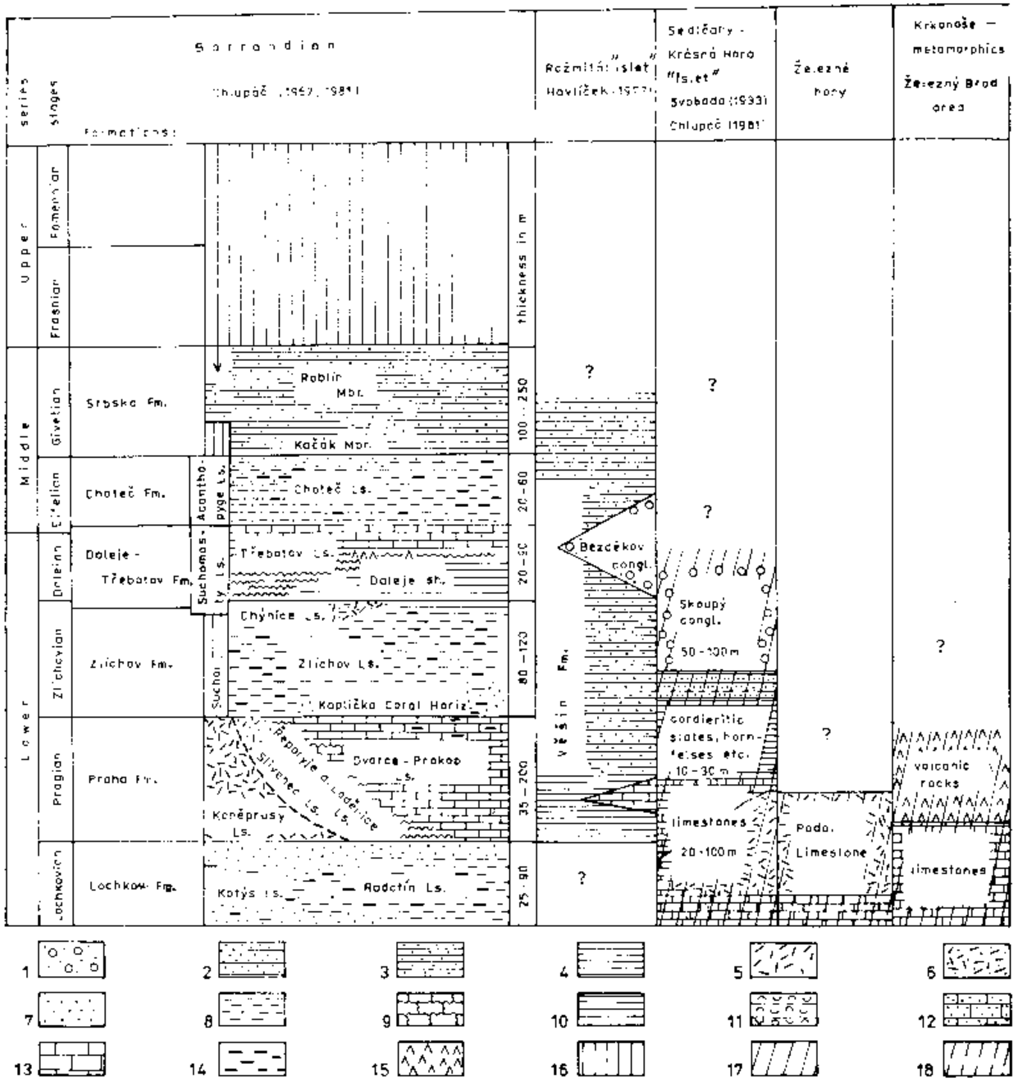
On the Bohemian side of the Lusatian region the Devonian has been reliably established only in the Ještěd crystalline complex. According to palaeontological finds, Devonian in age are dark phyllitic slates with volcanic products and Frasnian and Famennian faunas (Koliha 1929, Galle - Chlupáč 1976), and the overlying granular and micritic limestones, in which a complete succession of Famennian conodont zones has been determined (Zikmundová 1964). The overlying shales yielded the trilobite fauna of the Devonian—Carboniferous boundary beds (Chlupáč 1964).

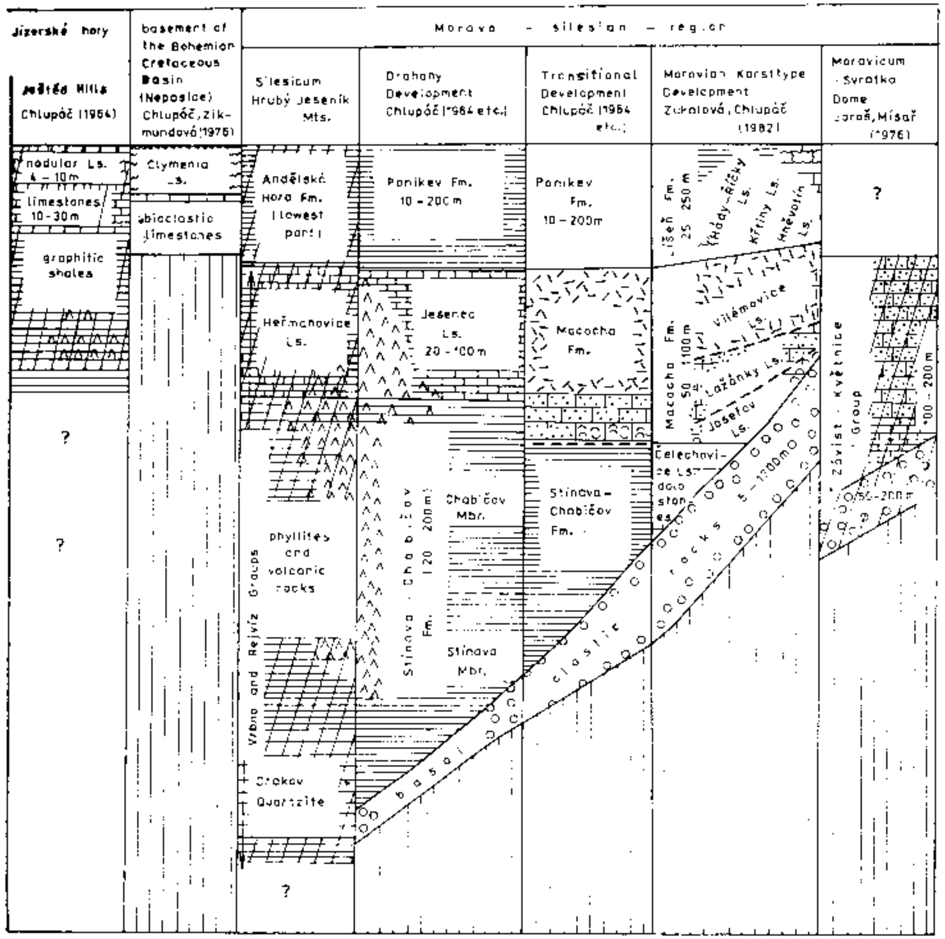
The upper limestone layers and overlying volcanites in the Železný Brod area of the Krkonoše-Jizerské hory Crystalline may also belong to the Devonian, but their age has not yet been palaeontologically evidenced.

Devonian of the Moravo-Silesian region

The most extensive occurrences of the Devonian in Czechoslovakia are in the Moravo-Silesian region. The deposits belong there to the southern projection of the Hercynian mobile system and lie transgressively on the older, for the most part Proterozoic basement.

The transgression proceeding from the north first reached, as early as in the lower Devonian (Pragian), the central parts of the basin, which even subsequently were the sites of intensive subsidence, mobility and submarine volcanism. This development distinguished by predominant deeper-water psammitic-pelitic facies and abundant volcanites (with Fe-ore deposits) is denoted as

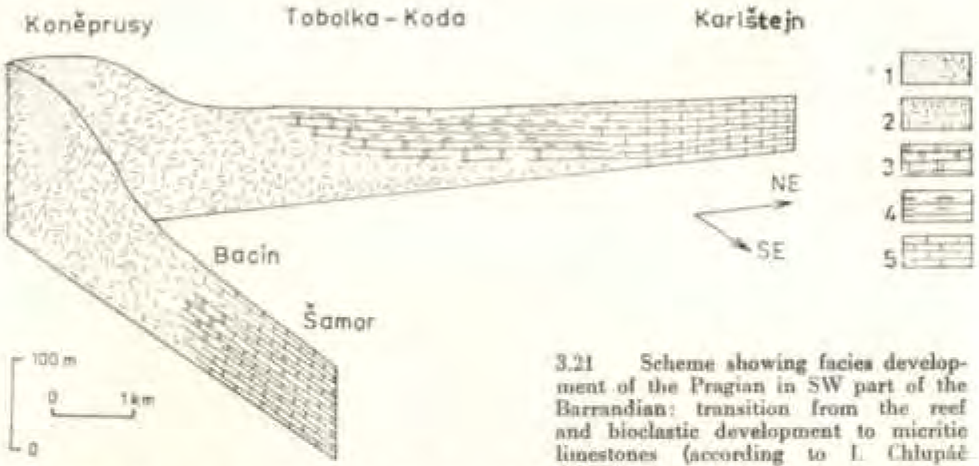




3.21 Stratigraphic scheme of the Devonian (I. Chlupáč, orig.)
1 — clastic sediments with a predominance of conglomerates and sandstones; *2* — sandstones and quartzites; *3* — alternating siltstones and sandstones; *4* — shales (siltstones, claystones, calcareous shales); *5* — white and light-grey reef and organodetrital limestones; *6* — rosy bioclastic crinoid limestones; *7* — grey sparitic limestones; *8* — dark-grey sparitic and micritic limestones (locally with shale interbeds); *9* — reddish nodular micritic limestones; *10* — grey nodular micritic limestones; *11* — limestones with thick-shelled brachiopods ("Stringocephalus Limestone"); *12* — dark-grey "Amphipora Limestone"; *13* — limestones and dolomites in general; *14* — cherts; *15* — volcanic rocks; *16* — stratigraphic breaks; *17* — metamorphosed rocks; *18* — rocks affected by subsurface alterations

the Drahany or basinal development. It is represented mainly in the Hrubý Jeseník Mts. (affected by medium-grade metamorphism), the Nízký Jeseník Hills (the Šternberk-Horní Benešov belt) and in the northern part of the Drahanská vrchovina Upland (southern part of the Konice-Mladeč belt, the area of Stínava, etc.). Whereas the basal clastics contain shallow-water faunas of the Rhenish type (typically developed in the Drákov Quartzites in the Hrubý Jeseník Mts.), the pelagic faunas of the Bohemian type (e.g. Chabičov, Kříšťanovice, Horní Benešov) predominate in the upper part (the Stínava-Chabičov Formation). The Ponikev Formation in the uppermost part of the sequence yields only considerably impoverished pelagic faunas with conodonts.

In the peripheral parts of the basin, which were invaded by the sea only during the Middle Devonian, the frequently very thick clastic sediments are overlain



3.21 Scheme showing facies development of the Pragian in SW part of the Barrandian: transition from the reef and bioclastic development to micritic limestones (according to I. Chlupáč (1969)

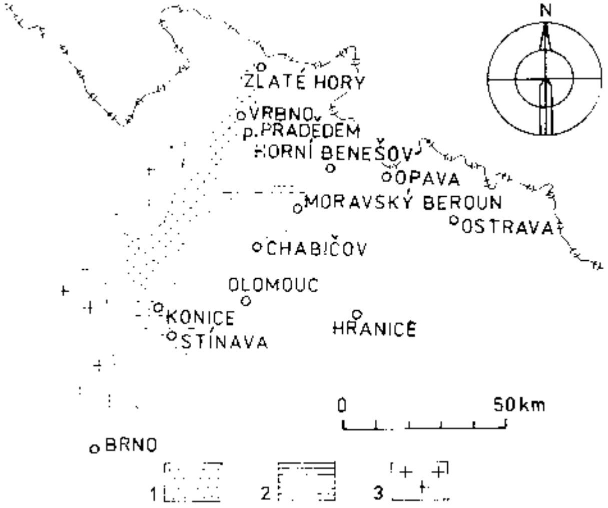
1 — light-coloured reef organoclastic (Koněprusy) limestones; *2* — red organoclastic Slivenec and Vinařice Limestones; *3* — thick-bedded Loděnice Limestones; *4* — reddish micritic Řeporyje Limestones; *5* — grey micritic Dvorce-Prokop Limestones

3.22 Stratotype of the boundary of Lower Devonian stages Lochkovian—Pragian in the gorge Černá rokle near Kosoř in the Barrandian. The boundary lies at the level of the lower end of hammer
Photo by B. Matoulková

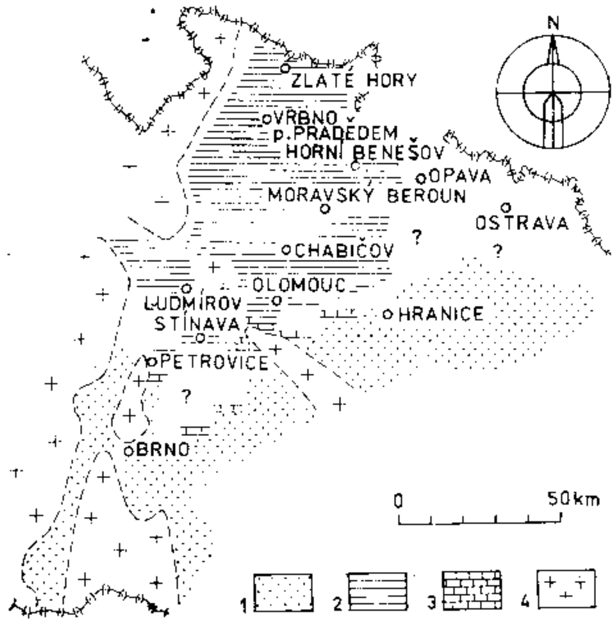
3.23 Kotýs Limestone (Devonian) on southern slope of Kotýs near Koněprusy ("Elephant's Head"). Barrandian, west of Prague
Photo by J. Rubín

3.24 International parastratotype of the Lower/Middle Devonian boundary — Prastav quarry in Praha - Holyně, Barrandian. Třebotov and Choteč Limestones; the boundary shown by white line
Photo by I. Chlupáč

3.25 Three important representatives of primitive ammonoids from the Lower Devonian of **Bohemia** (Zlíchov Formation, Barrandian): *1* — *Palaeogoniatites lituus* (Barrande), Praha - Zlíchov, Švagerka, natural size; *2* — *Anetoceras solitarium* (Barrande), Stydlé vody at Sv. Jan pod Skalou, natural size; *3* — *Mimagoniatites fecundus* (Barrande), Čeřinka near Bubovice, natural size
Photo by B. Matoušková

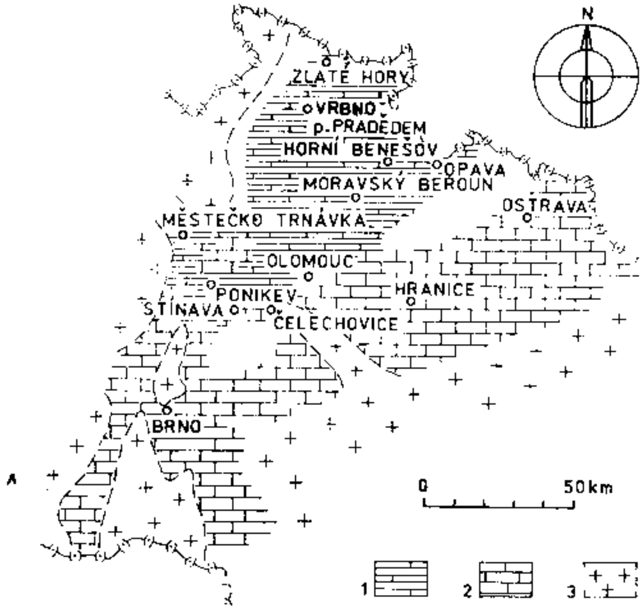


3.26 Lithofacies map of the Moravo-Silesian Devonian in the Pragian stage (V. Zukalová - I. Chlupáč 1982)
1 — clastic sediments, sandstones and conglomerates; *2* — shales (pelites and siltstones) of the Stínava Formation; *3* — pre-Devonian rocks

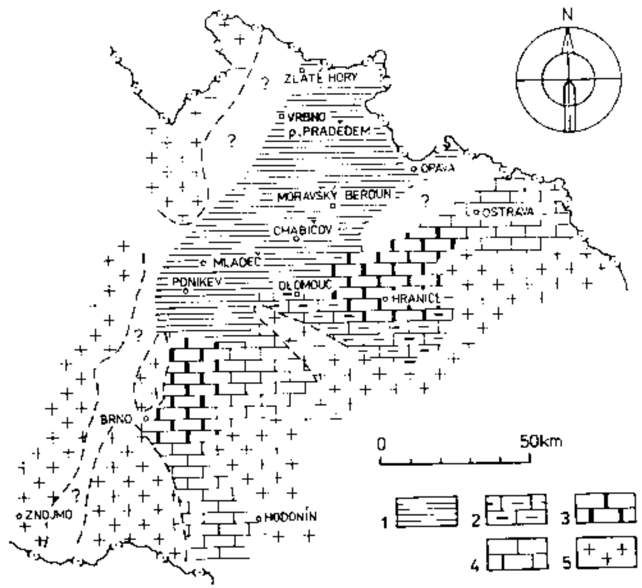


3.27 Lithofacies map of the Moravo-Silesian Devonian in the Dalejan to Eifelian (V. Zukalová - I. Chlupáč 1982)
1 — clastic sediments (conglomerates and sandstones); *2* — shales (pelites and siltstones) with volcanite bodies, Chabičov Member; *3* — carbonates; *4* — pre-Devonian rocks

by the sequences of shallow-water carbonates of the Macocha Formation. They attain a thickness of several hundreds of metres and contain Givetian—Upper Frasnian reef complexes. Conspicuous facies changes and differentiation did not occur before the final phase of the Devonian sedimentation, when various bio-

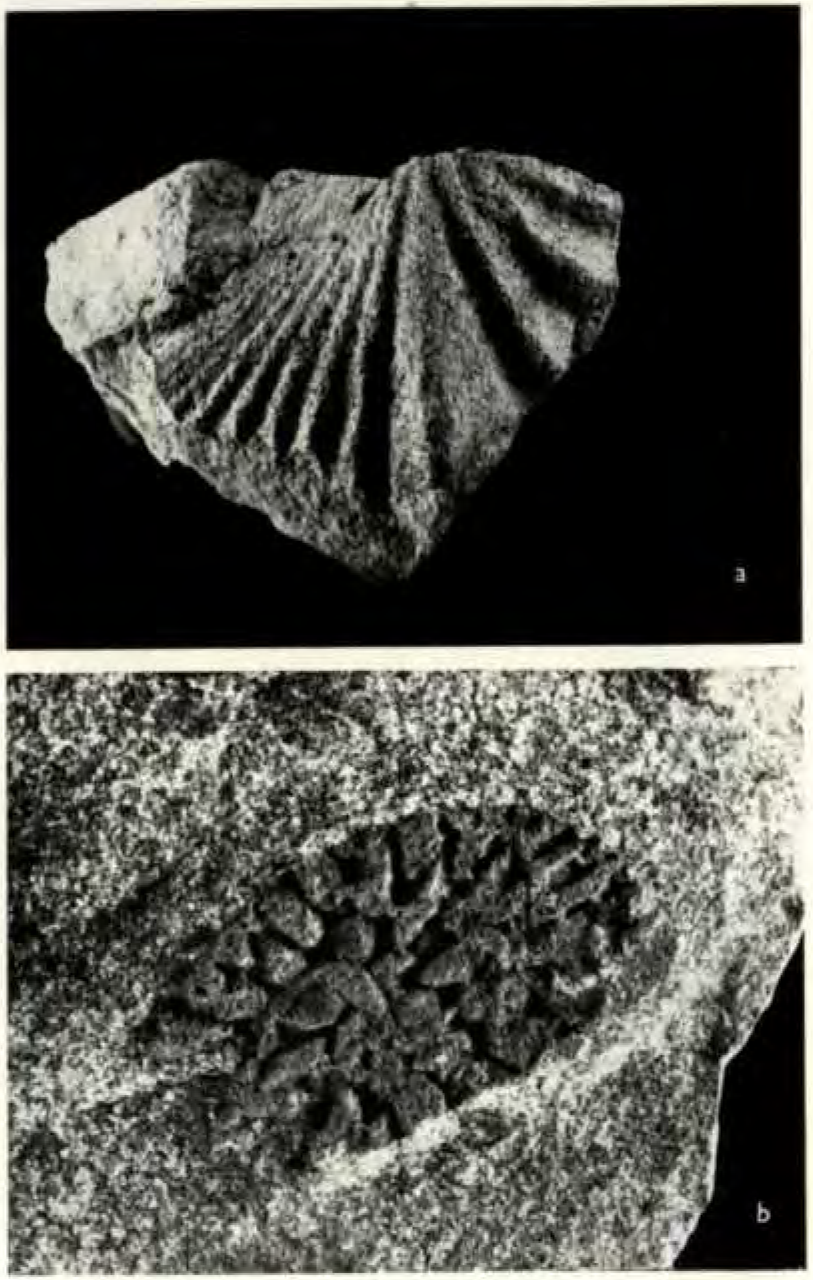


3.28 Lithofacies map of the Moravo-Silesian Devonian in the Givetian stage (V. Zukalová - I. Chlupáč 1982)
1 — pelitic-carbonate facies with volcanic rocks (Jeseník Limestones, etc.); *2* — shallow-water carbonate facies, Macocha Formation; *3* — pre-Devonian rocks



3.29 Lithofacies map of the Moravo-Silesian Devonian in the Fammenian stage (V. Zukalová - I. Chlupáč 1982)
1 — shaly facies, Ponikev Formation; *2* — carbonate facies with a predominance of laminites (Hněvotín Limestones); *3* — carbonate facies with a higher content of pelites (Křtiny and Hády-Říčky Limestones); *4* — carbonate facies without a higher content of pelites; *5* — pre-Devonian rocks

clastic, micritic and pelitic facies were deposited, included in the Líšeň Formation. This development called after its typical area the development of the Moravian Karst, is widespread particularly in the foredeep and basement of the Carpathians from northern to southern Moravia (from the area of Český Těšín to



3.30 Two significant fossils of Rhenish development of the Lower Devonian (Drakov Quartzite in northern Moravia, Hrubý Jeseník): *a* — brachiopod *Acrospirifer primaevus* (Steininger), *b* — tabulate coral *Pleurodictym problematicum* Goldfuss. Starý Rejvíz, ×2

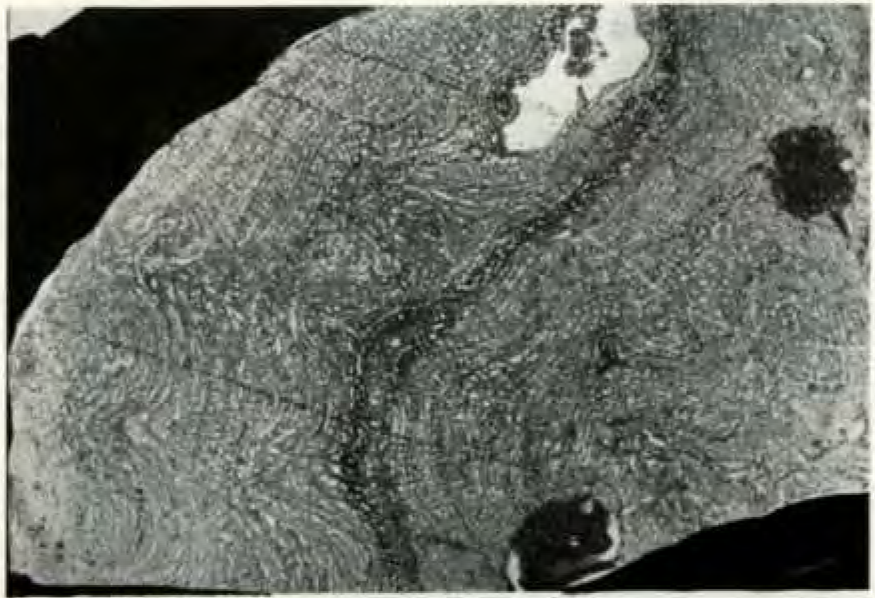
Photo by H. Vršťalová

3.31 An example of fossil preservation (brachiopods, bivalves) in metamorphosed quartzite of the garnet metamorphic zone. Vrbno Group, Dolní Údolí near Zlaté Hory in the Jeseníky Mts. Natural size

Photo by A. Kadlecová

3.32 Stromatoporoides. *Actinostroma clathratum* Nicholson. Sections of *Stachyodes* sp. branches at the upper left, thin section. Měnín-1 borehole, depth 397—402 m. Palaeozoic of Moravia, Givetian Photo archive ÚÚG Praha

3.33 *Amphipora rudis* Lecompte, *Amphipora laxeperforata* Lecompte, thin section. Měnín-1 borehole, depth 52—57 m. Palaeozoic of Moravia, Frasnian. ×3
Photo archive ÚÚG, Praha



3.34 *Trupetostroma* aff. *bassleri* Lecompte, astrorhizal systems, thin section. Němčičky-2 borehole, depth 5233—5234 m, Frasnian. ×2
Photo archive ÚÚG, Praha

3.35 *Pseudoactinodictyon* sp. (in the upper part of fig.), *Actinostroma* sp. (centre, on the left), *Scoliopora denticulata* (M. Edw. et Haime). Longitudinal and cross-sections of branches (bottom left and in the centre of lower part). *Clathrocoilona* sp. (bottom right), thin section. Němčičky-2 borehole, depth 5233—5234 m. Palaeozoic of Moravia. ×2 Photo archive ÚÚG, Praha

Znojmo). It crops out at the surface in the Moravian Karst, and in the environs of Olomouc, Přerov and Hranice; in the Tišnov area it occurs in the metamorphic form (J a r o š - M í s a ř 1968). The faunas of shallow-water carbonate facies of the Middle Devonian and Frasnian (with a predominance of corals and stromatopores) show a cosmopolitan character of a warm climatic zone. The Famennian faunas are strikingly different, reflecting differentiated environments and a change in climate (cooling) in the latest Devonian (C h l u p á č et al. 1968, Z u k a l o v á - S k o č e k 1979).

The Drahany development and the development of Moravian Karst pass into each other laterally. In this "transitional development" of the Devonian the shale facies common in the Drahany development (t h e S t í n a v a - C h a b i č o v and P o n i k e v F o r m a t i o n s) predominate in the basal and top parts of the sequence, and carbonates comparable with the Moravian Karst development (M a c o c h a F o r m a t i o n) in the Givetian—Frasnian part. This development is typical of the central part of the Konice-Mladeč belt (C h l u p á č - S v o b o d a 1963) and in the Němčice belt north of the Moravian Karst.

For summary reports on the stratigraphy and palaeogeography of the Moravian Devonian see D v o ř á k (1958b, 1973b), C h l u p á č (1964), Z u k a l o v á - C h l u p á č (1982), B a r t h (on volcanism 1963, 1964) and S k á c e l (deposits of Fe-ores 1966).

3.1.3 Upper Palaeozoic and Triassic

Lower Carboniferous

The Lower Carboniferous deposits are of the largest extent in the Moravo-Silesian region, and minor occurrences are known from the Ještědské pohoří Mts. and from the basement of the younger formations to the east of Hradec Králové. In the Early Carboniferous the filling of the Lower Silesian basin was initiated.

T h e M o r a v o - S i l e s i a n r e g i o n

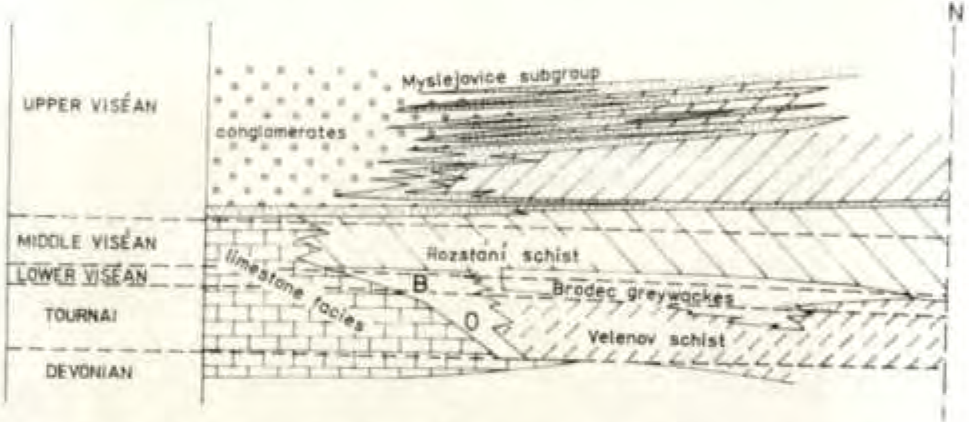
In the Moravo-Silesian region the principal lithostratigraphic units pass from the Devonian to the Lower Carboniferous without conspicuous facies changes both in shaly (P o n i k e v F o r m a t i o n) and carbonate facies (L í š e ň F o r m a t i o n).

In the Nízký Jeseník area the absolute majority of the Lower Carboniferous beds belong to t h e f l y s c h f o r m a t i o n called the Culm. In the western part (at the boundary between the Hrubý and Nízký Jeseník) the basal unit is t h e A n d ě l s k á h o r a F o r m a t i o n, the sedimentation of which began in the latest Devonian, persisting to earlier Lower Carboniferous (K o v e r d y n s k ý - Z i k m u n d o v á 1966). In the eastern part (the Sternberk-Horní Benešov belt) t h e P o n i k e v F o r m a t i o n (shales with silicites) was being

3.36 *Clymenia laevigata* (Münster), a significant ammonoid cephalopod from the uppermost Devonian (Fammenian), preserved on the bedding surface of the Křtiny Limestone. Ostrov near Macocha in the Moravian Karst

Photo by H. Vršťalová

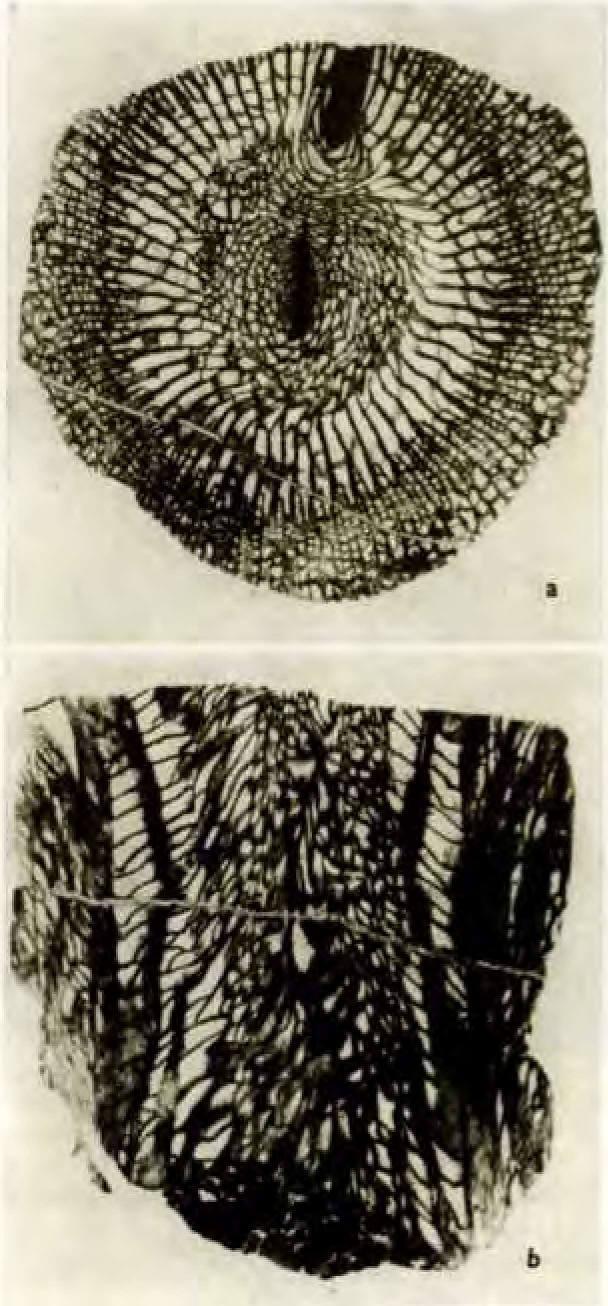
deposited in the Late Devonian nearly to the Tournaisian—Viséan boundary. The overlying H o r n í B e n e š o v F o r m a t i o n has a predominance of greywackes (Lower—Middle Viséan according to superposition); at the boundary between the pre-flysch formations there are in places calcareous conglomerate and sandstone facies, rimming the elevation structures (e.g. the Moravský Beroun Conglomerates). The age of the higher Culm units of the Jeseník area (M o r a v i c e F o r m a t i o n and the overlying H r a d e c a n d K y j o v i c e F o r m a t i o n s), which some authors unite into t h e H r a d e c - K y j o v i c e F o r m a t i o n, is demonstrated by the goniatite and other faunas from the interval of upper Viséan to the lowest Namurian A (e.g. K u m p e r a 1974, 1976). The individual Culm members imbricate from W to E, their maximum thickness in the western part reducing strikingly eastwards.



3.37 Stratigraphic scheme of the Lower Carboniferous in the Drahanská vrchovina Upland, according to J. Dvořák 1973
B — Březinka Shales, O — Ostrov Shales

3.38 Stratigraphic scheme of the Lower Carboniferous in the Nízký Jeseník Hills (J. Dvořák, orig.)
AH — Andělská hora Formation, HB — Horní Benešov Formation, M — Moravice Formation, — H-K — Hradec-Kyjovice Formation, P — Ponikev Formation, upper part, L — Líšeň Formation, upper part, O — Ostrava Formation (Namurian A)

In the Drahanská vrchovina Upland, the sedimentation of the Ponikev Formation continues in the central part from the Devonian to the Lower Carboniferous; in the S and E carbonate sedimentation persists (Hády-Říčky and Křtiny Limestones of the Líšeň Formation, e.g. in the Moravian Karst, see Dvořák-Freyer 1961, 1965, 1966, Chlupáč 1962, 1966, et seq.). The Culm flysch sequence began probably to sediment in the Bouzov synclinorium in the NW, spreading during the Tournaisian and particularly Lower Viséan over the remaining part of the Drahanská vrchovina Upland. In the Drahany block a sequence of greywackes (Brodce Greywackes), up to 1000 m thick, presumably accumulated as early as the early Viséan, and higher up the Rozstání Shales with a predominance of siltstones. In the southern and eastern parts (Moravian Karst)



3.39 Rugosa: *Cyathoclisia tabernaculum* Dingwall. Hranice in Moravia, Mariánské valley. Palaeozoic of Moravia
a — cross-section, b — longitudinal section, thin section. Lower Carboniferous — Tournaisian, ×3
Photo archive ÚÚG, Praha

3.40 Devonian limestones SE of Hranice na Moravě. Surf gravels of Miocene sea on the top of the limestone
Photo by A. Zeman

the Culm facies begins with the Březina Shales containing trilobite fauna of early to middle Viséan age (Chlupáč 1966). They are overlain by equivalent greywackes and shales of the Protivanov Formation in a reduced thickness. The youngest unit is the more than 3000 m thick Myslejovice Formation (Dvořák 1968, 1973b); in the southern part its prominent members are the Račice and Luleč Conglomerates with pebbles of Moldanubian rocks and non-metamorphosed Devonian and Lower Carboniferous limestones (see e.g. Štelcl 1960). Towards N and NE the conglomerate facies are replaced by greywackes and shales, which in the Vyškov area yield a rich upper Viséan fauna (Kumpera - Lang 1975).

In the foreland and basement of the Outer Carpathians and in some isolated surficial occurrences (Hranice area) carbonate sedimentation continued from the Devonian until the late Viséan. In the extreme eastern (platform) part, however, interruption of sedimentation (e.g. S and SE of Ostrava) has been substantiated by the absence of the Tournaisian and Famennian conodont zones. The units of the Culm development are there of a rather reduced thickness, although their existence has been evidenced biostratigraphically (Chlupáč - Kumpera 1972).

In the slightly regional-metamorphosed Lower Carboniferous of the Ještědské pohoří Mts. the limestones containing Famennian faunas are overlain conformably by shales with the trilobite fauna of the Devonian—Carboniferous boundary beds (Chlupáč 1964). Higher up the shales pass abruptly into greywackes and polymictic small-grained conglomerates of the Tournaisian to Viséan age (thus far without palaeontological finds).

In a deep borehole near Nepasice E of Hradec Králové, the Devonian/Carboniferous boundary has been encountered amidst the nodular micritic Křtiny Limestones, which on biostratigraphic evidence are Famennian and Tournaisian in age (Chlupáč - Zikmundová 1976). The upper Tournaisian is represented by bioclastic limestones with shale interlayers and faunal and plant fossils (an analogue of the Hády-Říčky Limestones). The Lower Carboniferous sequence ends with clastic sediments of the Culm facies (probably Viséan).

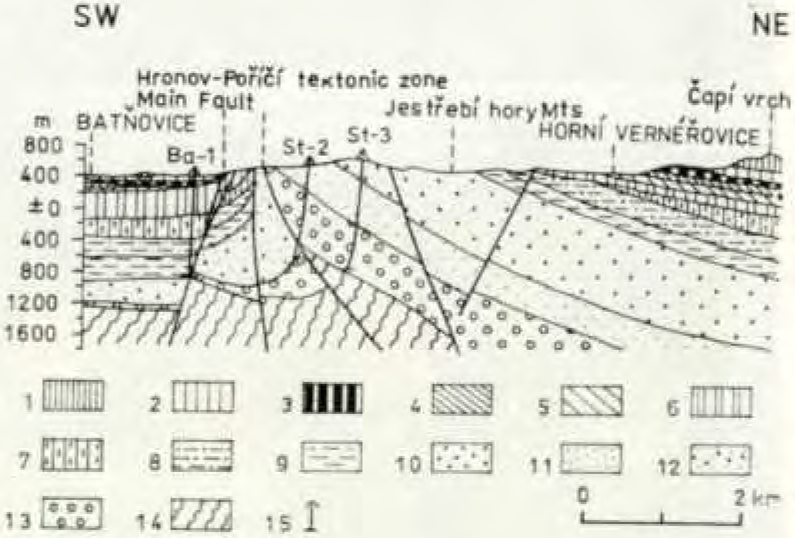
The Lower Silesian Basin

The Lower Carboniferous deposits of the Lower Silesian Basin occur predominantly on the Polish territory, along the northern and eastern margins of the basin; in Czechoslovakia they have been established only by boring in the Žacléř area. The Lower Carboniferous sediments in Lower Silesia were deposited in two sedimentary cycles: the earlier cycle (upper Tournaisian to middle Viséan) is characterized by fluviatile sedimentation (so-called fluviatile Culm, represented by the Marciszów Member, Żakowa 1963). The younger, upper Viséan cycle

3.41 Devonian limestones near the town Hranice na Moravě. On the horizon etchplain of the margin of the Bohemian Massif, depression in the foreground is the Carpathian foredeep

Photo by V. Zeman

consists of marine sediments; in Poland they form the Stary Zdrój Member (Augustyniak - Grocholski 1968) and higher up the Jabłów Member; this is of regressive character and contains continental fauna.



3.42 Geological section through the SW limb of the Bohemian part of the Lower Silesian basin (V. Holub - R. Tásler 1980)
1 — Middle Turonian; *2* — lower Turonian; *3* — Cenomanian; *4* — Bohdašín Formation (Lower Triassic); *5* — Bohuslavice Formation (Thuringian); *6* — Trutnov Formation (Saxonian); *7* — Broumov Formation (upper Autunian); *8* — Bečkov Member (lower Autunian); *9* — Vernéřov Member (Stephanian C — lower Autunian); *10* — Jívka Member (Stephanian A, B); *11* — Svatoňovice Member (Westphalian D); *12* — Jívka and Svatoňovice Members, undifferentiated; *13* — Žacléř Formation (Namurian C — Westphalian C); *14* — crystalline complex; *15* — borehole

At the western and northern margins of the basin there are Lower Carboniferous sediments of different facies development, which were described as the deltaic Culm (Błażków Member). They yielded plant remains of continental character. Their surface outcrops occur near the Czechoslovak—Polish frontier; in Bohemia they have been encountered by deep boring near Bobr, Černá Voda and Královec. According to Czechoslovak geologists the sequence is of fluvial origin.

3.43 Rhyolite effusion at Vraní hory near Bernartice, Žacléř area, Bohemian part of the Lower Silesian basin, Autunian Photo by B. Matoulková

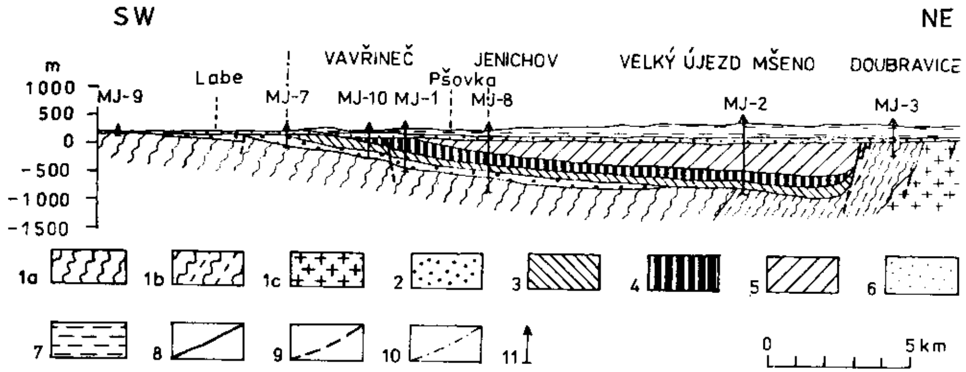
Upper Carboniferous (Silesian), Permian and Triassic

Towards the end of the Viséan and at the beginning of Namurian A the sea retreated from a large part of the Bohemian Massif. Sedimentation continued only in the Upper Silesian region, but it was replaced by the paralic molasse and the extent of the sedimentary area was considerably reduced. In the Bohemian part of the Lower Silesian Basin the Lower Carboniferous sedimentation (Błażków Member) terminated during the Viséan; during the Namurian A and B the Massif in this and other areas became a continental source area.

In the *Upper Silesian Basin* the marine sedimentation of the Kyjovice Member terminated in the lower part of the Namurian A. The Ostrava Formation, limited at the base by the Stur marine band and stratigraphically corresponding to the Namurian A, is a continental complex with marine layers, which are denoted as marine bands. The Karviná Formation was deposited after a minor hiatus between Namurian A and B and further areal reduction of the sedimentary basin. In the Polish part of the basin sedimentation continued, whereas it was closed by the deposition of the Doubrava Member in the Czechoslovak part.

In the *Permo-Carboniferous area of north-eastern Bohemia* the Upper Carboniferous sedimentation began in the Lower Silesian Basin in Namurian C by the deposition of the Žacléř Formation, and continued until Westphalian C. The richest coal deposits of the Žacléř Formation are in the Lampertice Member near Žacléř. Near Malé Svatoňovice (E of Trutnov) and Rtyně v Podkrkonoší at the foot of the Krkonoše Mts. the coal seams of the Žacléř Formation are mined mainly in the Prkenný Důl-Žďárky Member. The following megacycle (Odolov Formation) dates from the interval of Westphalian D to Stephanian B. At the base of this megacycle there are the Svatoňovice Member (Westphalian D, Cantabrian to the lower Stephanian A) with the Svatoňovice group of seams worked near Malé Svatoňovice, and the Jívka Member (upper part of Stephanian A and Stephanian B) with the Radvanice coal seams.

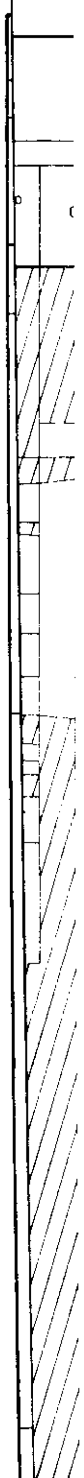
3.44 Boundary between Žacléř and Odolov Formations (Petrovice and Svatoňovice Members). Beds showing selective weathering are volcanoclastics of the upper tuffaceous horizon; boundary between Westphalian C and D. Bohemian part of the Lower Silesian basin. Road cutting near factory Lenka in Petříkovice near Trutnov
Photo by V. Holub



3.43 Geological cross-section of the western part of the Mšeno basin (between Mělník and Bezděz)
Crystalline complex: *1a* — Upper Proterozoic (quartz-albite-muscovite-chlorite subfacies), *1b* — Upper Proterozoic (quartz-epidote-biotite subfacies), *1c* — igneous rocks (granodiorite, diorite, granite); Upper Palaeozoic: *2* — Lower Grey Formation, *3* — Lower Red Formation, *4* — Upper Grey Formation, *5* — Upper Red Formation; Upper Cretaceous: *6* — Cenomanian, *7* — Turonian; *8* — faults, established; *9* — faults, inferred; *10* — break in the section line; *11* — deep boreholes (V. Holub - R. Tásler 1980)

The Stephanian C is followed by the megacycle represented by the Chvaleč Formation (Stephanian C to lower Autunian). The higher megacycle, Broumov Formation was formerly placed in the upper Autunian on the basis of strong volcanic activity (e.g. Petrascheck 1934 et seg., Holub-Prouza-Tásler 1965), but its greater part is nowadays placed in the Lower Autunian on its lithostratigraphic (Tásler-Valín 1982) and biostratigraphic (Holub-Kozur 1981) correlation with the Krkonoše-piedmont basin. The Olivětín and Martínkovice Members contain significant correlative horizons of limestone and bituminous pelocarbonates; abundant fossil fauna and flora found in these rocks was described by Frič (1879—1901, 1912). After a major interruption of sedimentation, corresponding to the Saalic orogenic movements, the Saxonian (Trutnov Formation), Thuringian (Bohuslavice Formation) and Triassic (Bohdašín Formation) sequences were deposited. The post-Saalian sedimentation in the Lower Silesian Basin was of a similar character as sedimentation in the Krkonoše-piedmont basin.

The sedimentary area of the *Krkonoše-piedmont* and *Mnichovo Hradiště basins* nearly coincided with that of the Lower Silesian basin. They differ in that sedimentation in the Krkonoše-piedmont basin began as late as the Westphalian C and in the Mnichovo Hradiště basin even later — in Westphalian D. In the Krkonoše-piedmont basin no seams equivalent to the Svatoňovice group of seams are known; the Syřenov group of seams (with a recently discovered bituminous coal deposit E of Lomnice nad Popelkou) corresponds to the Radvanice group of seams of the Lower Silesian Basin. The new biostratigraphic investigations permit to parallelize the upper Prosečná Member of the Krko-



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3.46 *Linopteris germari* (Gieb.) in red aleuropelites, Týnec Member in the Plzeň basin, western Bohemia. Stephanian A, borehole Nř-3, depth 45.00—49.00 m, ×3
Photo by H. Vršťalová

nože-piedmont area with the Martínkovice Member of the Broumov area (H o l u b - K o z u r 1981a) and the Kalná horizon with the Hejtmánkovice Horizon. The stratigraphic position of the Chotěvice Member is rather uncertain. T h e T r u t n o v F o r m a t i o n (Saxonian) could be divided into four subunits on account of its very good development in the whole area (H o l u b 1972, see Pl. II). At the boundary with the Bohuslavice Formation, at the margin of the sedimentary area, a moderately transgressive relation is observed but in the centre of the basin the transition is quite gradual. On the basis of lithological development in the area S of Trutnov (around Hajnice and Úpice), H o l u b (1972) distinguished in the Thuringian sequence the Maršov Member in the upper part, formed of non-calcareous sandstones and arkoses with aleuropelite interbeds, and the carbonate complex in the lower part. In the eastern part H o l u b (1972) divided the Triassic sequence into three units on the basis of lithostratigraphic correlation and palaeontological finds. He placed the Bachoviny and Výšinka Members in the Lower Triassic (Scythian), and the Devět křížů Member in the Anisian on palaeontological evidence. The sedimentation of this last unit closed the filling of the basin in the Triassic period. In the Mnichovo Hradiště basin sedimentation was terminated in the Autunian.

According to the geological and tectonic conditions, the sediments of the *Orlice basin* are assigned to the Autunian and Saxonian (without palaeontological evidence). However, the whole stratal sequence is unknown and, consequently, we cannot exclude the presence of earlier complexes that are known from other structural units of north-eastern Bohemia.

In *central and western Bohemia* the Carboniferous sedimentation began in the Westphalian, according to N ě m e j c (e.g. 1953) at the beginning of Westphalian C, but the correlation with the Prkenný Důl-Žďárky Member in the Lower Silesian Basin and palaeontological studies of J. Šetlík suggest that it could have started already in the Westphalian B. W e i t h o f e r (1897 and 1902) introduced a stratigraphic division of the sequence, based on the alternation of four complexes of different colour, which is still in use. In the ascending order the Lower Grey Group, Lower Red Group, and Upper Grey and Upper Red Groups were differentiated. P e t r a s c h e c k (1921—1923) gave place-names to these units which, according to the principles of stratigraphic nomenclature, are given preference. In the mining practice numerical denotation is used (I for the Plzeň-Kladno Formation, II for the Týnec Formation, III for the Slaný Formation, and IV for the Líně Formation). The Slaný Formation is subdivided in the greatest detail with the application of several stratigraphic conceptions. The classification developed by the Geological Survey and used in map legends has issued from the division of F. Němejc, J. Obrhel, and the investigation results achieved by the staff of the Geological Survey, taking into consideration the optimum development of the units. At the base the Jelenice Member (H o l u b 1965) and the Malesice Member (N ě m e j c 1934) were defined. O b r h e l (1958) justifiably subdivided the latter into the Mšec and Hředle Members and established the Kamenný Most Member in the uppermost part. H a v l e n a - P e š e k (1980) contradict the separate position of the Mšec and Hředle Members, and join the Ledce, Kounov and Kamenný Most Members into the Otruby Member. The correlation of the lithostratigraphic horizons in the Líně Formation is still questionable. Opinions also differ as concerns the age of the upper part of the Líně Formation (V. Havlena and J. Pešek presume only Stephanian C age), although the most recent investigation of the Líně Formation in the Žatec area, which substantiated the presence of the Autunian (H o l u b - S k o č e k - - T á s l e r 1981) may have already solved the problem. The filling of the sedimentary basins of the Permo-Carboniferous area was interrupted by two major stratigraphic hiatuses evidenced by the erosion of underlying beds: the earlier hiatus occurred between the deposition of the Radnice and the Nýřany Members (between Westphalian C and D) and the later separated the sedimentation of the Slaný and the Líně Formations (between Stephanian B and C).

The Permo-Carboniferous area of central and western Bohemia also includes the *Upper Palaeozoic occurrences* in the Bohemian part *of the Krušné hory Mts.*

3.47 *Callipteridium pteridium* (Schloth.) in dark-grey aleuropelites, Roudnice basin (Líně Formation). Borehole Be-1 (Bechlín near Roudnice), depth 537.00—538.30 m. ×2
Photo by H. Vršťalová

3.48 Kaolinitic sandstones used for decoration purposes. Triassic (Scythian—Anisian). Quarry "U devíti Křížů" near Červený Kostelec
Photo by V. Holub

The two rocks complexes that developed there are separated by a long hiatus. The older, Carboniferous complex contains coal seams which stratigraphically correspond to the Radnice group of seams. It is not clear enough when the sedimentation of the older complex had begun; V. Havlena thinks it to be synchronous with other occurrences in central and western Bohemia, but N ě m e j c (e.g. 1953) presumed that it had started earlier (in early Westphalian B or even in Westphalian A). The younger complex showing the character of red-beds with abundant products of explosive volcanism, is regarded as being partially equivalent to the Líně Formation.

Subsequently to the Asturian movements, sedimentation began in *the Boskovice and Blanice Furrows* in the late Stephanian and lasted until the Autunian; the lack of palaeontological finds does not permit to determine the time of the end of sedimentation accurately. With regard to a tectonic revival and the formation of marginal facies in the uppermost part of the profile, it is believed to fall in the late Autunian, after the earlier Saalic movements. The Carboniferous—Permian boundary (in the sense of R e m y - H a v l e n a 1962) is lithologically quite indistinct; in the Blanice Furrow it runs between the lower and upper seam horizons, and within the range of the R o s i c e - O s l a v a n y g r o u p of seams in the Boskovice Furrow. The predominantly grey-coloured sediments in the lower part of the filling of the Blanice Furrow were termed by H o l u b (1980) t h e Č e r n ý K o s t e l e c F o r m a t i o n; the lower Peklov Member bears the older coal horizon (at Peklov near Kostelec nad Černými lesy and in boreholes near České Budějovice). The upper Lhotice Member contains small seams of bituminous coal and anthracite, which are worked near Lhotice and at several localities near Vlašim (Nesperská Lhota, Chobot, etc.), and representatives of the upper coal horizon in the Český Brod area. The upper parts of the furrows are filled with sediments of the red-beds type which, chiefly in the Boskovice Furrow, are represented by layers of grey bituminous pelocarbonates and limestones rich in fossil fauna (e.g. insect, fishes and crustaceans); they are of help in biostratigraphic classification and correlation. The marginal lithofacies of the Boskovice Furrow representing the whole stratal sequence in the basin is t h e R o k y t n á C o n g l o m e r a t e.

The Upper Palaeozoic sediments in the *Železné hory Hills* and sediments recently encountered by boring W of Hradec Králové (localities Žižkovec, Urbanice) have been interpreted as relics of the filling of the *Jihlava Furrow*. Lithological analysis, however, has shown that they are older than those in the Boskovice and Blanice Furrows. They are correlated with the Týnec Formation of the central Bohemian region and with a part of the Permo-Carboniferous Odolov Formation in north-eastern Bohemia (Stephanian B).

In the territory of NE Bohemia, there was truncated Permian sedimentation in the Lower Silesian and Krkonoše-piedmont basins ("Pfalzian" phase). After a short break a new platform sedimentation continued in the Lower Triassic. The Triassic sediments (Scythian — Anisian) are developed in the Germanic facies. With these sediments the megacyclus of Late Palaeozoic deposition ends.

3.1.4 Jurassic and Cretaceous

The Jurassic in the Bohemian Massif

The Jurassic of the Bohemian Massif forms a closed sedimentary cycle, which begins with a transgression in the Oxfordian, Callovian and ends with the regression in the late Tithonian. The sea invaded the area of the Bohemian Massif gradually. At first the south-eastern part of the Massif in the foreland of the Eastern Alps and the West Carpathians was flooded (B r i x et al. 1977). As early as in the Liassic this region was the site of continental sedimentation of coal-bearing beds, interrupted repeatedly by sea incursions (paralic type of coal sedimentation). Sedimentation of this type lasted until the Callovian, and locally effusions of basic lava occurred. The deposits (Diváky Formation) have been dated on palaeontological evidence, when V a š í č e k (1977) found a lytocerate ammonite in the Březí 1 borehole near Mikulov. Thus, all those coal-bearing sediments cannot be interpreted as being of Late Carboniferous age.

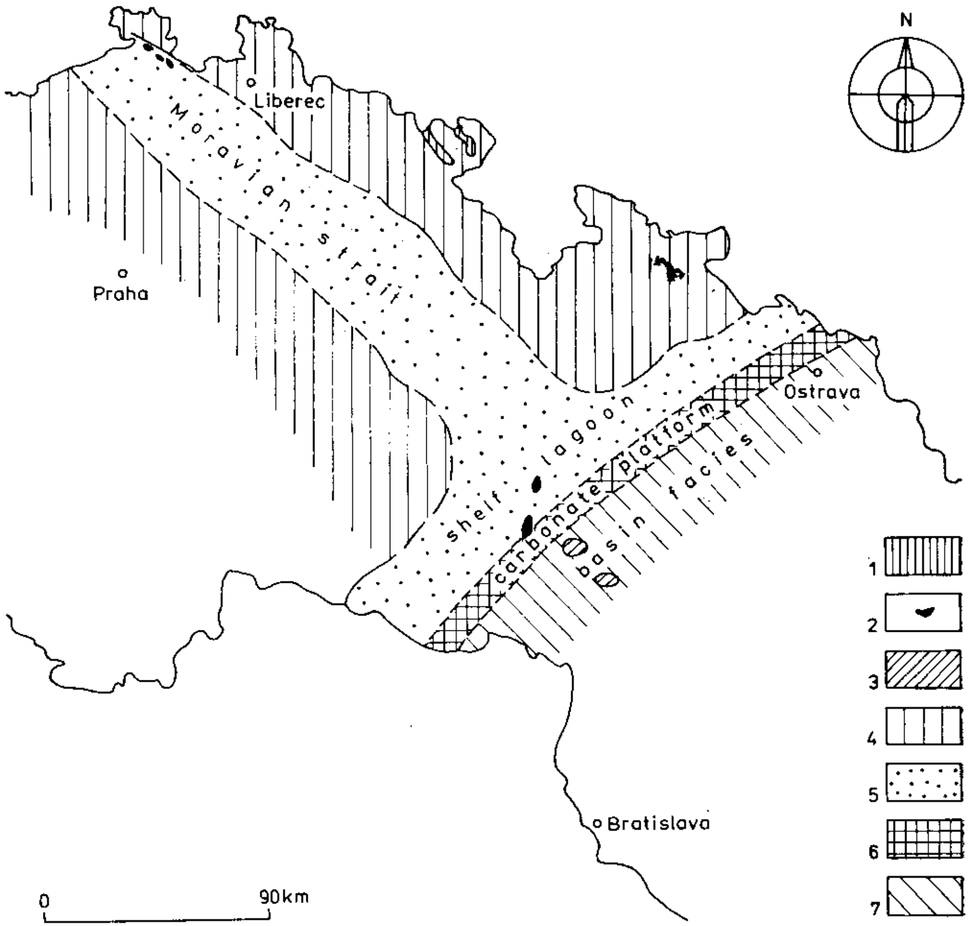
The Callovian-Oxfordian transgression proceeded into the Bohemian Massif both from the Boreal and Mediterranean (Tethydian) regions. Jurassic sediments have been chiefly preserved in the Dyje block, i.e. in the area situated SW of the fault zone of the Nesvačilka trough and extending to the basement of the flysch complex of the Wienerwald. North-east of this line the Jurassic sediments have been found in autochthonous position by boring near Uhřice and Ježov (K o s t e l n í č e k et al. 1979, Ř e h á n e k 1980). The finds of Jurassic relicts in the environs of Brno and Moravian Karst, combined with the distribution of pebbles of Jurassic rocks in Upper Cretaceous and Lower Badenian sediments suggest a considerable extent of the transgression. The Boreal sea invaded the area of the Bohemian Massif through the Labe zone.

At the time of maximum inundation the two seas became joined through the Moravian (Saxon, in the German literature) straits (D v o ř á k *in* S v o b o d a et al. 1966).

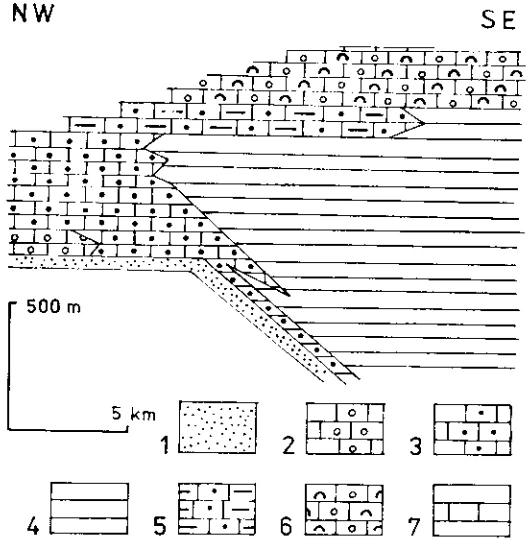
In northern Bohemia, in the blocks sunken along the Lusatian fault (around Doubice, Kyjov and Brtníky) the thickness of the Jurassic exceeds 120 m. The basal B r t n í k y M e m b e r consists of sandstones with layers of microconglomerate and claystone (secondary red beds, whose pigment had been redeposited from Permo-Carboniferous sediments). These beach, littoral and bar deposits are overlain by the Doubice Dolomite more than 100 m thick (E l i á š 1981). The diagenetic or epigenetic sparry dolomites represent original limestones deposited in an open shelf environment with a good circulation and normal salinity of sea water (a bay or a sea channel). On faunal evidence the stratigraphic range of the Jurassic in northern Bohemia is the Callovian—Kimmeridgian.

The Jurassic in the south-eastern part of the Bohemian Massif has a range of Callovian to Upper Tithonian and a thickness of over 2000 m.

On the Dyje block, the transgression deposited the N i k o l č i c e Formation, mainly in the predisposed NW—SE running Hustopeč-Nosislav depression, and partly also on the parallel Mikulov-Drnholec elevation situated farther to the south. These clastic sediments are interpretable as littoral, beach and bar or



3.49 Palaeogeography of the Triassic and Jurassic in the Bohemian Massif (M. Eliáš, orig.)
1 — contemporaneous extent of Jurassic; *2* — outcrops of Jurassic carbonates of shelf lagoon; *3* — occurrences of rocks of basin and carbonate platform development; *4* — landmass, presumed extent; *5* — shelf lagoon, presumed extent; *6* — carbonate facies, inferred extent; *7* — basin development — assumed extent



3.50 Lithofacies scheme of the Jurassic in the Bohemian Massif (M. Eliáš, 1978)
1 — Nikolčice Formation; *2* — Hrušovany Limestones and Dolomites; *3* — Nové Sedlo and Vranovice Limestones and Dolomites; *4* — Mikulov Marls; *5* — Kurdějov Limestones (lower part); *6* — Kurdějov Limestones (upper part); *7* — Kobylí Limestones and Dolomites

probably lagoonal deposits. The sequence is independent of the distribution of facies in the overlying units, which show the arrangement following the Carpathian trend (e.g. trends of palaeogeographic and facies boundaries).

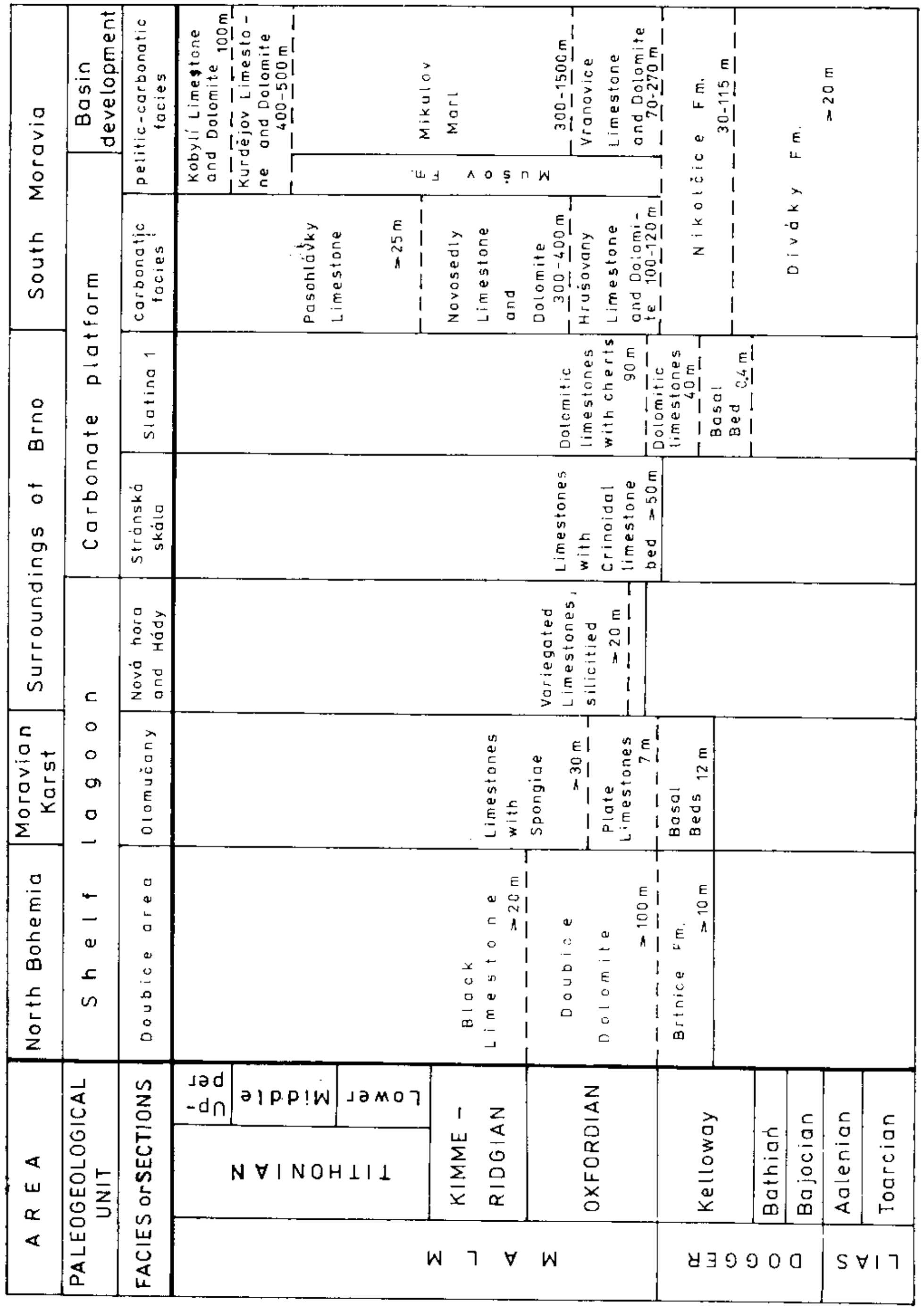
In the Jurassic of the Dyje block the pelitic-carbonate facies and the carbonate facies are discriminated in the Callovian, Oxfordian up to upper Tithonian interval (see Fig. 3.50).

Palaeogeographically, the Jurassic deposits in the SE of the Bohemian Massif are ranged to the Tethys shelf — a wide area of shallow-water carbonate sedimentation, which bordered the Tethys in the foreland. The following facies have been distinguished in the shelf area:

a) t h e b a s i n f a c i e s, a pelitic-carbonate development in the eastern part of the Dyje block, broadly E of the Dolní Dunajovice—Nikolčice line. Towards the E the facies links on the Jurassic sedimentary area of the Outer Carpathians. The sediments are of a neritic to bathyal type, forming below the level of wave movement, in an insufficiently aerated environment. The facies gradually petered out westwards on a shallow carbonatt platform, which was a source of clastic carbonate material for this area. As a result, the bodies of carbonate clastics in the basin wedge out towards the east;

b) t h e f a c i e s o f t h e c a r b o n a t e p l a t f o r m and its slopes in the eastern part of the Dyje block and SE of Brno (Stránská skála, Švédské valy). It is represented by shallow-water carbonates (including oolite benches, patch-reefs, sponge mounds, oncoid and stromatolitic limestones, etc.). The carbonate platform was 10—15 km wide and passed into a shelf lagoon to the NW;

c) t h e f a c i e s o f s h e l f l a g o o n (northern vicinity of Brno, Moravian



3.51 Stratigraphy of the Jurassic in the Bohemian Massif

Karst) deposited in the area of shallow-water carbonate sedimentation with a normal salinity and open circulation.

The shelf lagoon was probably of a large extent in the eastern part of the Bohemian Massif. It is evidenced by the finds of limestone and silicite pebbles in the Upper Cretaceous conglomerates in the wider area of Svitavy (Soukup 1956), in the lower Badenian of the Carpathian Foredeep between Znojmo and Vyškov, in the Neogene relics near Moravský Krumlov (Dvořák 1956) and in the environs of Třebíč (Zapletal 1926, K. Žebera, personal communication).

It is assumed that the connection with the Jurassic of northern Bohemia was realized through this area.

In the late Tithonian the sea retreated from the Bohemian Massif and this area became dry land.

The Cretaceous in the Bohemian Massif

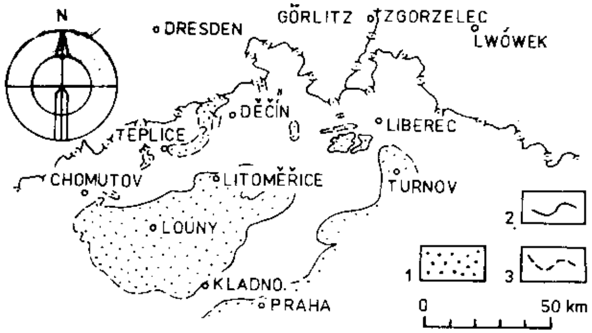
Lower Cretaceous — the Rudice Formation

The Rudice Formation (originally placed in the uppermost Jurassic) is represented lithologically by variegated clays with fragments of Jurassic cherts and quartz pebbles, and with locally developed limonitic Fe-ores at the base. In the vicinity of Rudice, Olomučany, Habrůvka and Babice it lies transgressively on the Devonian and Jurassic. The overlying fresh-water Cretaceous (Peruc-Korycany Formation) is of a definitely transgressive character. On the basis of superposition but without direct faunal and floral evidence the Rudice Formation is assigned to the Lower Cretaceous.

Of separate position, relatively far from the eastern margin of the Bohemian Massif, is the Cretaceous microfauna found near Kuřim NW of Brno; planktonic foraminifers with representatives of the genus *Hedbergella,* corresponding stratigraphically to the Aptian—Albian interval, have been recovered there in breccias. This facies, however, is clearly connected with the older Cretaceous development of the Carpathian Externides, which formed part of the Tethys. As a result of great subsidence of the margin of the Bohemian Massif, the transgression probably expanded along tectonic lines of NW—SE direction, which were strongly active mainly during the Tertiary giving rise to the Nesvačilka trough SE of Brno.

The Bohemian Cretaceous Basin

The Korycany Formation of ?Albian—Cenomanian age (Čech et al. 1980) is divided into the Peruc and Korycany developments. The Peruc development is generally older. The residual sediments and products of kaolinitic and lateritic weathering at its base are followed by kaolinitic sandstones, sandy claystones, and conglomerates. Thin seams of brown coal occur in the top part.



3.52 Palaeogeographical map of fresh-water Cenomanian in northern Bohemia (J. Valečka 1979)
1 — Conglomerates, sandstones, siltstones to claystones; *2* — verified boundary of the sedimentary area; *3* — presumed boundary of the sedimentary area

The whole sequence consists of continental alluvial, lacustrine and deltaic sediments, which in the younger part show even a lagoonal character.

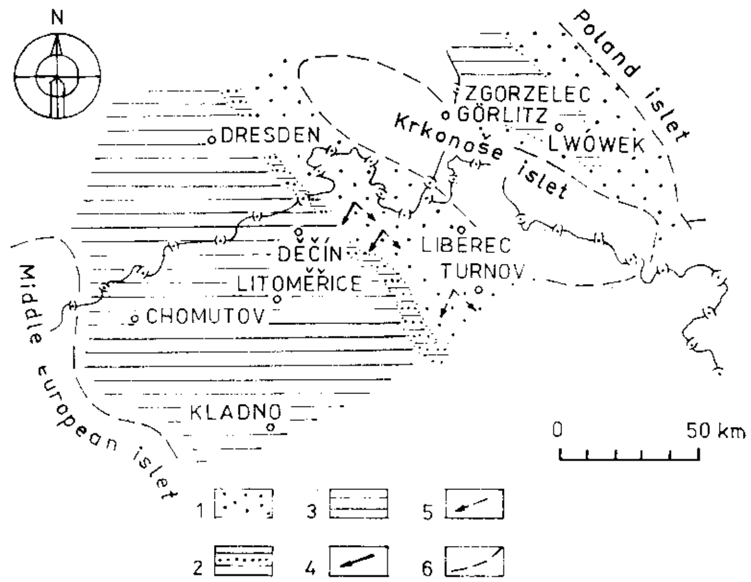
The Peruc development yielded rich macrofloral finds (e.g. Knobloch 1971) of angiosperms and gymnosperms with *Cunninghamites elegans* Corda, *Frenelopsis alata* (Feistmantel) Knobloch, and *Myrtophyllum geinitzi* Heer. The comparative palynological studies (Pacltová 1978) have revealed that the upper part of the Peruc development corresponds stratigraphically to the later Cenomanian.

Sedimentation of fresh-water complexes is limited to the topographical depressions developing along the tectonic lines in the Cretaceous basin (Fig. 3.52). The Peruc development attains a maximum thickness of 50 m.

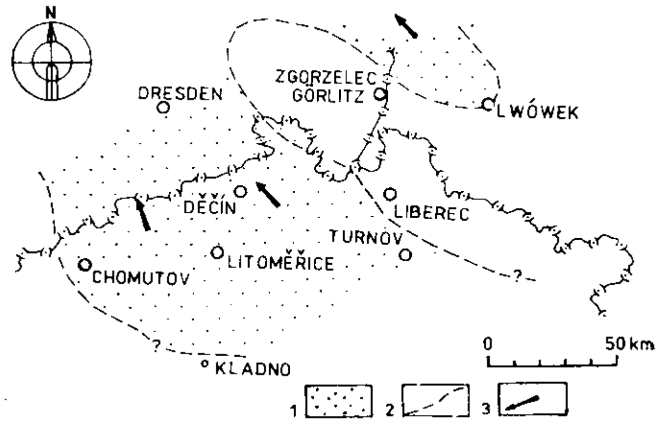
The Korycany development is predominantly younger and lithologically represented by quartzose and kaolinitic sandstones. At the base there are conglomerates in places, and in the uppermost part calcareous clays to clayey sandstones occur. Littoral sediments deposited in this period contain rich marine sessile fauna. The index bivalves comprise *Inoceramus crippsi* Mantell and *I. pictus* Sowerby; *Actinocamax plenus* (Blainville) is a typical bellemnite. In the Cenomanian the sea extended to the Bohemian Massif first from the Tethys and only later it became connected with the Cenomanian sea of northern Germany. The maximum thickness of the Korycany development does not exceed 100 m.

In the early Turonian, the Bílá Hora Formation was deposited in a deeper sedimentary area. Marlstones predominate and sponge spicules and spongolites occur frequently. Along the northern and southern margins of the basin there are siliceous sandstones. The average thickness of this sequence ranges from 30 to 60 m and up to 130 in the northern part of the basin. The

lower Turonian is characterized by foraminifers, as *Praeglobotruncana stephani* (Gandolfi), bivalves as *Innoceramus labiatus* (Schlotheim) and *Inoceramus cuvieri* Sowerby, ammonites as *Mammites nodosoides* (Schlotheim) and *Lewesiceras peramplum* (Mantell), and ostracodes *Bairdia supplanata bohemica* Pokornyi.



3.53 Palaeogeographical map of the lower Coniacian (J. Valečka 1979)
1 — sandstones; *2* — marlstones to calcareous claystones with sandstone interbeds; *3* — marlstones, claystones; *4* — predominant direction of transport; *5* — subordinate directions of currents and transport; *6* — presumed boundary of sedimentary area



3.54 Palaeogeographical map of lower Santonian (J. Valečka 1979)
1 — sandstones with siltstones and claystones interbeds; *2* — presumed boundary of sedimentary area; *3* — probable direction of transport

The upermost part of the Bílá Hora Formation seems to correspond chronostratigraphically to the middle Turonian, in the sense of the stratotype of this stage in the Anglo-Parisian basin.

In the middle and upper Turonian — the Jizera Formation — two cycles with alternating marlstones, marly sandstones and sandstones (often glauconitic) can be distinguished. The average thickness of this unit varies between 100 and 200 m; the maximum thickness of up to 400 m was established in the northern part of the basin. Typical fossils of the Jizera Formation are *Globotruncana "lamarcki"* (group), *Scaphites geinitzi* d'Orb. and *Rehacythereis pertubatrix* (Pokorný).

During the deposition of the Jizera Formation the sedimentary area became shallower and local regressions took place in marginal parts of the basin.

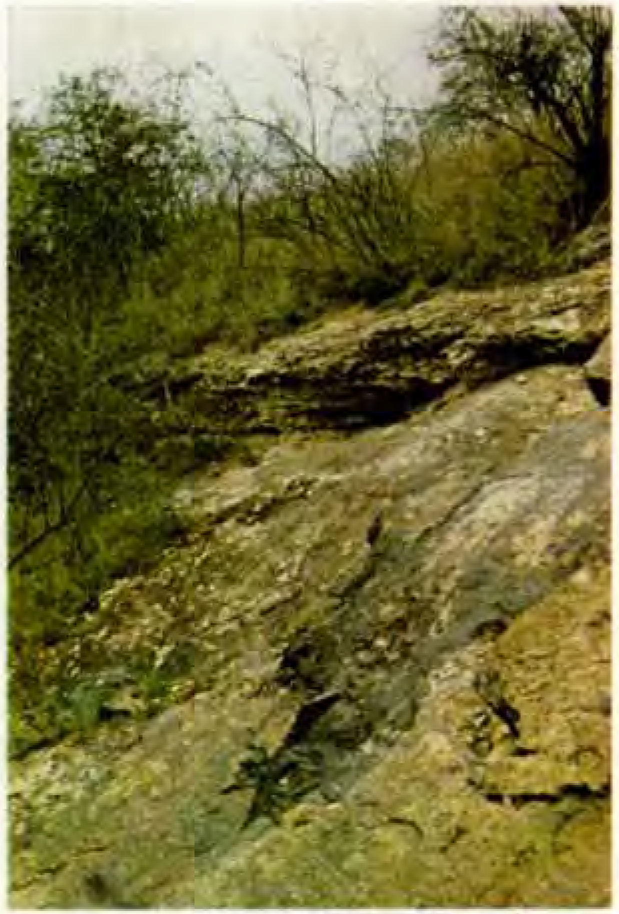
The uppermost Turonian to lower Coniacian is represented by the Teplice Formation in limestone facies in the lower part, and higher up composed of claystones and marlstones with limestone interlayers. The average thickness of the sequence ranges from 30 to 80 m, the maximum thickness reaching up to 110 m. The basal boundary is characterized by a thin coprolite bed. Typical fossils of the Teplice Formation are e.g. *Globotruncana linneiana* (d'Orb.), *Inoceramus costellatus* Woods, *Innoceramus rotundatus* (Fiege), *Placenticeras Orbignyanum* (Geinitz) and *Phacorhabdotus semiplicatus* (Rss.). During sedimentation of the Teplice Formation the sedimentary area was deepened again.

The Březno Formation corresponds to the Coniacian and very likely also to the earliest Santonian. Its lower part is an equivalent of the so-called Rohatec facies, but this belongs stratigraphically to the Coniacian and partly substitutes for the Teplice Formation.

Lithologically, the Rohatec facies is represented by alternating claystones and marlstones, and in the west of the Bohemian Cretaceous Basin locally by glauconitic sandstones. It is characterized by fossils such as *Inoceramus waltersdorfensis* Andert and *Inoceramus deformis* Meek.

The Březno Formation is a typical representative of the flyschoid facies of the Hercynian Cretaceous with an alternation of marlstones and psammites. The maximum thickness of up to 560 m is known to occur in the eastern limb of the Bohemian Cretaceous Basin, but the average thickness is about 240 m. Typical fossils of this unit are *Globotruncana* aff. *concavata* (Brotzen), *Inoceramus koeneni* Müller, *Inoceramus involutus* Sowerby, *Martoniceras pseudotexanum* Grossouvre and *Karsteneis karsteni karsteni* (Rss.).

Typical of the latest Santonian Merboltice Formation is the sedimentation of psammites under the conditions of decreasing subsidence of the whole Bohemian Cretaceous Basin and gradual constriction of the sedimentary area. Both fauna and flora are considerably impoverished; it comprises e.g. *Inoceramus* sp., *Sequoia reichenbachi* Geinitz, *Myrthophyllum angustum* (Velenovský) Knobloch. Regressive Santonian sandstones are known from the W of the České středohoří Mts.



3.55 Middle Cretaceous (Cenomanian) transgression on the garnetiferous gneisses of the Moldanubicum. Zbyslav near Čáslav
Photo by M. Suk

As emphasized above, the Bohemian-Saxonian (Hercynian) Cretaceous basin was a link betwen the Mediterranean and Boreal regions. This connection existed with great probability from the Cenomanian and culminated in the Turonian. During the Santonian the sea retreated completely from the area of the Bohemian Massif.

The beds of the Bohemian Cretaceous Basin lie horizontally or nearly horizontally. Structurally, the basin is a syneclise whose axis runs from Dresden through the northern tract of the Elbe (Labe) valley across NE Bohemia to the NW of Moravia. Tectonic movements were produced by the "Saxonic" folding. Saxonic tectonic lines, however, had remained active even during the Cenozoic.

3.56 *Prediscosphaera cretacea* (Arkchanelsky) Gartner. Bohemian Cretaceous Basin, Teplice Formation (base), Krysta locality, Turonian—Coniacian boundary. ×6500 (material of L. Švábenická)
Photo archive ÚÚG, Praha

The Cretaceous of the Osoblaha area

The occurrence of younger Cretaceous sediments was assessed in the Osoblaha area (Skácel 1970), in the OS-5 borehole near Slezské Pavlovice. Soukup (1968) found in the lower part of the sequence (413—491.5 m) formed of light-grey calcareous claystones a rich inoceramic fauna (e.g. *Inoceramus lusatiae* And., *Inoceramus waltersdorfensis* And., *I. striatoconcentricus* Gümb.). This assemblage is dated as late Turonian.

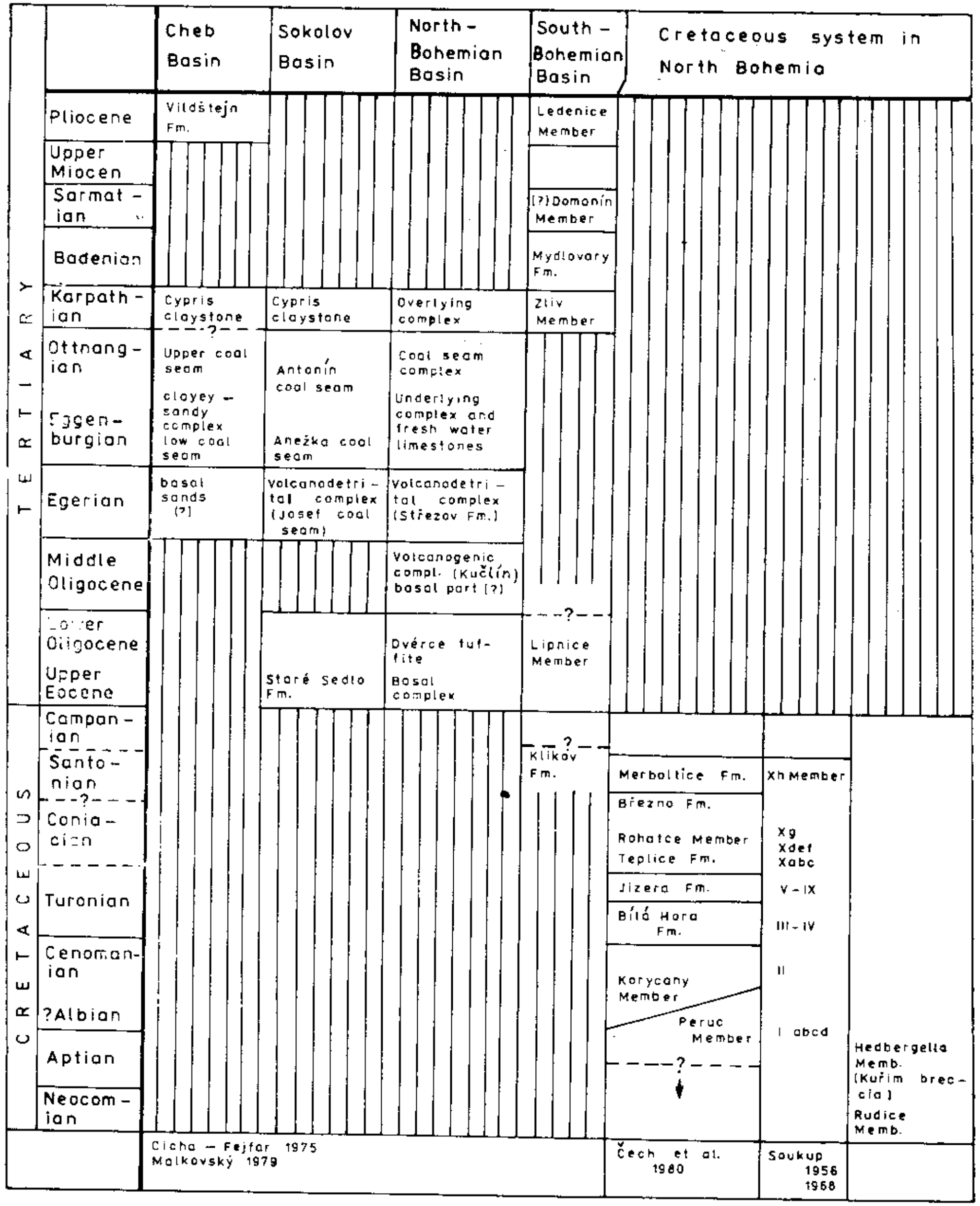
The overlying light-grey silty micaceous claystones and siltstones with coal detritus encountered in the depth interval of 223.3—413.0 m correspond to the Coniacian. The lower part of the sequence yielded *Inoceramus* ex gr. *inconstans* Woods, and the upper part *I. kleini* G. Müll. The overall lithological character of the Cretaceous from the OS-5 borehole recalls the Coniacian and Turonian sediments from the Kłodzko graben (Králíky trough). They are in part equivalent to the Kieslingswald "Beds". In the N part of the Osoblaha area salient relics of Cenomanian glauconitic and kaolinitic sandstones lie on the Culm. Their Cenomanian age is documented by the occurrence of *Exogyra columba* (Lam.) and *Protocardia hillana* Beyrich.

Cretaceous in the South Bohemian basins

Klikov Formation: During the late Turonian and early Senonian the southern part of the Bohemian Massif experienced subsidence movements in contrast to a gradual upheaval of its northern part. In the Třeboň and Budějovice depressions a varied lacustrine sequence of coarse-grained sand, conglomerates, often arkosic, variegated clays, and sandstones with coalified plant remains and Cretaceous plant imprints, was deposited. The maximum thickness of the Klikov Formation has been established in the Třeboň basin (450 m). The

3.57 *Credneria senonense* (Knobl.) Němejc et Kvaček. Budějovice basin, Klikov Formation, Zahájí locality, Santonian. Natural size (material of E. Knobloch)
Photo archive ÚÚG, Praha

richest finds of macroflora come from the neighbourhood of Hluboká nad Vltavou and Zliv in the České Budějovice area; the presence of *Cucculophyllum extincum* (Velen.) Němejc et Kvaček and *Quercophyllum pseudodrymejum* (Velen.)



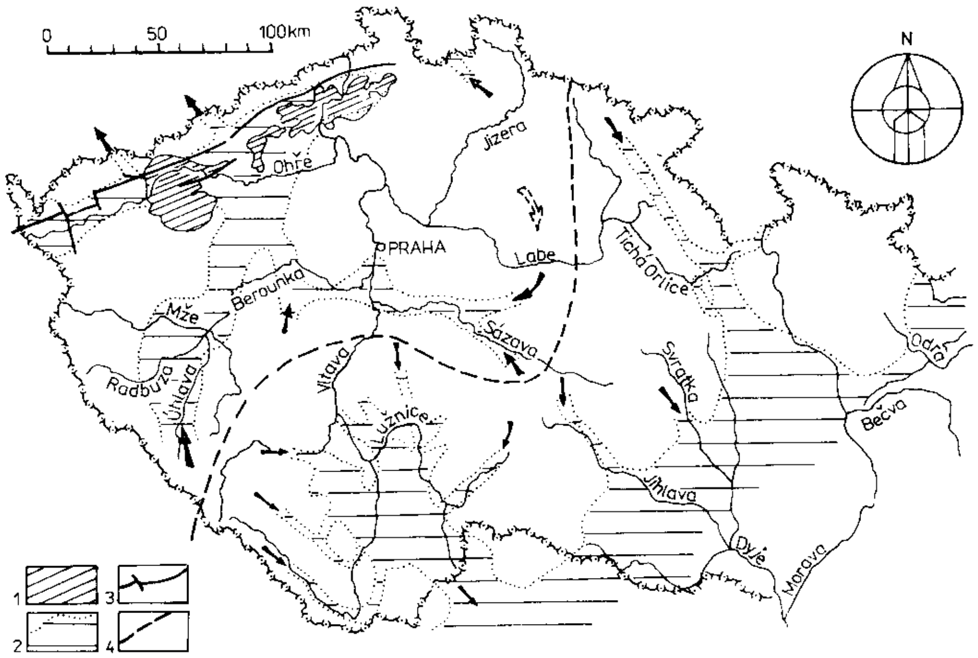
3.58 Stratigraphy of the Cretaceous and Tertiary in the Bohemian Massif

Němejc *f. latifolium* Němejc substantiate close relations of this flora with the Senonian flora of northern Bohemia and Lower Silesia.

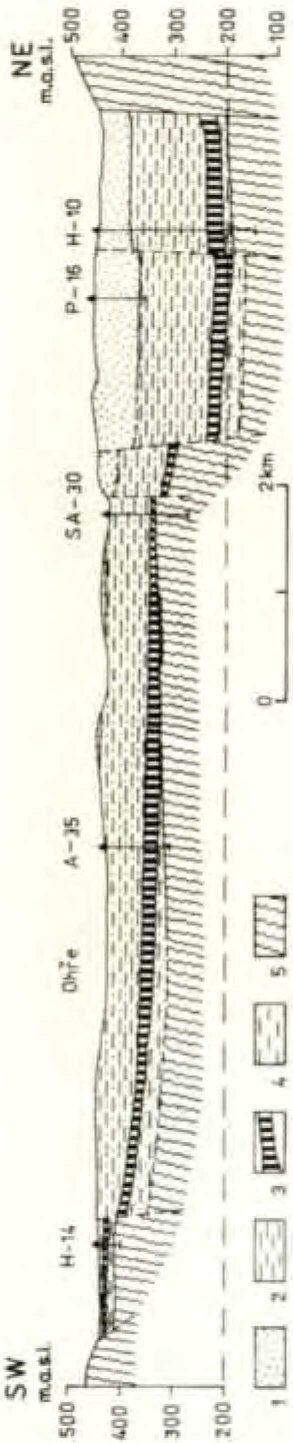
The comparative palynological studies of the Coniacian marine sediments with those of basal beds of the South Bohemian Upper Cretaceous have shown that sedimentation in South Bohemian basins began at the latest in the Coniacian and lasted until the Santonian (P a c l t o v á 1979).

3.1.5 Tertiary

The stratigraphy of the Tertiary basins and occurrences in the Bohemian Massif is summarized in the stratigraphic table (Fig. 3.58). It was compiled from all data available, critically considered and confronted with the tectonic and palaeogeographic history of the Bohemian Massif during the Cenozoic (M a l k o v s k ý 1979). The objective of the following brief description is to point out some peculiarities of the development of the basins.



3.59 **Distribution of the Tertiary in the Czech.** Soc. Republic (M. Malkovský 1975)
1 — neovolcanites; *2* — assumed distribution of Miocene sediments; *3* — faults; *4* — Miocene watershed between the German—Polish sea and the Alpine-Carpathian foredeep



3.60 Geological section of the Cheb basin (after P. Šantrůček, *in* M. Malkovský 1980)
1 — Vildštejn Formation, Pliocene; *2* — Cypris Formation, Miocene; *3* — Main seam Formation; *4* — Lower sands and clays, Miocene; *5* — crystalline complex (Upper Proterozoic)

Basins at the foot of the Krušné hory Mts.

In contrast to the deep-rooted hypothesis that the basins below the Krušné hory Mts. fill a graben, a model of volcanic-tectonic subsidence at the site of the volcano-tectonic zone running across the Bohemian Massif, has been developed. It is based on the fact that each basin has its own separate development (Malkovský 1980).

The Cheb basin. The principal tectonic direction of NNW—SSE of the basin coincides with that of the Cheb-Domažlice graben. The maximum subsidence of this asymmetric basin of 300—400 m has been established at the eastern tectonic limitation by the Mariánské Lázně fault against the crystalline ridge Chlum nad Ohří. The thickness of Neogene sediments is up to 300 m.

The relics of Eocene sediments, i.e. equivalents of the Staré Sedlo Formation only form fillings of open fissures at the western margin of the basin. Neovolcanites produced in the major lower Miocene phase are not very widespread, usually occurring also as fissure fillings. Depressions in the basin bottom are filled with the Lower clay and sand Formation, which is followed by the Coal-seam Formation of larger extent (<50 m thick, the maximum thickness of the coal seam <32 m). Coal sedimentation occurs in three parts of the basin: in the Oldřichov-Pochlovice, Odrava and

3.61 *Dryophyllum furcinerve* (Rossm.) Schmalh., Sokolov basin, Staré Sedlo locality, upper Eocene (material of E. Knobloch)
Photo archive ÚÚG, Praha

Františkovy Lázně partial basins. The Coal-seam Formation is overlain by the Cypris Formation, consisting of claystones with pyrite concretions and carbonate interlayers. It is of the greatest thickness at the eastern margin of the basin. These sediments belong stratigraphically to the lower Miocene (upper Egerian to Ottnangian). The finds of mammal remains suggest that sedimentation at some places, e.g. in the environs of Františkovy Lázně occurred still in the latest early Miocene (Karpatian). In the Cheb basin extensive sedimentation took place in the Pliocene, particularly in the latest Pliocene (Romanian), when the Vildštejn Formation was deposited. In its continuation there are Neogene relicts in the Cheb-Domažlice graben (Tertiary of Mariánské Lázně — area 2b). Their thickness is up to 100 m at the eastern margin.

In the Quaternary, neovolcanic effusions occurred in the Cheb basin (Komorní hůrka, age 0.26—0.85 Ma, Železná hůrka, age 1.0—5.0 Ma; Šibrava - Havlíček 1980), and a small postglacial basin had originated and was filled with diatomaceous earth and peat — Soos near Hájek, in the proximity of Františkovy Lázně. The Cheb basin has been up to date the most seismically active area in the Bohemian Massif (Dvořák 1958a,b).

The Sokolov basin. In contrast to the Cheb basin, the structure of this basin is controlled mainly by the faults of WSW—ENE trend, although the earlier tranverse faults of NW—SE direction (i.e. of another trend than shown by those of the Cheb-Domažlice graben) had been involved in the formation of the basin filling. Two major strike faults bound the basin structure: the Krušné hory fault in the N and the Ohře fault in the S.

In the Sokolov basin and at the southern margin of the Doupovské hory Mts. the Staré Sedlo Formation occurs in its classic development. Fine- to coarse-grained sandstones with kaolinic cement, secondarily silicified, are the predominant rock type. Their maximum thickness has been assessed at the southern margin and in the centre of the Sokolov part of the basin. The plant assemblage is of ancient type, of late Eocene age, with many subtropical and tropical elements (Knobloch 1962).

After a stratigraphic hiatus, the sequence of the Josef seam was deposited. Hokr (1962) proved that the Josef seam is a component of continuous coal-forming sedimentation, suppressed by clastic fluviatile and lacustrine material and deposition of pyroclastics. The volcanogenic complex developed from the sequence of the Josef seam. The volcanic material was supplied by the Doupovské hory stratovolcano. The volcanogenic complex attains maximum thicknesses in the area of Nové Sedlo and Alberov, apart from the western margin of the Doupovské hory, where the thickness increases abruptly. As conclusive evidence of the age of the volcanogenic complex in the Sokolov basin is not yet available, and the pollen spectrum resembles that of the Main seam (Pacltová - Žert 1961), we place it into the Aquitanian (Upper Egerian).

Directly above the lower part of the volcanogenic complex, the coal-forming sedimentation of the Main coal-seam Formation began. It includes the Anežka and Antonín coal seams in the Sokolov basin. The Anežka seam is developed only in its western part at a thickness of 5—12 m. In the central part of the basin the Anežka seam merges with the Antonín seam, forming its lower part. The Antonín seam is the thickest (20—30 m) and most persistent coal seam of the Sokolov basin. The united Anežka and Antonín seams in place of their conjunction attain a thickness of 60 m. Sedimentation of the Main coal-seam Formation was closed by a sudden rise of water level and

development of an extensive lake instead of coal-forming swamp. The Cypris Formation which sedimented in it is formed of pelites. Exceptional are the Čankov Sands, 10—30 m thick, constituting an alluvial cone extending from the N, in the upper part of the Cypris Formation.

The Sokolov basin is distinguished by a special development of Neogene sequences, due to synsedimentary subsidence of individual blocks into which the basin is dissected. The sediments are of early Miocene age (late Egerian—Ottnangian).

The North Bohemian Basin. It is a typical example of a basin formed as a result of volcano-tectonic subsidence. The Žatec sector between the Střezov and Podbořany faults subsided into emptied magmatic chambers, which supplied material for the Doupovské hory Mts., and the Most sector between the Krušné hory and Bílina faults sank into the space left after the extrusion of volcanic material for the western part of the České středohoří Mts.

Palaeogene sediments are known from the Podbořany area. In the kaolinic sands equivalent to the Staré Sedlo Formation, plant remains near Valeč and mammal finds in the basal part of the volcanogenic sequence (Dětaň, Dvérce — Bůžek - Kvaček - Fejfar 1979) provide evidence of the late Eocene age of this complex.

The Volcanogenic Formation, represented for the most part by a thick layer of tuffs and tuffites, is not developed over the whole area. It dates from the main lower Miocene phase of neovolcanic effusion in the Doupovské hory and the České středohoří Mts. The start of volcanic activity has not been conclusively dated so far. On the basis of the only floral genus *Doliostrobus* (Bůžek - Kvaček - Fejfar 1979) and the only faunal genus *Elomeryx*, and of the radiometric K/Ar age (L. Kopecký 1978) the basal beds are thought to be 35,000,000 years old (early Oligocene).

The lower Miocene filling of the North Bohemian basin is divided (according to miners' usage) into the Underlying Formation, Formation of brown-coal seams, and the Overlying Formation. Their total thickness in the deepest Most sector of the basin surpasses 500 m.

The Underlying Formation composed dominantly of sands and clays fills the depressions in the basin floor. In places there are indications of coal sedimentation and thin seams of brown coal. The sequence is not developed within the whole basin.

The Formation of brown-coal seams in the Chomutov, Most and Teplice sectors of the basin is represented by a uniform coal seam with a thickness exceeding even 40 m. The coal seam shows a complicated development at the mouths of ancient streams in the Bílina and Žatec areas. The alluvial cones greatly affected the formation of the coal seam. In the Bílina area, a typical delta-like development on a small scale is observed (Hurník - Prokš 1977), whereas in the proximity of Žatec the seam became split (from N to S) into three minor seams, which gradually pass into coal clays and clays with coal admixture. Simultaneously, the thickness of inter-seam sequences and their contents of psammites increase.

The Overlying Formation, which at a thickness of up to 500 m covers the coal seam, implies the deepening of the lake basin and deposition of clays in particular, and of sand in the environment of the two deltas. Sandy sedimentation which also appears in places at the Krušné hory margin of the basin indicates a supply of material by minor streams from the Krušné hory crystalline area. Sedimentation of the Overlying Formation is for the most part quiescent, monotonous. Only in the uppermost part of the sequence, in the Lom Member (Váně 1961, Elznic 1966) the coal and sand sedimentation demonstrates a gradual evanescence of the lake.

On rich palaeontological evidence the age of the basin filling is early Miocene (late Egerian to Ottnangian).

The Tertiary of the Plzeň area (2a) belongs genetically to the North Bohemian basin. It was deposited by a system of streams that opened into the North Bohemian basin in the Žatec and Bílina areas (Čadek 1966, Malkovský 1975, Pešek 1972). The fluvial and occasional limnic deposits are coeval with the sediments of the North Bohemian brown-coal basin.

Tertiary of western Bohemia

The new palaeogeographic assessment of the Tertiary of W Bohemia is based on the analysis of the Neogene of the Bohemian Massif and the Alpine and Carpathian foredeeps (Malkovský 1975). The conception of a uniform drainage system in Neogene time (Kodym, Sen. 1963) and of the identical age of all Neogene occurrences within the interval of late Egerian — early Badenian (Václ - Malkovský 1962) has proved untenable.

The system of streams opening into the North Bohemian basin, to which the Tertiary of the Plzeň area belongs (2a) and on which the river system of central Bohemia is linked, is of early Miocene age. It drained the Moldanubicum region to the NW.

On the contrary, the system of streams opening into the Cheb basin, to which the Tertiary of Mariánské Lázně belongs (2b) existed in the late Pliocene. They flowed through the Cheb-Domažlice graben, draining the adjacent mountain ranges.

The stratigraphic range of the neovolcanic complex of the Doupovské hory and České středohoří Mts.:

a) The Doupovské hory Mts. The beginning of the activity of the Doupovské hory stratovolcano was previously placed in the Aquitanian. At the present it is dated, on evidence mentioned above, as early Oligocene. On an indirect evidence, i.e. the occurrence of volcanogenic material in the Antonín seam and close above it, the volcanic activity expired at the Eggenburgian/Ottnangian boundary. There are no reliable proofs for the existence of later volcanic phases in the Doupovské hory.

b) The České středohoří Mts. The beginning and termination of the main neovolcanic phase were synchronous with those of the volcanic activity in the Doupovské hory Mts. However, the ascent of neovolcanites continued here in a second phase. It is demonstrably represented in the area of Teplice (Lom near Most, Štrbice); it is younger than the sedimentary filling of the basin but its stratigraphic position is not known so far. There is no safe evidence available of whether it is an independent phase or a phase approximate to or identical with the latest, Pliocene to Pleistocene phase (Šibrava - Havlíček P. 1980). An intricate stratigraphy of the volcanic complex of the České středohoří is also suggested by very young sedimentary interbeds in the central part (Sarmatian — Řeháková 1967).

The Žitava basin

The Žitava basin extends on the territory of Czechoslovakia, the German Democratic Republic and Poland. Although it is separated from the eastern part of the České středohoří Mts. by a narrow transverse horst trending NW—SE (the Lužice fault), it belongs to the Neogene zone of volcano-tectonic subsidence.

Its development is consistent with the history of other basins at the foot of the Krušné hory Mts., and the sedimentary filling consists of lower Miocene beds (upper Egerian to Ottnangian).

In the vicinity of Hrádek nad Nisou, the sediments are underlain by neovolcanites of the main lower Miocene phase. The almost 400 m thick sedimentary filling is divided into the "Lower Hrádek Member", which occurs in the W of the Hrádek part of the basin, is maximum 140 m thick and bears the lower brown-coal seam (4—23 m in thickness). The "Upper Hrádek Member" overlies the lower brown-coal seam within the whole Bohemian part of the basin; its thickness exceeds 270 m. About 160 m above the coal seam there is a barren middle seam horizon of a thickness of 20—35 m; about 200 m above the lower coal seam the upper seam horizon covered with 50 m overlying clays has been worked until recently.

The relicts of lower Miocene between Frýdlant, Kundratice, Višňová and Arnoltice are also grouped with the Žitava basin. They represent a reduced development of the two units, and Václ (1964) considers the seam mined in the part near Víska as an equivalent of the lower coal seam.

The Žitava basin was supplied with clastic material by a stream flowing from the western margin of the Krkonoše-Jizerské hory pluton and its contact (Václ-

- Čadek 1962). Sediments occurring near Chrastava, Machnín and in Liberec (Janův Důl, Horní Hanychov) are of the same age as the "Upper Hrádek Member".

The Tertiary in the basins of southern Bohemia

The Neogene filling of the Třeboň and České Budějovice basins is to be considered with respect to the drainage pattern during the middle Miocene, when a predominant part of Bohemia was drained into the Alpine and Carpathian foredeeps in the SE, and in the Pliocene, when the streams flowed north- and southwards from the upheaving area of central Bohemia. Sedimentation in the two basins was contemporaneous.

The Palaeogene (Oligocene) Lipnice Formation is preserved only in relics, formed of sandstones of fluviatile and lacustrine origin and usually silicified.

The Zliv Formation is the oldest Neogene unit. It had also succumbed to erosion and the preserved relics are silicified. The thickest and most extensive complex is the Mydlovary Formation composed of clays, diatomaceous earth and coal. It is also best preserved and readily comparable with the lower Badenian of the Alpine foredeep (Řeháková 1965, Malkovský 1975, 1979). Its character was modified by ingressions of salt water from the Alpine foredeep. The following fresh-water moldavite-bearing Domanín Formation overlies it in places; along the basin margins it consists of psammites and psephites and in the centre of clays. In age the complex corresponds most probably to the earliest Sarmatian (late Badenian?). The Ledenice Formation lying unconformably on the Mydlovary and Ledenice Formations is of Pliocene age and again of fresh-water, generally lacustrine derivation.

Of primary importance for the development of the South Bohemian basins was the early Badenian transgression extending from the Alpine and Carpathian foredeeps into the Bohemian Massif at the time of the deposition of the Mydlovary Formation. The sea advanced through the river valleys far into the interior of the Massif (up to Lanškroun, Ústí nad Orlicí and Tišnov), and in flat areas, as were the South Bohemian basins, is caused the salinity of streams and formation of through-drainage lakes. The sediments of the streams that opened into the bay of the early Badenian sea near Lanškroun are known from the areas at the foot of Orlické hory Mts. and around Králíky.

The lower Sarmatian sediments of the South Bohemian basins are linked with the Sarmatian fresh-water molasse in the foreland of the Alps. The Sarmatian sediments are traceable, for example, in the Schwandorf valley (Tillmann 1964), i.e. at the same geographic latitude as is the northern border of the Třeboň basin near Tábor.

Tertiary in Silesia

Along the state frontier with Poland, the fresh-water lacustrine sediments extend to Czechoslovakia in the neighbourhood of Vidnava. Grey kaolinitic clays with illite admixture were mined together with a coal seam at Uhelná. The Neogene sequence attains a total thickness of up to 40 m and belongs to the lower Miocene (Mazancová 1958). Recent investigations (Gabriel et al. 1982) have not provided unambiguous stratigraphic data.

3.1.6 Quaternary

The dating of Quaternary sediments in the Czech Soc. Rep. is based on the universally accepted fundamental division of the Quaternary into the Lower, Middle and Upper Pleistocene and the Holocene. We are well aware that there is a certain inconsistence in assigning the former earliest Pleistocene, i.e. the stages termed Donau, Biber, Butley, Tegelen, Pretegelen, Brüggen, etc., to the relatively well recognized Lower Pleistocene, although we do not know either the number and character of their climatic oscillations or their duration. Moreover, this classification does not take into consideration the geological peculiarities of the sediments or the differences in the palaeorelief of the site of sedimentation. The last but not least important reason is the lack of unanimity on the date of the Pliocene—Pleistocene boundary, which varies between 3.5 to 1.8—0.69 million years, i.e. within a range longer than was the whole Quaternary in the classic conception.

With respect to these facts we deal, at least in a detailed description, separately with the oldest period and designate it in agreement with Žebera (*in* Svoboda et al. 1966) as the Early Glacial and Interglacial; the First Glacial is here meant to be the Günz.

The Early Glacial (Donau, Biber, Pretegelen)

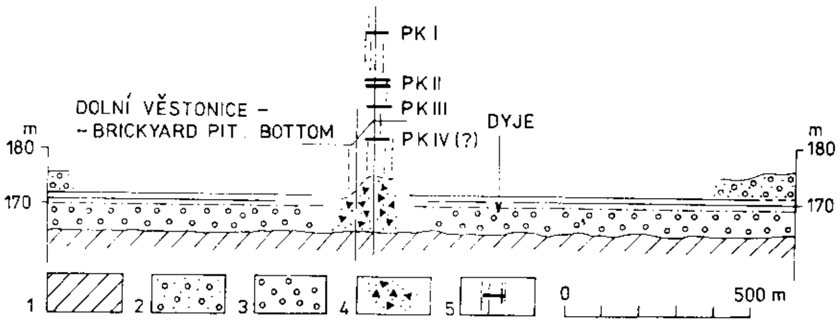
This period embraces several, not accurately defined cold and warm oscillations at the beginning of the Quaternary, occupying at least one third of its whole duration. The oldest sediments of this age in the region studied are usually preserved on platforms above the valley of the present-day rivers or as basal members of the Quaternary complex in depressions.

In the Cheb basin Pacltová (1962) assigned the Vildštejn Formation to this period but this stratigraphic position is not quite conclusive (Knobloch 1965, Šibrava 1974).

		EXTRAGLACIAL REGIONS				REGIONS OF CONTINENTAL GLAC.		
STRATIGRAPHY	Rodentia Fejfar-Heinrich 1980	Vltava Záruba-Bucha-Ložek 1977	Ohře Balatka-Sládek 1975	Labe area Sekyra 1967	Central Moravia Zeman et al. 1980	North Bohemia Šibrava 1972	Odra region Macoun et al. 1965, Šibrava 1972	Opava Highland Macoun 1980
W 1–3 Weichselian	Thoringian	VII. Maniny	valley (3/4 m) terrace; VII_3	0-2/11m; 3/7m; 5/4m	loess; PK I.; loess; PK II.; loess; valley terrace level I.	loess, slope sedim.; low terraces undiff.	loess; Ostrava f. soil; loess; Opava f. soil; loess; valley terrace, slope sediments	upper loess; Ostrava foss. soil; middle loess; Opava foss. soil; lower loess; valley terrace, slope sediments
R/W Eem		PK III.	(hatched)	PK III, gyttja	PK III, travertines Předmostí, Přerov, Radslavice	(hatched)	Pišť fossil soil	Pišť fossil soil
R_2 Warthian		VI. Veltrusy	VII_2; VII_1	confluence terrace; 10/0-2 m; 18/5 m	loess, proluvium; Nenakonice terrace level II.	8-12 m terrace	loess, soli-fluction, proluvium; 8m terrace	loess; loess; loess; loess series; Neplachovice
$R_{1/2}$ Treene		PK IV	VI_4 (6/2m)	20/14 m	PK IV, Předmostí (older travertine)	(hatched) ?	peat bog; Kravaře ter.	fossil soil
R_1 Saalian s.s.		V. Dejvice	VI_3 (8/4m); VI_2; VI_1 (17/11m)	24/18m	loess, proluvium; main terrace level III.	15-18m terrace unspecified	Saale glaciation; main terrace upper accumul.	Oldřišov glaciation; Neplachovice interst.; Pathcnec glaciat.; main terr. upper accumulat.
M/R Holstein s.l.		PK V +?	V_2 (21/15m); V_1 (25/19m)	(hatched)	Tučín, Želatovice (travertine); main terrace lower accum.; PK V +?	(hatched)	younger w. oscill. relic lakes; main terrace lower accumul.; older w. oscill. peat bog	Jaktař interglacial
M_2 Elster	Biharian	IV. Letná	IV_5 (27/21m); IV_4 (30/25m)	38/30m	loess, proluvium; Brodek terrace level IV.	Elster glaciation; preglacial terraces	Muglinov terrace; Elster glaciation; preglacial terraces	Kravaře glaciation; 2nd advance; main terrace middle accum.; Uhlířov warm osc.; 1st glac. advance; main terrace lower accum.
$M_{1/2}$		PK VI	IV_3 (33/28m)	? /35-30m				Otice warm period
M_1		IIIb Vinohrady	IV_2 (38/32m); IV_1 (43/37m); III_2 (52/45 41m); III_1 (55/46m)	55/46m	fluvial lacustrine sediments			Early Elster (Opava) glaciation
G/M Cromer s.l.		(hatched)	(hatched)	(hatched)	old fossil soils, ferreto	(hatched)	(hatched)	Slavkov interglacial
G_2 Menap		IIIa Kralupy	II_3 (64/59m)	77/70m	old loess series; 5 separate gravel accumulat.; younger gravel sheet level V.	preglacial terraces ?	higher preglacial terraces	late pre-glacial; fluviolimnic sediments; 35m terrace
$G_{1/2}$ Waal		Cromerian? Únětice	II_2	88/80m				
G_1 Eburon		II Pankrác	II_1				high preglacial terraces	
D/G Tiglian	Villányian	(hatched)	?	90/88m ?				Kobeřice interglacial
D_2	Villafranchian	Ib Suchdol	I_4 (87/84-80m); I_3 (98/93m)		3 separate gravel acc.; travertine Kokory conglomerate; older gravel sheet level VI.			early pre-glacial; local limnic sediments; 50m terrace
$D_{1/2}$		(hatched)	I_2 (112/110m)					
D_1 Pretiglian		Ia Lysolaje	I_1 (125/120m) ?		lacustrine sediments, "varicoloured series"			fluviolimnic sediments ?

3.62 Stratigraphic scheme of Quaternary in the Bohemian Massif and the Carpathian Foredeep (orig. J. Tyráček)

In the Vltava-river valley most authors think the terraces of group I to belong in this stage (Záruba - Bucha - Ložek 1977), the Lysolaje terrace to stadial D1, and the Suchdol terrace to stadial D2. In the Labe valley, above the junction with the Vltava, it is the Horní Přím terrace (Žebera 1956) and downstream of the Vltava—Labe junction the Krabčice terrace (Balatka - Sládek 1976) that are ranged here. In the relic of the last named terrace near Ústí nad Labem, bones of elephant Archidiskodon genus were found (Liebus 1929, Šibrava 1972). In central Bohemia banded lacustrine clays to marls, whose relics have been preserved between Budeč and Dřetovice in the Kladno area probably correspond to stadial D1 (Ž e b e r a *in* S v o b o d a 1966). The existence of a large lake in central Bohemia and in the area of Říp Hill postulated by Ž e b e r a (1972) is still questionable.

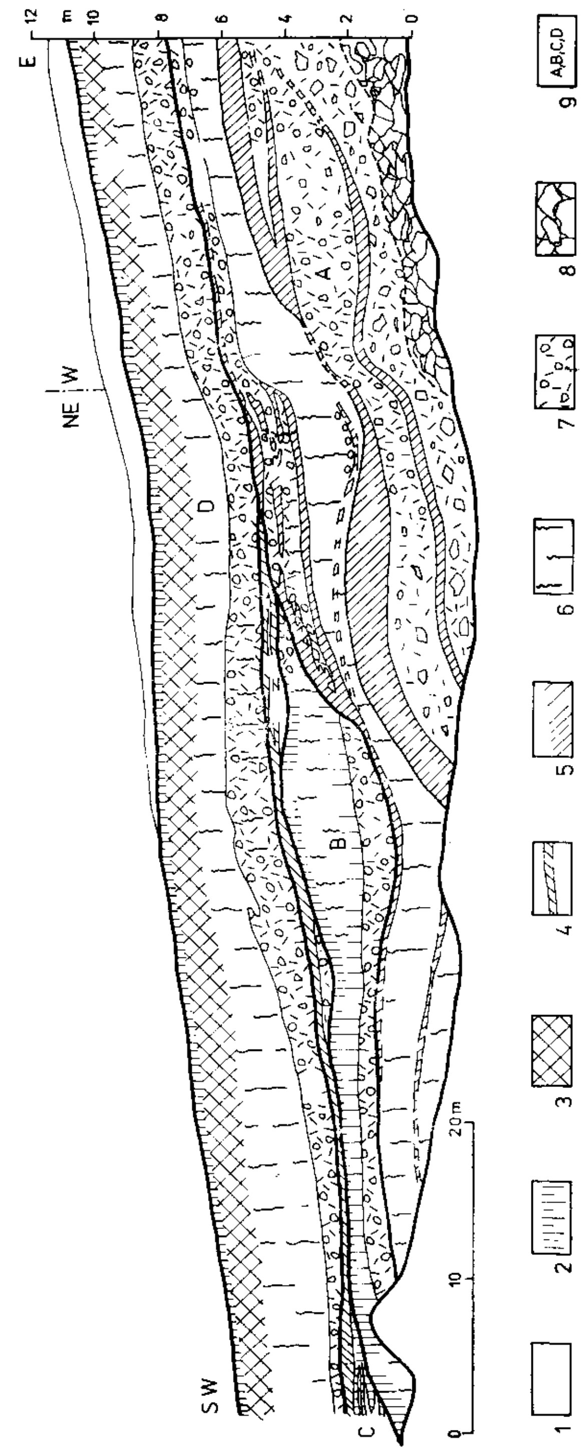


3.63 Dolní Věstonice loess series in relation to low terraces of the river Dyje (A. Zeman)
1 — substratum (Outer flysch); *2* — sandy gravel of the Main terrace; *3* — fluvial sandy gravel of valley terrace; *4* — stony slope loam; *5* — loess with fossil pedocomplexes

In the drainage basin of the river Ohře, four highest terraces of group I have been placed in the Early Glacial (B a l a t k a - S l á d e k 1962) and parallelized with the Labe terraces. According to palaeomagnetic measurements of A. Kočí, the Vysočany terrace (I_2) falls in the Matuyama phase, either 0.9 or 1.7 million years B. P. The second date appears to be more probable. Although it is only an approximate interpretation of a single measurement, the great difference between the age of the Lysolaje terrace group (820—980 thousand years, Z á r u b a - B u c h a - L o ž e k 1977) and the almost twice as great age of the Vysočany terrace indicates that the correlation of river terraces in the Bohemian Massif is not only the question of topographic position, and that it will not be simple to settle.

In northern Moravia, the relics of high terraces preserved along the rivers flowing from the Beskydy Mts. and from the Bohemian Massif as well (T y r á - č e k 1961a, M a c o u n et al. 1965, M a c o u n 1980) are ranged to this period. They are represented by gravel without Nordic material. Of the same age are very likely preglacial sediments of through-drainage lakes, which have been found at the base of the Quaternary in the depressions and tectonically sunken valleys ? of the old drainage network in the Opava area.

The upper part of the "Pliocene varied sequence" of the Upper Morava depression is demonstrably of Quaternary age (M a c o u n - R ů ž i č k a 1967), similarly as the analogous fluvio-lacustrine sediments of the Prostějovská and



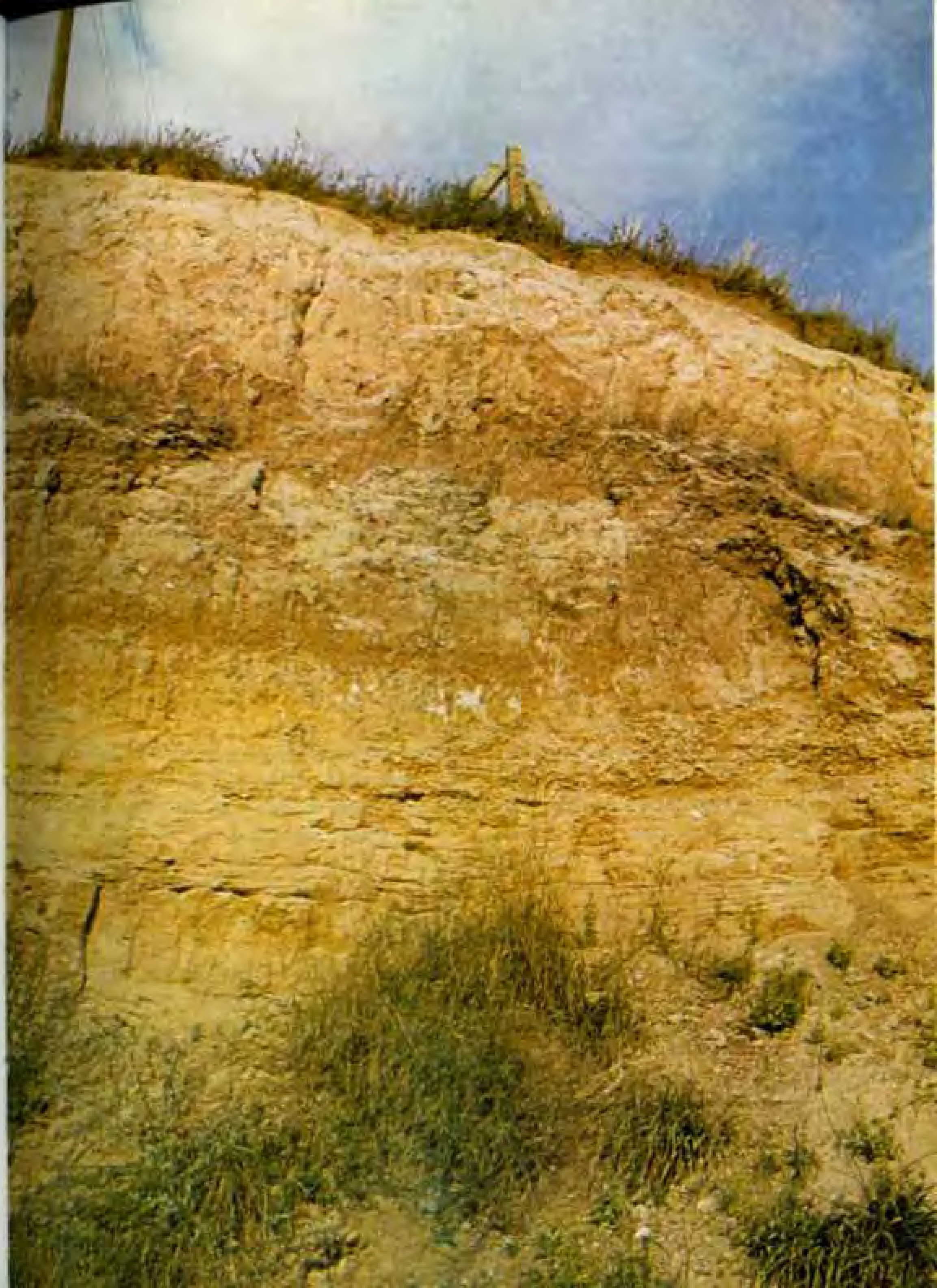
3.64 Section through the slope of eolian sediments. Kurovice-klippe (J. Kovanda - E. Smolíková - O. Fejfar 1982)
1 — made-up ground; *2* — humic soils and soil sediments; *3* — recent soil; *4* — fossil soil sediment of orange colour; *5* — fossil soil and soil sediment coloured in red; *6* — eolian sediments; *7* — stony loamified slope deposits; *8* — eluvium of Kurovice limestones; *9A—D* — climatic and sedimentary cycles represented by slope deposits, fossil soils, soil sediments and eolian deposits. Basal part of the oldest cycle corresponds to some warm oscillation (of interglacial character) between the Cromerian and Holstein

3.65 Parabraunerde of the PK III — loess section Popovice near Brno
Photo by A. Zeman

Litenčická pahorkatina Uplands, and probably also of the Hradiště trough of the Lower Morava depression S of Uherské Hradiště. Early Pleistocene age (Villafranchian) has been proved safely for the limnic and terrestrial deposits near Kurovice on the Holešov plateau, where remains of primitive vole species *Mimomys* were found (A. Zeman et al. 1980, Kovanda et al. 1982), and for similar sediments near Zdounky in the Zdounky Furrow, with fairly rich thermophile ostracode fauna.

Somewhat younger are presumably the Kokory Conglomerates (Tyráček 1961b) and the highest terrace of the Moravian rivers preserved in the Moravian Gate and on the elevated margins of the depressions (Tyráček 1961a, Macoun et al. 1965), and the so-called older gravel sheet which is developed mainly in the Dyje-Svratka depression and in the Vyškov Gate (A. Zeman et al. 1980).

3.66 Fossil soil, equivalent of PK V — loess section Sedlešovice near Znojmo
Photo by A. Zeman



The Early Interglacial (Donau-Günz, Tegelen)

No satisfactorily concrete evidence has so far been gathered for the Early Interglacial on the territory of the Czech Soc. Rep. On the basis of the morphostratigraphic position, only part of the marly-stony colluvial sediments of the platform at the foot of Říp Hill in Ctiněves might be a sole representative of it. The malacofauna includes the index species *Gastrocopta serotina* Ložek, which is characteristic of the oldest group of Quaternary molluscs (Záruba et al. 1977). The finds of vole species *Mimomys pitimyiodes, M. reidi* and *Borsodia* sp. place this layer decidedly in the Villanfranchian faunistic stage (Fejfar - Horáček 1983).

The First Glacial (Günz, Menap)

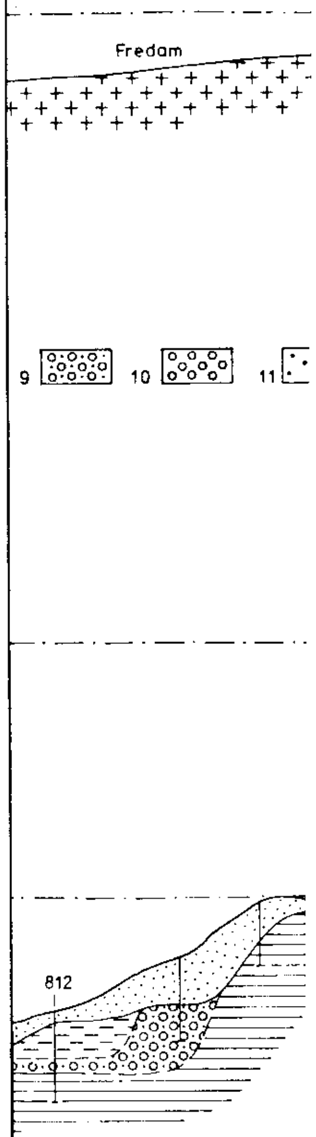
On the river Vltava it is represented by a group of upper terraces, i.e. the Pankrác terrace (G1) and Kralupy terrace (G2) (Záruba et al. 1977); on the Malé Labe by the Hrádek and Těchlovice terraces (Žebera 1956), and high terraces with a base at 88—70 m above river level in eastern Bohemia (Sekyra 1967); below the junction of the Vltava with the Labe by the Ledčice and Straškov terraces (Balatka - Sládek 1962), and the Neštěmice terrace (Šibrava 1972). In the Říp area Žebera considers the G2 sediments as lacustrine-fluvial and substantiates the existence of the lake by a 3—10 m thick bed of fine-grained sand and varved clay.

In Moravia, the 35 m-terrace of the river Opava (Macoun 1980) and analogous terrace on the rivers Morávka, Lučina and Bečva (Tyráček *in* Macoun et al. 1965), and the younger gravel sheet in the Moravian depressions may be equivalent (A. Zeman et al. 1980). This sheet is developed most markedly in the Dyje-Svratka depression and in the Vyškov Gate. The oldest proluvia with interbeds of loess and wind-blown sand, preserved locally at the margins of depressions, and old loess below Červený kopec near Brno are stratigraphic equivalents of it.

In the Ohře river basin three terraces of group II are ranged to the First Glacial (Balatka - Sládek 1976), but the parallelization is uncertain.

An analogue are thought to be the loams in Cave VI on Chlum near Srbsko in the Bohemian Karst with the fauna corresponding to the oldest phase of the Biharian (Fejfar 1961), and the Lower Pleistocene filling of the karst cavity Holštejn in the Moravian Karst (Musil 1966), which yielded similar mammal fauna.

Záruba - Bucha - Ložek (1977) allot to the interstadial G1/G2 the rank of Interglacial and correlate it with the Cromerian.



) to 30° denoted); 5 — 70
loess and fossil soils of

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3.67 Braunlehm of the PK X. — loess section Červený kopec (Red Hill) near Brno. Under the soil the B/M boundary was found

Photo by A. Zeman

The First Interglacial (Günz-Mindel, Cromer)

In the warm interval the braunlehm fossil soil complex VI and/or VII on Červený kopec and the soils of the ferreto type on gravel sheets had developed. The paludal sedimentary series with the Cromerian fauna above the Suchdol terrace (I B) near Únětice is reckoned to it, as well as the basal part of the filling of karst pocket C 718 on Zlatý kůň, the remains of sediments in Cave VI near Srbsko and the deposits of the small limnic-fluvial basin near Přezletice. The

Palaeolithic culture (Přezletician) of the Acheuléan type in the very profile, accompanied by rich fauna (Š i b r a v a et al. 1979), places the locality among the foremost in Europe. The vertebrate fauna corresponds to the younger phase of the faunistic stage Biharian in the sense of F e j f a r - H e i n r i c h (1980).

In Moravia, this date is ascribed to the fillings of karst pockets in Stránská skála near Brno with *Machairodus* fauna and *Banatica* molusc assemblage, with index interglacial species *Helicigona čapeki* (Pbk) (L o ž e k - F e j f a r 1957; Ž e b e r a *in* S v o b o d a et al. 1966), and detritus accumulations on the western slope of Stránská skála containing young Biharian fauna (M u s i l 1968), which cover the younger gravel sheet (Z e m a n A. 1974).

Travertines at Kokory near Přerov are also ranged with the early Pleistocene, without more detailed assignment (T y r á č e k 1961b).

The Second Glacial (Mindel, Elster)

In the Vltava-river valley Mindel 1 is represented by the Vinohrady terrace and Mindel 2 by the Letná terrace (Z á r u b a et al. 1977). In the Labe valley above the conjunction with the river Vltava the Lhotka and Nepolisy terraces, in the eastern part of the Labe valley five terraces at rel. altitudes 62 m (surface) and 50 m(base), 58/52, 55/46, 35/30 and 38/30 m, and the Nový Hradec and Čičín terraces at the Labe/Orlice junction (S e k y r a 1967) are thought to be of Mindelian date.

In the Ohře-river valley Balatka and S l á d e k (1976) place seven separate accumulation terraces of groups III and IV in this interval. Loess deposits in Letky, Žalov and Sedlec near Prague and in Horky nad Jizerou also belong here (K u k l a - L o ž e k 1961). The lower part of sedimentary filling of the karst pocket C 718 obviously dates from interstadial M 1/2; it contains typical *Machairodos* fauna with skeletal remains of *Macaco* cf. *florentina,* the first find of a monkey in Bohemia (F e j f a r 1976). The upper part of the profile falls in M 2.

In northern Bohemia, in the area of Nordic glaciation, denudation relics of Elster glacial sediments, which had been transported by melt waters into the Ploučnice valley and deposited there at a rel. altitude of 40—50 m, extend into the Labe valley near Děčín (Š i b r a v a - V á c l 1962, Š i b r a v a 1967). Proluvial accumulations in the České středohoří Mts. have been recognized by B u č k o v á - R ů ž i č k o v á (1967).

The first-order morphostratigraphic level is the Vinohrady terrace (IIIB), which can be traced along the whole course of the Vltava from Prague basin up to its junction with the Labe, and further along the Labe river as the Straškov and Neštěmice terraces; in the neighbourhood of Děčín the latter links up with the sediments of the Elster glaciation.

In the sediments of the continental glaciation in the Opavská pahorkatina Upland, M a c o u n (1980) distinguished the older Opava (M 1) and the younger Kravaře (M2) glaciations, separated by the Otice warm oscillation. In the remaining area of northern Moravia the sediments of this glaciation are assigned to the Elster without further subdivision.

In the extraglacial area of Moravia, the Mindel deposits comprise loess sheets at the foot of Nová hora and Červený kopec near Brno (K u k l a - L o ž e k 1961, S m o l í k o v á - K o v a n d a 1983); the younger fluvio-lacustrine sediments in the Upper Morava depression (M a c o u n - R ů ž i č k a 1967); group IV of the Moravian river terraces (Z e m a n A. et al. 1980). In the initial phase of the Mindel the sedimentation of detrital deposits on Stránská skála probably came to an end.

The Second Interglacial (Mindel-Riss, Holstein, s. l.)

In the interior of Bohemia this period is characterized by the development of intensely weathered soils of complex V (Horky nad Jizerou) yielding thermophile molluscan fauna (K u k l a - L o ž e k 1961); cave sediments (Dobrkovice II, F e j f a r 1965); in Moravia by interglacial deposits on Turold near Mikulov; travertine in Tučín (L o ž e k - T y r á č e k 1958, K h e i l 1965); paludal sediments above the Rvenice terrace near Stránce on the Ohře river; and the Labe terrace near Čilec, in which the index species *Corbicula fluminalis* (Müll.) was found. This fauna was always considered to be typical of the Holstein Interglacial, but the morphostratigraphic position of the terrace in the Labe-river terrace system is not so unambiguous.

In the area of the Nordic glaciation the older accumulation of the Main terrace (M a c o u n et al. 1965) and analogous accumulations in the Upper Morava depression and on the middle Morava (M a c o u n - R ů ž i č k a 1967, A. Z e m a n et al. 1980) correspond to the cold oscillation within the Holstein Interglacial. In the Ohře river valley two (pre-Riss) terraces of group V are parallelized with it (B a l a t k a - S l á d e k 1976).

The organic and paludal sediments in Ostrava-Muglinov, Skřečoň and Dolní Lutyně (M a c o u n et al. 1965) date from the earlier warm oscillation, and the organic and lacustrine sediments of the Stonava relict lake from the later warm oscillation. Sediments of relict lakes and ancient valleys in the Opavská pahorkatina Upland are correlated with the interglacial, in general.

The Third Glacial (Riss, Saale s. l.)

In the Vltava-river valley the Dejvice terrace (V) is ranged to R 1 and the Veltrusy terrace to R 2 (VI. — Z á r u b a et al. 1977); in the Malé Labe valley the Velký Barchov and the extensive younger Urbanice terraces, and with uncertainty the R 3 terrace, developed not very markedly and only in places (Ž e b e r a *in* S v o b o d a et al. 1966) are placed in this glacial stage. In the eastern sector of the Labe valley S e k y r a (1967) assigns four terraces and the complicated Krňovice terrace at the Labe—Orlice junction to this interval.

In the Labe valley below the confluence with the Vltava, the Cítov and Mlčechvosty terraces (B a l a t k a - S l á d e k 1962) or the Nebočady and Travčice terraces (L o ž e k - Š i b r a v a 1968, Š i b r a v a 1972) are parallelized with the above terraces.

In the Ohře-river valley two groups of six separate terraces (B a l a t k a - - S l á d e k 1976), i.e. VI_1 to VI_4 and VII_1 and VII_2 are dated as Rissian on the basis of morphostratigraphic correlation.

In the region of highlands and mountain ranges of the Bohemian Massif, the markedly developed accumulation of the Main terrace on most of the rivers, particularly in South Bohemian basins, the older glaciation of the Krkonoše Mts., and the basal parts of late Pleistocene loess sheets fall in the Riss stage.

In the extraglacial part of Moravia and in the Moravian depressions the younger accumulation of the Main terrace and the Radslavice terrace on the river Bečva had developed at that time. The latter is one of the most important stratigraphic key horizons in Europe for the correlation of the Nordic glaciation with the extraglacial area in the Danube drainage basin and the mountain glaciation of the Alps (T y r á č e k 1963). In the younger phases of the Riss stage prominent accumulations of slope deposits were formed as well as the most extensive proluvia and gravel fans coalescing into proluvial belts at the foot of mountains, and loess beds underlying PK IV in the environs of Brno.

In the area of Nordic glaciation in northern Bohemia the existence of the Saale glaciation has not been evidenced although it is very probable, at least in places. In northern Moravia the Saale glaciation was of maximum extent (T y r á č e k 1961c). According to M a c o u n (1980), traces of two Saale glaciations are preserved in the Opavská pahorkatina Upland: the older Oldřišov phase is separated by a moderately warmer phase of the Neplachovice interstadial from the younger Palhanec glaciation. The new division has not been applied to the Ostrava basin and the Karviná area.

Intensive loess sedimentation within the entire Bohemian Massif is demonstrated by Riss loess deposits at the base of young loess series, occurring abundantly in the interior parts of Bohemia (in the environs of Prague, in the Labe valley, the lower course of the Jizera valley, Kutná Hora area, and the areas of Kladno, Ústí nad Labem, Podbořany and Žatec), and in Moravia (vicinity of Brno and the Moravian depressions).

The Third Interglacial (Riss-Würm, Eemian)

The last Interglacial is distinguished by a reduction of sedimentation and a predominance of weathering processes. Exception to this rule are karst areas and the formation of travertines. In river valleys the oxbows were gradually filled with sediments (Plotiště nad Labem near Hradec Králové — Ž e b e r a 1958, Babice and Jaroměř — S e k y r a 1967). Cave deposits were laid down (fossil-rich basal sediments in the Chlupáč Cave in the Beroun area, possibly also Dobrkovice near Český Krumlov), which contain thermophile vertebral fauna and last occurrences of the Banatica mollusc fauna with index species *Helicigona banatica* Rsm., *Soosia diodonta* Fér., *Aegopinella ressmani* West. and others, which are to date extinct in Central Europe (L o ž e k 1973).

In this period the last typical interglacial soils of PK III were forming; they are known from many localities in the loess areas of Bohemia and Moravia (Sedlec, Kladno, Horky nad Jizerou, Kutná Hora, Ústí nad Labem, Nová hora, Červený kopec, Modřice, Předmostí, Dolní Věstonice). Soils of terra fusca type and fresh-water carbonates also developed, the latter e.g. in Radslavice, Předmostí and Přerov (below the castle).

The Last Glacial (Würm, Weichsel, Vistulian glaciation)

In the valleys of virtually all streams in Bohemia and Moravia, independently of their size, the youngest thick sandy gravel of valley terrace had accumulated. The higher one or two terraces (W 1 and W 2) with separate rock bases are sometimes ranged to the Würm and, on the other hand, lower erosion or inset terraces have been discriminated in the uniform accumulation of the valley terrace.

The Würm loess sheets are also of the largest extent. At suitable localities three separate covers are distinguishable, separated by fossil soils PK II and PK I. Towards the end of the Würm, sedimentation of blown sands set in, persisting until the early Holocene. The development of slope deposits, debris materials, solifluction sediments, boulder fields and stony and detrital cave sediments was very intensive.

The Würmian vertebral fauna, abundant in loess profiles is distinguished by three species: mammoth, wooly rhinoceros and moose (Předmostí, Věstonice, Ústí nad Labem, vicinity of Hradec Králové). *Ursus spelaeus, Bos primigenius* and *Equus caballus* predominate in cave deposits. Most occurrences are accompanied by minor fauna of subarctic steppe (Chlupáč Cave, Cave above Kačák in the Bohemian Karst, Dobrkovice, Volyňka-river valley, and nearly all caves in the Moravian Karst, which also provide rich archeological finds).

In loess deposits the first to appear is the fairly thermophile molluscan *Striata* fauna, and above it the psychrophile *Collumela* fauna typical of the glacial maximum. The most intensive deposition of blown sands (Labe river valley, the Železné hory Hills, Moravia) took place during the expiring of the Last Glacial and its transition into the Holocene (Postglacial).

Holocene

The youngest epoch in the history of the Earth is the Holocene, occupying the last ten thousand years, since the retreat of the last continental ice sheet from Europe to Fennoscandia. Because of human interference, the Holocene, which would normally be an analogue of Pleistocene interglacials, is essentially different and has practically no analogy in the past. One of the main reasons is the evolution of agriculture, giving rise to pastures and fields to the detriment of forests. This duly resulted in a changed development of soils and more intensive erosion and denudation. The distinctive feature of this period is a practically permanent removal of the upper parts of soils profiles and, on the other hand, cumulation of the eroded particles (Ložek 1973).

Soils were ruined, resembling crude soils of cold Pleistocene intervals, vegetation also was adapting to changed conditions. Increased denudation caused filling of river beds, and deposition of flood loams.

The most widespread sediments are flood loams, deluvial sediments and alluvial cones. In places sandy gravel of the lower valley terraces was redeposited. Peats are typical sediments of mountain and highland areas. Swamp peat, lacustrine sediments (at Komořany, Čejč, Kobyla), terra alba, calcareous tufa, gyttja, calcareous fen peats and fen clays and/or diatomaceous earth formed in basins and plains. Fresh-water carbonates precipitated mainly from cold springs form abundant but minor occurrences of a small thickness (Kovanda 1971).

3.2 The stratigraphic development of the West Carpathian units in Moravia

The lithostratigraphy and spatial distribution of the West Carpathian units in eastern Moravia is fairly well known (Fig. 2.25).

3.2.1 Triassic

Pebbles of light-coloured quartzite and limestone, which were found sporadically in the material of the Magura Flysch, are thought to be Triassic on account of their lithological character (Chmelík et al. 1969). This indicates that Triassic sedimentation extended farther into the Vindelic landmass than was presumed, forming probablly a separate sedimentary basin.

3.2.2 Jurassic

The Jurassic sediments in the units of the Flysch Carpathians form part of a continuous sequence of strata only in the Silesian unit, which begins with Tithonian sedimentation. In its Godula development, the lower Těšín Member represents the pelitic basin facies, and the overlying Těšín limestones a micritic facies. In the Baška development of the Silesian unit, the Tithonian consists of the Štramberk Limestones, which belong to the perireefal talus cones of the Baška cordillera.

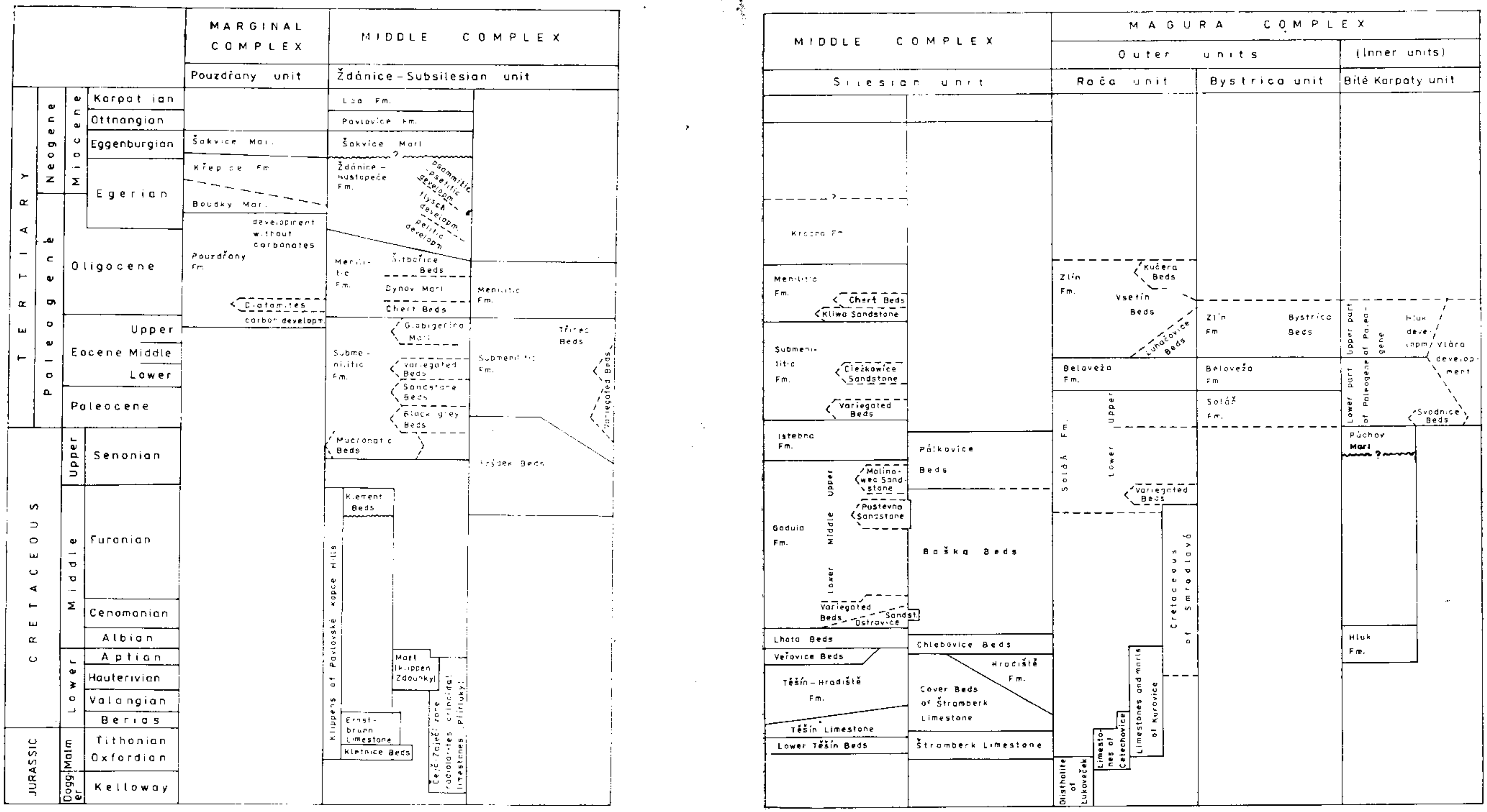
In other units the Jurassic sediments are only known from redeposited clastic material or tectonic klippes. These suggest that in the Dogger and Malm were deposited radiolarites (Přítluky) and lithologically differentiated limestone sequences of a small thickness (Přítluky, Cetechovice, Kurovice, Lukoveček); in some parts of the original Ždánice and Rača areas the limestone sedimentation preceded (as in Triassic) the initiation of the Outer Carpathian flysch geosynclinal area itself. The development of these sediments shows close palaeogeographical relations to the Jurassic of the Klippen Belt (Cetechovice geosyncline, sensu Andrusov 1930).

Only the Tithonian limestones with transgressive pelitic-sandy Turonian in the Pavlovské kopce Hills in front of the Ždánice unit (Pavlov zone, Kalášek et al. 1963) are indicative of the palaeogeographical and palaeotectonic link with the platform development of the Jurassic in the Bohemian Massif.

3.2.3 Cretaceous

The sedimentary areas of the Lower Cretaceous experienced similar development as the Jurassic basins. In the Silesian unit a continuous sedimentation proceeded from the Jurassic, being distinguished in the area of the Baška cordillera by disintegration and redeposition of clasts of the Štramberk Limestones. In the Godula development of the Silesian unit the Lower Cretaceous is characterized by a predominance of black flysch sediments (Těšín-Hradiště Formation, Veřovice Member), which were accompanied by synsedimentary volcanism of the teschenite association and transient supply of coarse sandy material (Hradiště sandstone bodies).

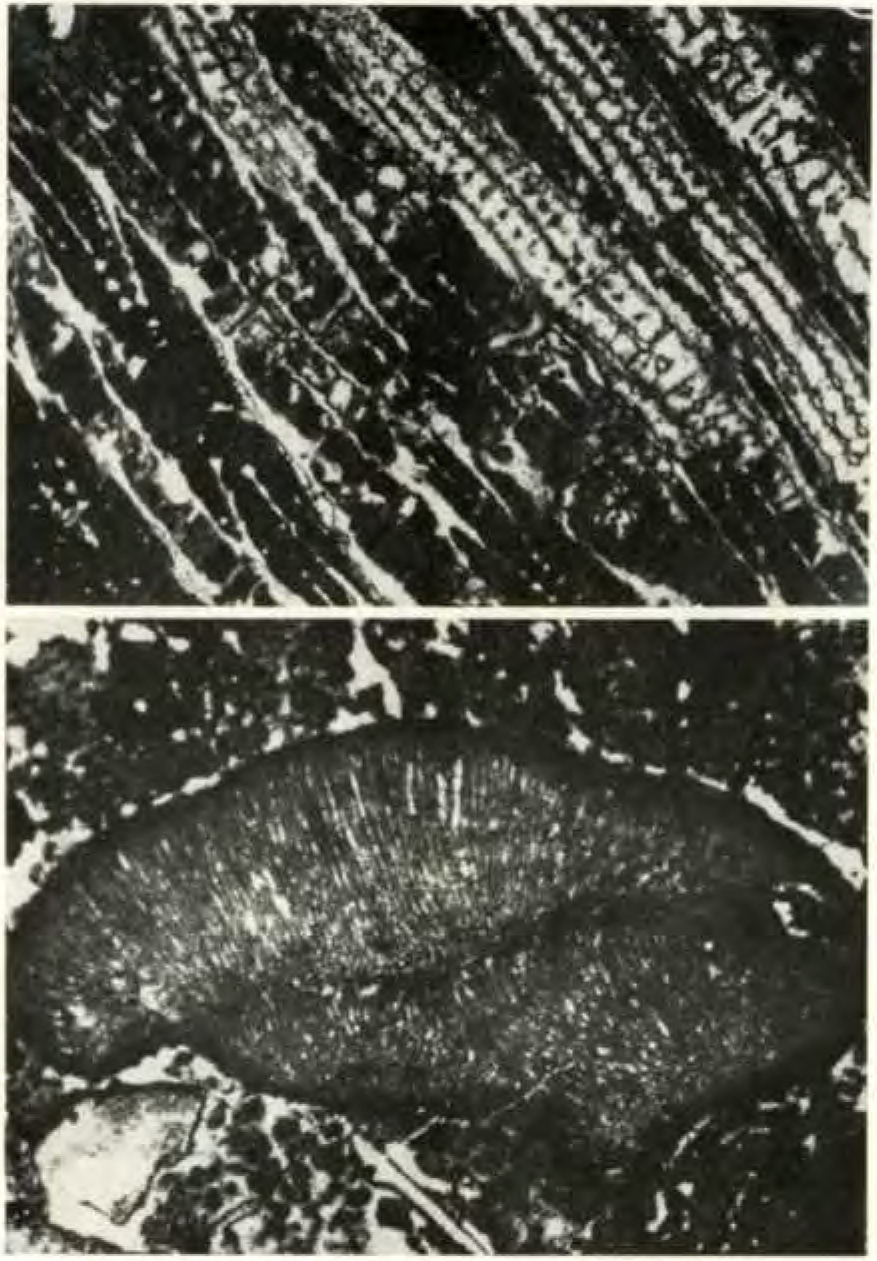
In the remaining flysch units the development of the Lower Cretaceous was palaeogeographically independent of the later palaeotectonic development. The



3.68 Stratigraphic scheme of the West Carpathians in East Moravia (E. Menčík, orig.)

continuation of the sedimentation of small thickness in the Cetechovice syncline is demonstrated by calcareous claystones and marlstones in the klippes of the Ždánice unit (Přítluky, Zdounky) and the Rača unit (Kurovice). The stratal sequences lithologically related to the sequence of strata of the Silesian unit — the Těšín-Hradiště Formation at Baraní (Matějka - Roth 1956) with the overlying Lhoty Member and the Varied Godula Formation (Albian—Cenomanian) at Smradlavá — folded in the frontal zones of the Rača unit in the Moravskoslezské Beskydy Mts. point to a palaeogeographically independent configuration of the sedimentary basins prior to the foundation of the younger Magura geosyncline.

The basin of the Bílé Karpaty unit in the Early Cretaceous and at the beginning of the Middle Cretaceous (Aptian—Albian) communicated with the



3.69 Scleractinia: *Pseudocoenia beskidena* Eliášová, 1981, thin section, Štramberk, Štramberk Limestone, Tithonian; *a* — cross section of the colony, ×5, *b* — longitudinal section of the colony, ×5 Photo archive ÚÚG, Praha

3.70 Algae: *Solenopora* sp. (*Corallinaceae*), thin section, Pavlovské vrchy Hills in southern Moravia, Tithonian, ×21.75 Photo archive ÚÚG, Praha

3.71 *Favia costata* d'Archiardi, Ždánice unit, Submenilitic Formation, Kurdějov-Holý vrch locality, upper Eocene, 1 1/2 : 1, (material of H. Eliášová) Photo archive ÚÚG, Praha

3.73

3.72 *Globorotalia (Turborotalia) cerroazulensis* (Cole), Pouzdřany unit, Pouzdřany locality (borehole), upper Eocene, ×100, (material of E. Hanzlíková)

3.73 *Globigerina praebulloides praebulloides* Blow, Carpathian foredeep, borehole Dražovice 2, Moravian (lower Badenian), ×75, (material of V. Molčíková) Photo archive ÚÚG, Praha area of the Klippen Belt. They are characterized by the sediments of the Hluk Formation (Buday et al. 1963).

The Middle Cretaceous is distinguished by the maximum sedimentation of sandy flysch facies of the Silesian unit, whose thickness ranges from several hundreds to several thousands of metres. It is foreshadowed by flysch sedimentation with spotted claystones (Lhoty Member). The Godula Formation itself consists of complexes of fine to middle-rhythmical flysch; in the basal part it is represented either by varied development (Varied Godula Member) or by sandy development (Ostravice Sandstone), which is also distinctive of the middle Godula Member. Sandstones of this sequence are characterized by mass occurrence of glauconite. Sedimentation of the Godula Formation persisted until the early Senonian. At that time gradual transition into the Istebna Formation (upper Senonian) is indicated by the deposition of isolated sandstone-conglomerate bodies, which are lithologically related to these upper layers (Pustevna Sandstones and Conglomerates and Malinowecka Skala Sandstones).

In the Baška development of the Silesian unit, the Chlebovice Formation and the overlying Baška Formation are equivalent to the Middle Cretaceous. The former is distinguished by sandstones and conglomerates with the largest accumulation of clasts from the Štramberk Limestones, derived from the destructed Baška cordillera, and the latter by cherty sandstones. Pelitic development of the Cenomanian and Turonian has been found only locally in the envelope of the Štramberk Limestone.

During the Middle Cretaceous (Turonian), sedimentation began at least in a part of the Subsilesian unit (the oldest beds of the Frýdek Formation, Roth et al. 1962). The geosyncline, in which the Magura flysch was deposited, had probably also been initiated, because the most recent studies indicate that the oldest beds of the Soláň Formation in the Rača unit (lower varied complex and part of the "Lower Soláň Member") are of the Turonian date, at the latest (Hanzlíková 1976).

Intensive differentiation of the sedimentary areas took place at the beginning of the late Senonian (Campanian—Maastrichtian) and continued until the early Palaeocene. In the sedimentary Ždánice-Subsilesian area the palaeogeographical conditions were partly responsible for the formation of variegated, predominantly pelitic facies. The Frýdek Formation has an increased silt admixture in pelites and a higher content of sand in subordinate sandstone beds. Green calcareous claystones are a component of Mucronata marls and of the Třinec Formation, which also contains purplish-brown calcareous claystones.

The Silesian sedimentary area was supplied with sandy and pebbly material from the Baška cordillera (Palkovice Formation) and the Silesian cordillera (Istebna Formation). The lateral variability of the Istebna Formation is due to the varying content of claystones, into which the sandstone-conglomerate bodies gradually wedge out in E—W direction (Matějka 1949).

A part of the "Lower Soláň Member" probably belongs to the Upper Cretaceous sediments of the Rača unit. In the Bystrica units the Upper Cretaceous sediments have not been evidenced. The Púchov Marls (Campanian—Maastrichtian) in the mantle of the Hluk Formation in the Bílé Karpaty unit convincingly document that the sedimentary area of the Bílé Karpaty unit was connected with that of the Klippen Belt.

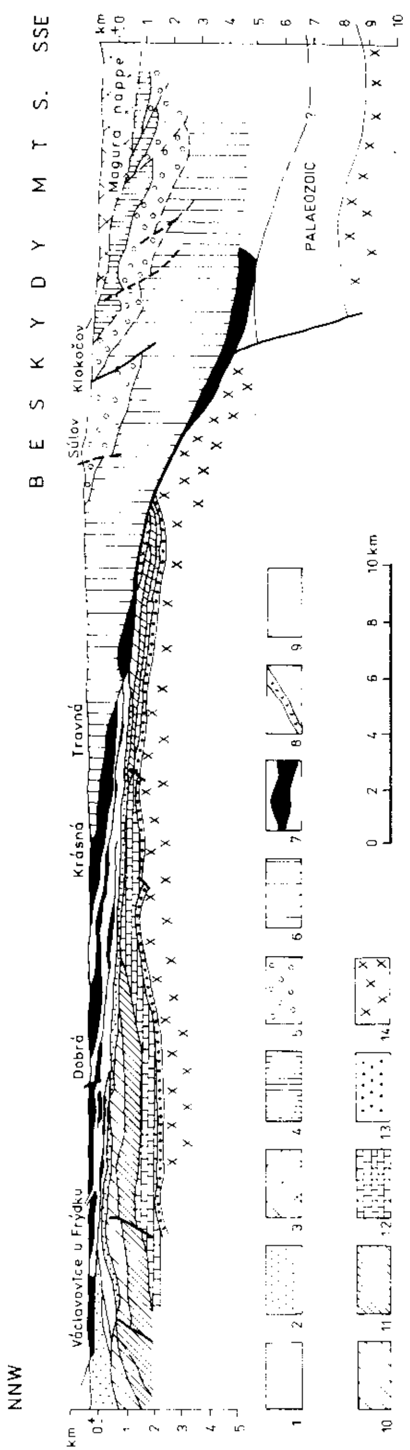
3.2.4 Palaeogene

The autochthonous Palaeogene deposits mainly fill the erosion-tectonic depressions (Nesvačilka and Vranovice troughs). At the base there are conglomerates and sandstones and higher up they are followed by claystones and calcareous claystones. Limestones are subordinate. These sediments are linked up palaeogeographically with the Pouzdřany unit of the Outer Carpathians on the one hand, and with the Palaeogene filling of the Alpine foredeep in Austria, on the other.

Since the Palaeocene, the palaeogeographical conditions in the Outer Carpathian geosyncline were simplifying: two fundamental flysch sedimentary areas came into being, which characterize different development of the Central and Magura groups.

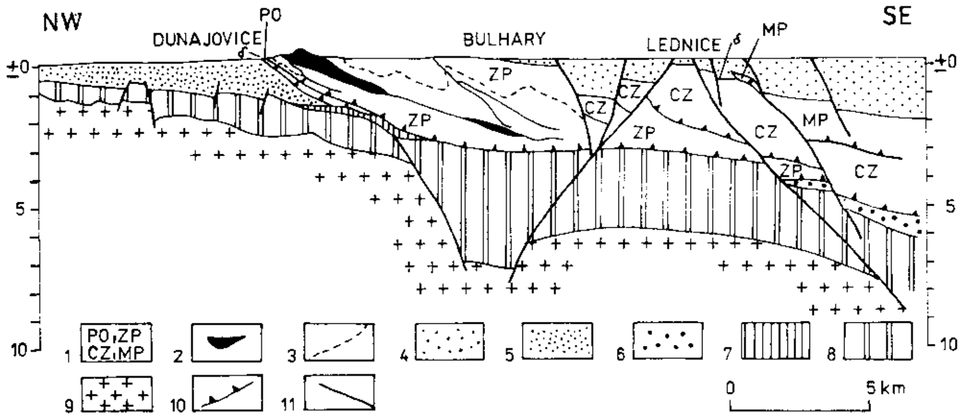
During the Palaeocene to late Eocene (the Submenilitic Formation) the Central group was distinguished by pelitic, subflysch or fine-rhythmical flysch facies, accompanied by subordinate impersistent sandstone-conglomerate bodies of a small thickness (Ciężkowice Sandstone, sandstone of Stráž type and others). The most marked pelitic development is the facies of blackish-grey claystones, predominantly of Palaeocene age. The facies of purplish-brown claystones, also of clear-cut lithology, constitutes several discontinuous horizons within the Palaeocene to upper Eocene; it is only in places the predominant facies of the Submenilitic Formation (part of the Subsilesian unit). Towards the overlying beds the supply of sandy material in the Submenilitic Formation gradually disappears, the carbonate content of claystones increases and the foraminifer plankton exhibits a rich development (Globigerina marlstones).

At the beginning of the Palaeocene, the flysch sedimentation of the Soláň Formation in the Magura group continued by cumulation of mainly sandy and conglomerate material ("Upper Soláň Member" of the Rača and Bystrica units); during the period of Palaeocene—middle Eocene it was replaced by sedimentation of the purplish-brown claystones of the Beloveža Formation. The supply of coarse-sandy material in this unit was limited to the Trnava-Staškov zone of discrete facies development (Pesl 1968).



3.74 Geological section of the West Carpathians in the area of the Moravo-Silesian Beskides (E. Menčík, orig.)
1–2 — Miocene foredeep: *1* — lower Badenian, *2* — Karpatian; *3* — Magura nappe; *4–7* — Silesian unit: *4* — Submenilitic, Menilitic and Krosno Formations, *5* — Istebná Formation, *6* — Godula Group, *7* — Jurassic Láby members of the Silesian unit; *8* — klippe at the base of the Godula nappe (basal Devonian clastics and crystalline rocks); *9* — Subsilesian unit; *10–14* — Variscides of the Bohemian Massif: *10* — coal-bearing Carboniferous, *11* — Carboniferous in Culm development, *12* — carbonate facies of Lower Carboniferous and Devonian, *13* — basal Devonian clastics, *14* — crystalline complex (biotite paragneisses to migmatites with granitoid intrusions)

In the Bílé Karpaty unit, the Palaeocene to middle Eocene are represented by the facies of variegated claystones which are represented by fine-rhythmical sandy flysch with green and greenish-grey claystones (lower division of the



3.75 Geological section of the southern part of the West Carpathians in Moravian area between Dunajovice-Lednice. (Menčík, according to Z. Stráník - J. Adámek - V. Ciprys 1979)
1 — nappe units of the Outer Carpathians: MP — Pouzdřany unit, ZP — Ždánice-Subsilesian unit, CZ — Čejč-Zaječí zone; *2* — Jurassic klippes of the Pavlovské kopce Hills; *3* — boundary of Ždánice-Hustopeče Formation against the basement; *4* — Vienna basin (Neogene filling); *5* — Outer Carpathian foredeep (Eggenburgian-Ottnangian and Karpatian); *6* — autochthonous Oligocene; *7* — Upper Cretaceous in autochthonous envelope; *8* — autochthonous Jurassic; *9* — crystalline complex; *10* — **principal nappe surfaces; *11* — radial** faults and partial **thrust faults**

Palaeocene of the Bílé Karpaty unit). More sandy developments have been assessed only in a small area, together with dark-grey both calcareous and non-calcareous claystones (Svodnice Member, P e s l 1968).

A characteristic member of the last part of middle Eocene and of the upper Eocene in the Rača and Bystrica units is the sandy flysch of t h e Z l í n F o r m a t i o n with a varying amount of calcareous pelites (in the Bystrica unit with clayey limestones — Łącko Marlstones). The lithofacies variability of the Zlín Formation in the Rača unit is manifested by the varying proportion of glauconitic or greywackeous sandstones in the flysch rhythms (Vsetín — Kyčera Member). The lower part of the flysch development of the Vsetín Member is replaced locally by the facies making up separate bodies of predominant sandstones and conglomerates in the marginal parts of the Rača unit (marginal development) or in the group of inner anticlines (Luhačovice Member). The transition of these facies into the Vsetín Member is indicated by subordinate layers of arkosic sandstone. This part of the sequence is termed the "Lower Zlín Member" of the Rača unit (M a t ě j k a - R o t h 1956).

In the Bílé Karpaty unit the facies of the upper Palaeogene division corresponds to the Zlín Formation. The Palaeogene is divided on the basis of the proportion of calcareous sediments (claystones and sandstones) into the Hluk (calcareous) facies and the Vlára facies (with an increased amount of sandstones). A transitional facies developed at the contact of Hluk and Vlára developments (B u d a y et al. 1963).

Over the larger area of the Magura group sedimentation came to an end in the late Eocene. Only in some zones of the Vsetín Member was the presence of the (lower?) Oligocene demonstrated.

Most widely developed is Oligocene sedimentation connected with the Submenilitic Formation in the Central group. It begins with the deposition of the Menilitic Formation distributed over the whole area (M e n č í k 1973); this is followed by t h e K r o s n o F o r m a t i o n (in the Silesian unit) or t h e Ž d á n i c e - H u s t o p e č e F o r m a t i o n (in SW of the Ždánice-Subsilesian unit). In the north-eastern part of the Ždánice-Subsilesian unit (at the foot of the Beskydy Mts.) sedimentation ends with the Menilitic Formation, but in the south-western part it continued from the Oligocene to the earliest Miocene (Egerian).

In contrast to all other units, the Pouzdřany unit does not contain older than upper Eocene beds; these open the deposition of t h e P o u z d ř a n y F o r m a t i o n, which continued up to the Egerian. The layers of diatomite at the boundary between the calcareous and non-calcareous development of the Pouzdřany Formation can be regarded as a facies equivalent of the cherty beds in t h e M e n i l i t i c F o r m a t i o n in the Central group. The Boudky Marls and Křepice Formation overlying the Pouzdřany Formation are lithofacies equivalents of the youngest part of t h e Ž d á n i c e - H u s t o p e č e F o r m a t i o n.

3.2.5 Neogene

The Pouzdřany unit is the only flysch unit in which sedimentation continued into the early Miocene, being represented by t h e Š a k v i c e M a r l s (Eggenburgian, S t r á n í k - M o l č í k o v á 1980). It is probable that in the Ždánice unit the Miocene beds (Eggenburgian—Ottnangian—Karpatian) are separated from the underlying Ždánice-Hustopeče Formation by a slight angular unconformity (personal communication, Z. Stráník). The sequence is divided into t h e Š a k v i c e M a r l s (Eggenburgian), P a v l o v i c e F o r m a t i o n (Ottnangian) and t h e L a a r F o r m a t i o n (Karpatian). These Miocene beds are preserved in the Ždánice unit only in small transverse depressions within the Hustopečská pahorkatina Upland.

The stratal sequence of the Pouzdřany unit, including the underlying Pouzdřany Formation, shows a similar development as the Oligocene—Miocene filling of the foredeep on which the Outer Carpathian units are overthrust in southern Moravia.

In agreement with the decision of the RCMNS (Regional Committee on Mediterranean Neogene Stratigraphy, 1975) so-called regional stages are applied to the chronostratigraphic classification of the West Carpathian Tertiary (i.e. the region of Central Paratethys). The application of global classification of the Upper Tertiary (i.e. the Aquitanian, Burdigalian, Langhian, Serravallian, Tortonian, Messinian, Tabian, Plaisancian and Astian stages) meets with many difficulties. A separate scale has been compiled for the Western and Central Paratethys, which would express specific features of the biostratigraphic, palaeogeographic and other developments of this region. The following stages are applied (the equivalent stages of the Mediterranean region are given in parentheses, for details see Tables 3, 4).

Egerian (Chattian—lower Aquitanian)
Eggenburgian (upper Aquitanian—lower Burdigalian)
Ottnangian (middle Burdigalian)
Karpatian (upper Burdigalian)
Badenian (Langhian—lower Serravallian)
Sarmatian (upper Serravallian—lower Tortonian)
Pannonian (upper Tortonian)
Pontian (upper Tortonian—Messinian)
Dacian, Rumanian (Tabian, Plaisancian, Astian).

The Eggenburgian beds occur in the Czechoslovak part of the Vienna basin above the sequence of the Klippen Belt. They also lie transgressively on the units of the Magura group.

Lithologically, the Eggenburgian is represented in the older part by conglomerates and sandstones (e.g. the Chropov and Dobrá Voda types). Glauconitic sandstones with claystones constitute the older part of the Eggenburgian in the Lužice—Hodonín area. Variegated continental to brackish facies of conglomerates to sandstones are characteristic of the base of the Eggenburgian in the neighbourhood of Štefanov—Petrova Ves.

The marine Eggenburgian facies is distinguished by a relatively rich foraminifer assemblage with *Cyclammina praecancellata* Volosh, *Haplophragmoides vasiceki vasiceki* Cicha et Zapletalová, and by large pectens.

The partly freshened basal facies of the Eggenburgian in the environs of Štefanov contain *Cibicidoides budayi*. The marine facies is here represented by *Chilostomella ovoidea* Rss. and *Lenticulina mezneriscae*.

The lower part of t h e L u ž i c e F o r m a t i o n (Bathysiphon—Cyclammina schlier) corresponds to the Eggenburgian especially in the area of Lužice.

Table 3.4

Stratigraphic scheme of the Neogene in Moravia

Stage	Subcarpathian Miocene (Foredeep, S part) Lithostratigraphy or biostratigraphy	Lithology	Volcan.	Thickness	Subcarpathian Miocene (Foredeep, N. part) Litho- or biostratigraphy
Rumanian					Kobeřice Mbr.
Pontian Dacian	Varied Formation	Var. sandy clay		200 m	
Pannonian					
Sarmatian					
Badenian lower middle upper	"Tegel", *Lithotham.* limestone Brno sand	limestone marl, gravel sands	Rh	700	*Bulimina-Bolivina* Bd, *Spiratella* Bd. *Evaporites Pseudotriplasia* Bd. detritus "Schlier"
Karpatian	Karpatian "Schlier"	sandy clay sandy "Schlier"		1200	grey and varied Mbr.
Ottnangian Eggenburgian	*Rzehakia* and Varied Mbr. Mbr. *Tracia pubescens Cibicidoides budayi* etc.	sands clay rhyol. tuff. sandy clay sands	Rd Rh	200 200	Jaklovec Bd.
Egerian	Mbr. *Miogypsina complanata*	clay marl		50	

Table 3.4

Lithology	Volcan.	Thickness	Vienna Basin (N. part) Czechosl. litho- or biostratigraphy	Lithology	Volcan.	Thickness	Ma	Medit. stages
gravels		20	Upper Coal gravel Fm.	gravels coal		130		Zancl.-Piacenzian
			Varied Mbr.	clay, sandy clay		150	5	
			Coal Mbr. *C. zahalkai* Bd.	clay, sandy coal		150		Messinian
			spathulata Bd E *subglobosa* *Congeria* Bd D *partschi* Bd D *hoernesi* Bd C *ornithopsis* Bd C *M. impressa* Bd A	coal sands clay sands		550	10.5	Tortonian
			empover Bd. *Mactra* Bd. *Ervilia* Bd. *Rissoa* Bd. varied Bd.	clay sands		700	13.5	
sandy clay	Rd	350	*Spiroplectamm.* Z.	sands/clay		500		Langh.-Serravallian
gypsum sandy clay		5680	*Bulim.-Boliv.* Z.	sands, clay limest., coal		600	15	
sandy clay ash, volc. breccia	Rb B	900	*Lagenidae-Orbulina* Z.	marls, sand gravels		600	16	
sandy clay clay		300	Jablonica Lakšárska Bd. (etc.) Týnec	sandy clays conglomer.		2300	18	Burdigalian
sandy clays conglomer.	B	50	*Cibicides-Elphidium* Schl. Lužice Mbr. *Bathysiphon-Cyclammina* Schl.	conglomerate sandy clay sands, conglomer.		700	22	Chattian Aquitanian
							28	

In the Vienna basin the following units are nowadays assigned to the Ottnangian: the Štefanov Sandstones, the older Miocene of Lednice type, the Cibicides-elphidium schlier of the Lužice Formation and Robulus schlier (formerly placed in the Eggenburgian). In the closing phase of the Ottnangian the "fish schliers" were deposited.

One of the significant Ottnangian species (Cibicides-Elphidium schlier) is *Sigmoilopsis ottnangensis* Cicha, Čtyroká. The marine facies contains besides lenticuline planktonic foraminifers, particularly the species *Cassigerinella boudecensis.* In the "fish schlier" representatives of the genus *Silicoplacentina* have been found. The maximum thickness of the Ottnangian, which is connected with the Eggenburgian by gradual transitions, attains in the Vienna basin 300 m.

The oldest facies of the Karpatian are Týnec Sands of the Lakšár Formation, the Jablonice Conglomerates being their marginal facies. The Lakšár Formation itself consists predominantly of fine sandy pelites. The younger Šaštín Sands and diatoms-bearing shales form a separate layer. The top layer of the Karpatian is represented by the Závod Formation and the Láb ostracode beds.

As concerns faunal content, the typical unit of the Karpatian is the Lakšár Formation with extremely rich foraminifer faunas, e.g. *Uvigerina parkeri breviformis.* The freshened Karpatian facies are characterized by the genera *Candona, Stenocypris* and others.

The nannoplankton of the Karpatian corresponds to the older part of zone NN5.

The maximum thickness of the Karpatian in the Vienna basin attains 2300 m. The Karpatian sequences lie transgressively on the Ottnangian. In many areas of the Vienna basin the lower Badenian usually begins with conglomerates, sandstones and varied pelites, and its upper part is formed of calcareous clays. In the oldest part of the marine substage Moravian the representatives of the genus *Globigerinoides* are most abundant. This development is known from the Malacky area. However, the lower Badenian is distinguished most typically by the associations of the Lanzendorf horizon with e.g. *Lenticulina echinata* (d'Orb.) and *Orbulina saturalis* Bronniman. In the upward direction the associations become impoverished. The overlying sequence contains *Semivulvulina pectinata kolmanni* Cicha et Zapletalová, and the complex with *Bolivina dilatata* Rss. is typical of the terminal part of the lower Badenian. Nannoplankton of the lower Badenian corresponds to zone NN 5.

The total thickness of the lower Badenian does not exceed 500 m.

The middle Badenian—Wielician consists of the lithologically varied Žižkov Formation, the Láb "amphistegina" beds and the marine pelites of the zone with agglutinants. The Žižkov Formation (gravel, varied pelites of the Velké Bílovice area, the central foredeep of Moravia) is usually sterile, whereas the Láb Formation (sandstones with interbeds of lithotamnion limestone) yielded some faunal finds. Marine pelites which partly substitute both the varied Žižkov facies and the Láb Formation contain rich fauna of agglutinants with *Pseudotriplasia* div. sp.

The upper Badenian—Kosovian is best developed in the area of Studienka, Leváre, Závod and Borský Jur. Lithologically it is represented chiefly by pelites of the Bulimina—Bolivina zone and Ammonia zone. The typical plankton species is *Velaoertina* div. sp. The sequence passes upwards gradually into impoverished facies with Ammonia, members of the miliolid family and ostracodes.

The Sarmatian occurs in marginal and basin facies. The marginal facies are composed of sands and sandstones, whereas in the basin development predominate pelites which in the lower layers are of varied character. The Sarmatian is divided on the basis of the molluscan fauna into Rissoa, Mactra and Ervilium-bearing beds and impoverished beds, or according to the microfauna (zone of large Elphidia, Zone Elphidium hauerinum-Elphidium antoninum, and the Zone Porosononion subgranosum). The Sarmatian shows a brachyhaline development and attains a maximum thickness of 700 m.

The Pannonian is divided into several zones. Zone A represents a zone of impoverishment and zone B is characterized by *Congeria ornitopsis* and *Melanopsis impresa.* Zones C and D are difficult to separate; *Congeria hoernesi* is frequent in sandy facies and *C. partschi* in pelitic development. *Congeria subglubosa* is a significant fossil of zone E. Ostracodes are the most important representatives of the microfauna. Lithologically, sands and sandy clays predominate. The first phase of coal-bearing sedimentation falls in zone B. The Pontian overlying the Pannonian begins with a coal-bearing sequence which contains *Congeria croatica.* Higher up there is a complex of variegated clays, less frequently of gravel (zones G and F). The upper part of the Pontian is generally faunistically barren, only in some layer appear the representatives of the genus *Candona.*

The Pliocene complexes correspond to the Dacian and Rumanian stages. In the Vienna basin they occur in a gravel and varied clay facies. It cannot be excluded that part of this sequence extends of the lowest Pleistocene.

The maximum thickness of the Pannonian attains 550 m and that of the Pontian 150 m; the Pliocene has a maximum thickness of 180 m. The Pannonian to Pontian appear in the oligohaline to completely freshened development.

In the Carpathian foredeep in Moravia, between Znojmo and Ostrava (northern boundary) and in the south in front of and partly under the overthrust units of the Outer Flysch belt, the Egerian in autochthonous position has been identified in a borehole near Malešovice. It is developed in the facies of dark claystones with *Miogypsina complanata,* but its total thickness is unknown.

In Moravia, the Eggenburgian of the Carpathian foredeep has been evidenced in the Znojmo and Ostrava areas and in the central part of the foredeep. The developments with the molluscan fauna occur there predominantly in sandy facies and more scarcely in pelitic facies. The marginal development passes centrewards into pelites, which are known to occur before and under the front of the overthrust Pouzdřany and Ždánice units. It should be emphasized that a part of the Neogene units are involved in the front of overthrust flysch units on the younger autochthonous Tertiary. The molluscan fauna of the Eggenburgian is characterized by *Thracia pubescens* and *Chlamys jaklowetziana*. Farther to the south in Moravia, the Ottnangian clays and sandy clays were deposited. Towards the margins of the foredeep in the region of the Bohemian Massif they pass into fresh-water to brackish sands with layers of gravel and varied clays. Within the whole sedimentary area of the Carpathian foredeep freshening of the basin continued in the upward direction and in the uppermost part Rzehakia sands with *Rzehakia socialis* were deposited. These beds are known in the vicinity of Brno, Maršovice and Rakšice. The Ottnangian sequences are of highly varied facies and in the lower part marine, brackish and fresh-water facies alternate.

The early Miocene, Eggenburgian was also a period of local volcanic activity: the basalt volcanism in the Opava area (Kamenná Hůrka near Otice) and rhyodacite volcanism in overthrust units in the southern part of the foredeep. The total thickness of the Lower Miocene does not exceed 450 m.

In the Karpatian the marine transgression in the foredeep expanded greatly. The sea reached as far as the western marginal part of the foredeep in Poland. In Moravia, sandy calcareous clays were deposited predominantly and to a lesser extent sands and sandstones. The fauna is known mainly from the clastic facies with *Chlamys macratis*. The sandy facies is developed in the southwestern part of the foredeep near Hevlín, Jaroslavice and Dolní Nětčice. In the northern part of the foredeep, the lower part of the Karpatian occurs in the grey facies, and the younger one is built up of variegated clayey beds. The pelitic facies of the Karpatian contain rich foraminifer fauna with uvigerins. In the central part of the foredeep scarce diatomite-bearing beds have been found. The maximum thickness of the Karpatian in the foredeep attains 1200 m. Sedimentation was interrupted between the Karpatian, which has a transgressive character, and the younger Badenian.

The transgression of the lower Badenian (Moravian) reached far into the eastern marginal part of the Bohemian Massif, extending from the area of the Boskovice Furrow as far as the vicinity of Ústí nad Orlicí. Part of the Nízký Jeseník Hills and of the Drahanská vrchovina Upland were washed away. In the southern part the area of Moravské Budějovice and Kralice nad Oslavou was flooded, and in the north the sedimentary basin proceeded into the foredeep in Poland, the Soviet Union and Rumania, and westwards from the Opava area into the Osoblaha projection. At the base of the lower Badenian gravel and sand were deposited. In the environs of Brno and Oslavany molluscs were rewashed into basal sands from the Ottnangian Rzehakia complex. Most widespread in the lower Badenian are non-sandy calcareous clays (called the "tegel facies"), very rich in fauna with the index foraminifer *Orbulina suturalis*. During sedimentation of the upper part of the lower Badenian, sands and Lithothamnion limestones were deposited closing the sedimentation in this stage. The Lithothamnion limestones are known from the neighbourhood of Židlochovice, Pratecký kopec Hill, the Boskovice Furrow, etc. In the Ostrava area the lower Badenian is developed in the facies of sandy calcareous clays, the Lithothamnion limestones are missing.

Sedimentation in the Carpathian foredeep between Ostrava and Znojmo—Mikulov ends with lower Badenian.

Te middle Badenian (Wielician) occurs only in the area between Opava and Hlučín. At the base there are pelites consistent with those of the Moravian. Higher up a gypsum sequence of the sabkha type, 60—70 m in thickness, terminates the middle Badenian sedimentation. The evaporite sedimentation gradually disappears in the upward direction. The overlying calcareous clays abounding in radiolarians and planktonic gastropods of the genus *Spiratella* form the base of the upper Badenian—Kosovian. Higher up the genera *Bulimina* and *Bolivina* occur frequently. In the late Badenian the marine sedimentation was closed in the Opava area.

Volcanism of basaltic type was active in the Opava area (tuffs and tuffites), and volcanites of a more acid character (rhyodacites) are known from the overthrust units within the whole Carpathian foredeep (lower Badenian tuffites). The total thickness of the middle Badenian does not exceed 200 m, and the maximum thickness of the upper Badenian is 300—350 m.

The limnic complex of varied clays and sands filling the depression zone of the Upper Morava valley is placed in the stratigraphic range of Dacian—Rumanian. The sequence is 200 m thick at the most. The Kobeřice Gravels with pebble material from the Culm of the Nízký Jeseník Hills occurring in the Opava area are conditionally ranged to the Pliocene.

4. Sedimentary history of the Bohemian Massif

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4.1 The bedding plane of the Třebotov Limestone, Praha Formation, Lower Devonian in the Hlubočepy Valley in the southern suburb of Prague Photo by Z. Kukal

4.1 Vertical variability of sedimentation

The first step to the characterization of the evolution of sediments in the Bohemian Massif was to assess their vertical variability. In all formations the proportions of the principal kinds of sediments have been computed or estimated (the method is described in the paper of K u k a l in press); the results are plotted in graph, Fig. 4.2. Some modifications had to be made in stratigraphic classification. The Andělská hora Formation had been relocated to the Lower Carboniferous. The Upper Carboniferous was divided into the Ostrava basin and the limnic basins which were ranged to the Permian. The following information is evident from the graph:

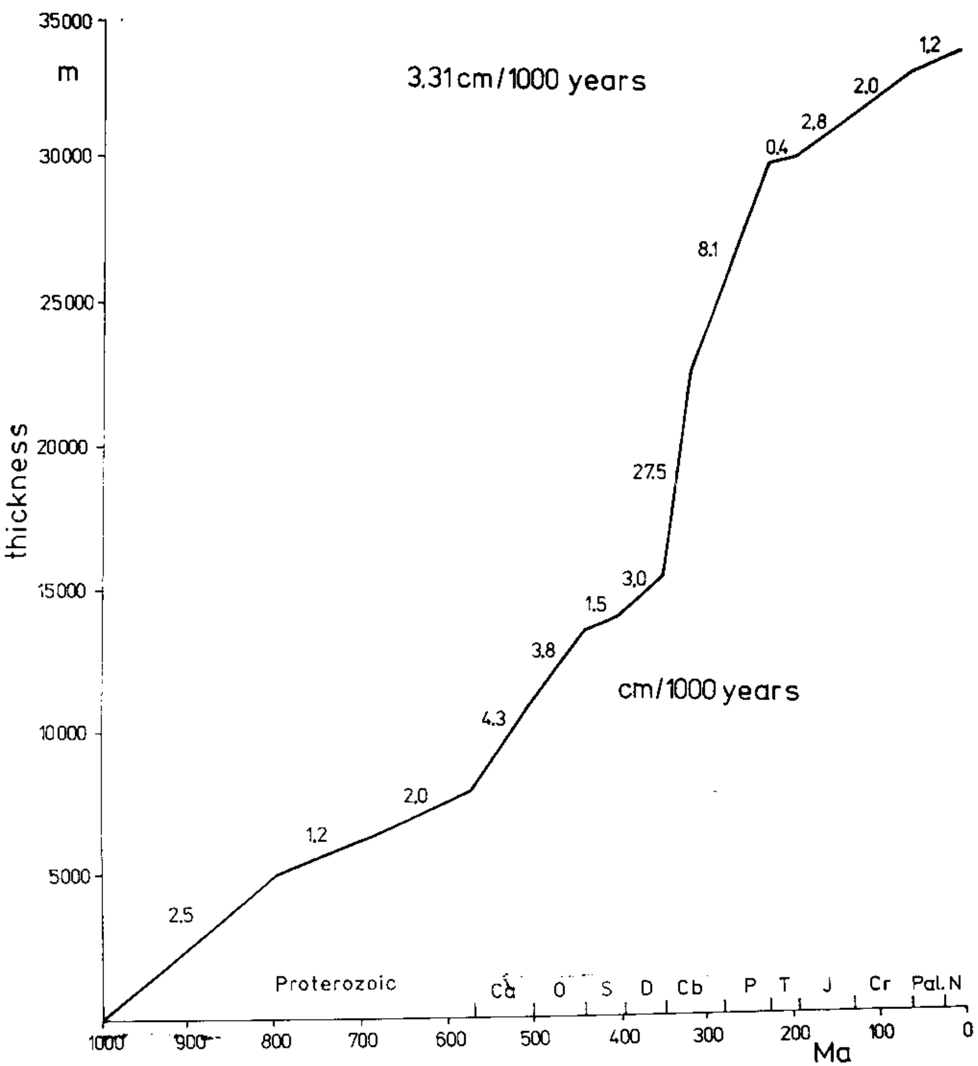
1. Sedimentation of coarse clastics attained its maximum in the Cambrian, Lower Carboniferous and in limnic Permo-Carboniferous and Triassic.
2. Two large maxima of carbonate sedimentation are in the Silurian—Devonian and in the Jurassic—Cretaceous.
3. Sedimentation of fine-grained clastics (siltstones and claystones) is relatively uniform throughout the stratigraphic sequence. The maxima are in the Cambrian and Triassic.

The maxima of sedimentation of coarse clastics occur in systems which followed (Cambrian) or accompanied (Lower, Upper Carboniferous) orogeny. In these periods, the high-energy relief of the source area was the controlling factor of conglomerate and sandstone sedimentation. In addition to tectonic movements, it was volcanism that contributed to the relief energy, but it had only secondary and short-term effects. In the Cambrian and Lower Ordovician, for example, the accumulation of volcanic products of a great thickness affected only part of the system. The influence of palaeoclimate was usually overcome by the effect of the relief but it was an important factor in the production of carbonates. At the time of the maximum carbonate sedimentation (Silurian—Devonian, Jurassic—Cretaceous) the Bohemian Massif occurred in the equatorial tropical and subtropical zones. Without favourable climatic conditions the rapid accumulation of shallow-water biogenic (also biohermal) carbonates would be impossible and the basin would have been filled with fine-grained clastics.

On the basis of data obtained in the individual stratigraphic units, the representation of sediments in the entire sedimentary cover of the Bohemian Massif was computed (metamorphic equivalents and volcanic products have not been included):

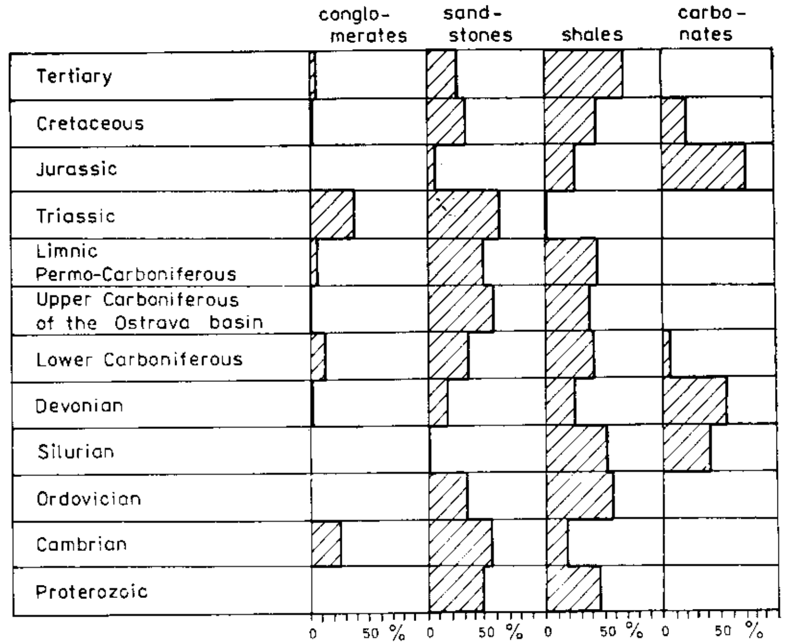
sediment	per cent
conglomerates	7
sandstones	43
siltstones+claystones	40
carbonates	9
other	1
	100

The numbers should be taken with reserve, as by averaging the not very precise values the errors may increase. Nevertheless, we think it useful to submit these calculations. The predominance of sandstones and siltstones+claystones is expressive, the sandstones prevailing slightly over the lutites.



4.2 Changes in rate of deposition of the sedimentary cover of the Bohemian Massit. Thickness (potential) of sediments is plotted on the vertical axis, and the geological history from Upper Proterozoic in millions of years on the horizontal axis. Slope of curve — rate of sedimentation. Numerals — sedimentation rate in individual stages in cm/1000 years. Average sedimentation rate from the Late Proterozoic to Quaternary is 3.31 cm/1000 years (Z. Kukal, orig.)

The rate of sedimentation was calculated from the potential thickness of sediments of the individual formations and the known time span. To express the rate of sedimentation, the empiric curves (also called Bubnoff's curves) were constructed (the thickness of sediments is plotted on the vertical axis and

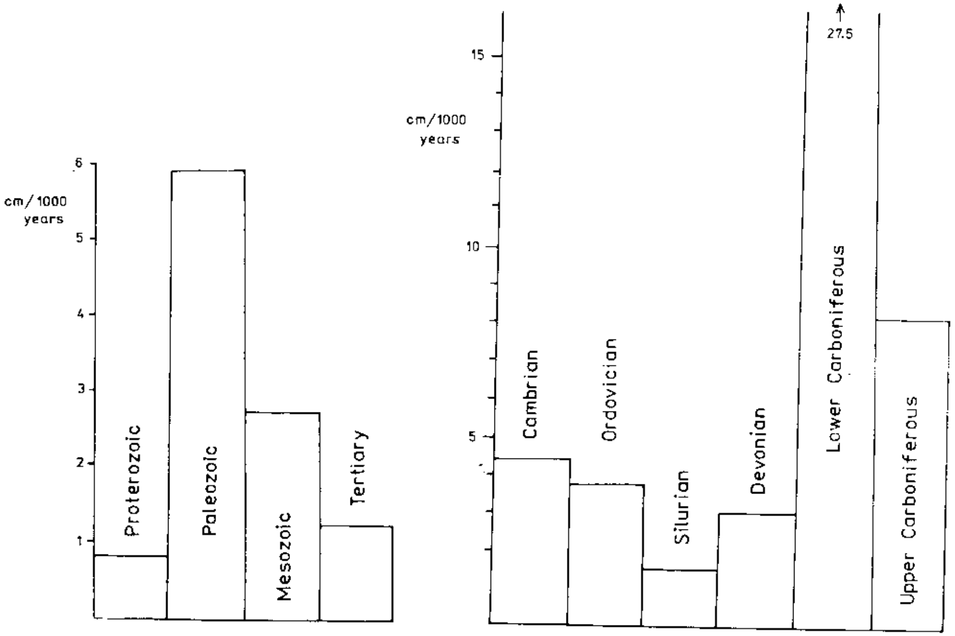


4.3 Graphic representation of sediment percentage in the formations of the Bohemian Massif. Only essential sediments are plotted, less frequent and pyroclastic sediments have been omitted (Z. Kukal, orig.)

the duration in millions of years on the horizontal axis). The slope of the curve gives the rate of sedimentation. The data on the absolute geological age and duration of the stratigraphic units are taken from the papers of Cohee et al. (1978 — all units), Jones et al. (1980 — Silurian and Devonian), Churkin et al. (1977 — Ordovician and Silurian), and Van Hinte (1976 — Cretaceous).

The empiric curve for the whole sedimentary sequence of the Bohemian Massif is in Fig. 4.2. The units are taken as wholes even if only a part of some of them is represented by the sedimentary sequence. The potential thickness of the entire sedimentary cover of the Bohemian Massif is 33,150 m (without metamorphites). The average rate of sedimentation from the Late Proterozoic to the Quaternary is 3.31 cm/1000 years. The curve shows a marked fluctuation of the sedimentation rate. The slow Proterozoic sedimentation is followed by a prominent acceleration; the increased rate of sedimentation continues in the

Ordovician, declines again in the Silurian to rise moderately in the Devonian. At the onset of the Carboniferous a conspicuous break takes place, in fact, the most prominent change in the sedimentary history of the Bohemian Massif, as concerns



4.4 Rate of sedimentation in the Bohemian Massif. Histogram on the left shows average values from the Proterozoic, Palaeozoic, Mesozoic and Tertiary; histogram on the right side indicates average sedimentation rates in the Palaeozoic (Z. Kukal, orig.)

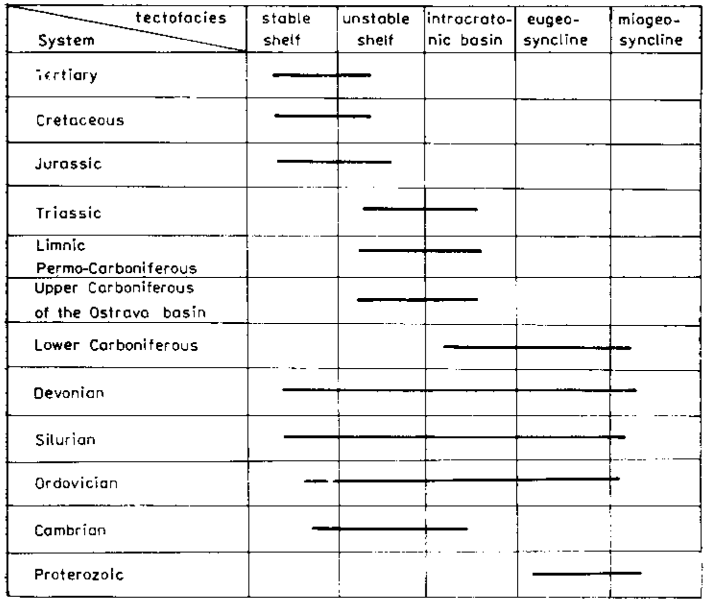
the rate of sedimentation. Subsequently to the average rate of 3.0 cm/1000 years in the Devonian, in the Early Carboniferous it increases eight times (27.5 cm/1000 years). During the Late Carboniferous the sedimentation rate slows down but still remains high enough. An opposite marked change occurs at the onset of Mesozoic. During the Triassic the rate of sedimentation drops to a minimum value to speed up somewhat in the Jurassic and Cretaceous. In the Tertiary sedimentation slows down again.

The data from the Precambrian cannot be taken very seriously as the thicknesses and stratigraphic assignment of the units are uncertain. It cannot thus be expected that the Precambrian orogenies will be expressed in the empiric curve. The post-orogenic sedimentation, however, shows an increased rate directly in the Cambrian and reasonably slows down in the mid-Palaeozoic to increase in the Devonian simultaneously with the initial phases of the Hercynian orogeny. The orogenic and late-orogenic sediments of the Lower and Upper Carboniferous and the Permian are deposited at an unusually high rate. The break at the Palaeozoic/Mesozoic boundary implies a transition to the platform development stage, which with its low sedimentation rate persists until the Quaternary. As seen in histogram in Fig. 4.4 the Palaeozoic is at the head, as concerns the sedimentation rate, being followed by the Mesozoic and Tertiary. As mentioned above, the low values in the Proterozoic are not very reliable. The second histogram (Fig. 4.4) shows the course of the sedimentation rate during the Palaeozoic, above all the drop of the rate between the Cambrian post-orogenic sedimentation and the Silurian and a new revival of sedimentation in the Devonian. The reversal between the Devonian and Early Carboniferous sedimentation rate is here well defined. The comparison of our computations with the relevant data from other basins (e.g. Spencer 1974, Ronov et al. 1976, Schwab 1976) has shown that the Palaeozoic average corresponds to preorogenic and synorogenic sedimentation, the Upper Palaeozoic average to postorogenic (or late orogenic) sedimentation. As a whole, the Bohemian Massif with its average sedimentation rate approaches rather to geosynclines than platforms. The diagram also reveals that the continuous carbonate series of great thickness exhibit unusually steady rates of sedimentation (from 3.5 to 5.0 cm/1000 years) and the Palaeozoic argillaceous sediments very low values (1.2—1.5 cm/1000 years).

4.2 Sedimentary environment

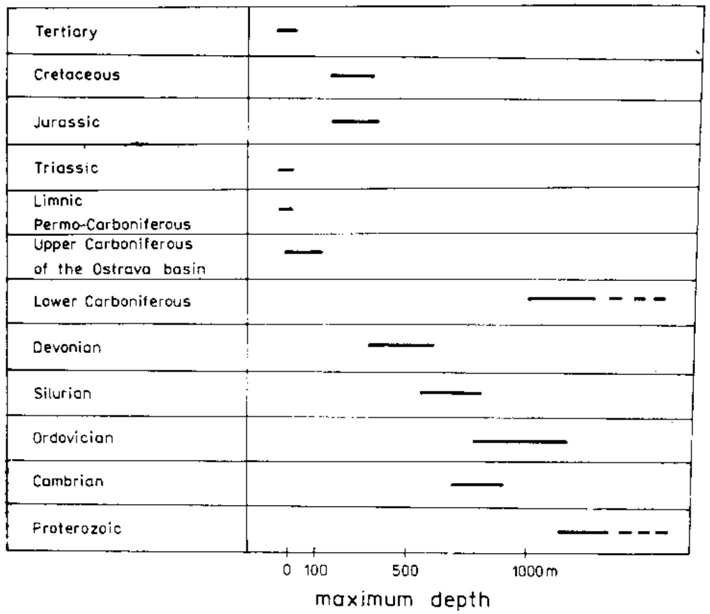
The sedimentary environments of the deposits of most stratigraphic units of the Bohemian Massif are known, although they have been reconstructed in different details and using different methods. The history of the environments and particularly their sudden changes are controlled by tectonic movements. To illustrate the development of the environment of the Bohemian Massif, a standard environment series has been used as is usually applied to ancient sediments (e.g. Kukal 1971b, Selley 1976, Reading 1978). The development of the environment is depicted in Tab. 4.1. In the Proterozoic deep-sea sedimentation predominated; it may have occurred in inland or marginal seas with a diversified relief of the sea-floor. Sedimentary series were partly deposited also in shallow-water, or littoral and supralittoral environments, as evidenced by the occurrences of stromatolites. In the early Cambrian, continental sedimentation took place in intramontane depressions with alluvial fans, which passed into alluvial plains and lakes. The Middle Cambrian marine sedimentation compares to rather deep marginal or inland seas, in places with a rather strong relief of the sea-floor. The late Cambrian sedimentation returned into minor intramontane basins with alluvial fans and intermittent streams at the margins and a lake in the interior. Ordovician sediments are typical

Table 4.1
Evolution of sedimentary environments in the Bohemian Massif. Heavy lines in systems denote the range of environment. Black wedges on the right — abrupt and great changes in sedimentary environments (Z. Kukal, orig.)



deposits of a broad zone of a shallow and medium-deep sea. The shallow-water environments extended as far as the intertidal zone, bays were numerous, and deltaic sedimentation was intensive. Shallow-water sedimentation also prevailed in the Silurian. Typical graptolitic shales are deposits of large bays or inland seas of smaller depths. The carbonate environments of the Upper Silurian were highly differentiated, ranging from biostromes in very shallow waters to basins attaining depths of up to several hundreds of metres. The Devonian in the Moravo-Silesian region began with alluvial sedimentation. Above the clastic deposits an extremely thick limestone complex was laid down, representing a shallow-water carbonate platform sloping into shallow-sea carbonate basins. The Devonian clayey shales sedimented in a somewhat deeper environment of marginal seas. In the latest Devonian the basin deepened at the site of deposition of the flysch (Andělská hora Formation). A strongly differentiated basin with troughs and shallower areas came into being. In the Early Carboniferous sedimentation continues on the carbonate platform in places but the greater part of the space is occupied by a deeper basin with flysch sedimentation. However, shallow bays and plateaus also developed and local transitions to continental environments probably existed. The transition to Upper Carboniferous paralic coal basins in the Ostrava area was slow. The sea became shallower changing gradually into shallow bays and lagoons, which alternated with wide coastal plains. Marine environments vanished and continental sedimentation of alluvial-lacustrine type was developing. Limnic sedimentary basins in the Permo-Carboniferous were filled with sediments of continental origin. Generally the sequence of alluvial fan — river channel — floodplain — lake has been reconstructed. Also eolian sediments — sands and loess have been described. In the Triassic the Permo-Carboniferous sedimentation type continued. The Jurassic sedimentation took place predominantly in the shallowest sea, on a carbonate platform with lagoons and bioherms. The eastern margin of the Bohemian Massif deepened into a somewhat deeper basinal environment. Continental freshwater Cenomanian sediments are deposits of lakes and streams. Alluvial fans extended from the elevated position into depressions. The marine Cretaceous sedimentation represents a set of shallow-water environments, ranging from the prograding sandy shoreline through shallow-water flats with bars, barriers and sand waves up to shallow basins with clayey and marly floors. Continental sedimentation in the Tertiary occurred predominantly in a lacustrine environment. The products of neighbouring fluvial environment and minor alluvial fans are also partly preserved. Lacustrine-deltaic sedimentation was marked.

Table 4.2
Maximum depths of basins in the sedimentary history of the Bohemian Massif. They are shown by line segments and not by points, because reconstruction, especially for great depths, is uncertain (Z. Kukal, orig.)



The most prominent break in the development of sedimentary environments occurred at the Proterozoic—Palaeozoic boundary; a minor one fell to the midst of the Late Carboniferous (approximately near the Westphalian—Stephanian boundary), another one between the Triassic and Jurassic and another between the Cretaceous and Tertiary. The picture is complemented by symbols showing maximum depths of the basins (Tab. 4.2). The values are only broad estimates, especially for deep-water deposits. For this very reason the maximum depths are shown by line segments and not by points. The maximum depths should have been attained during the Proterozoic and Early Carboniferous sedimentation, when depths of up to several thousands of metres may be expected. During the Palaeozoic, from the Cambrian to Devonian, sedimentation occurred in basins with monotonous clayey sedimentation at depths of several hundreds, possibly even thousands of metres. For Mesozoic marine sedimentation only the shallowest environments could be determined.

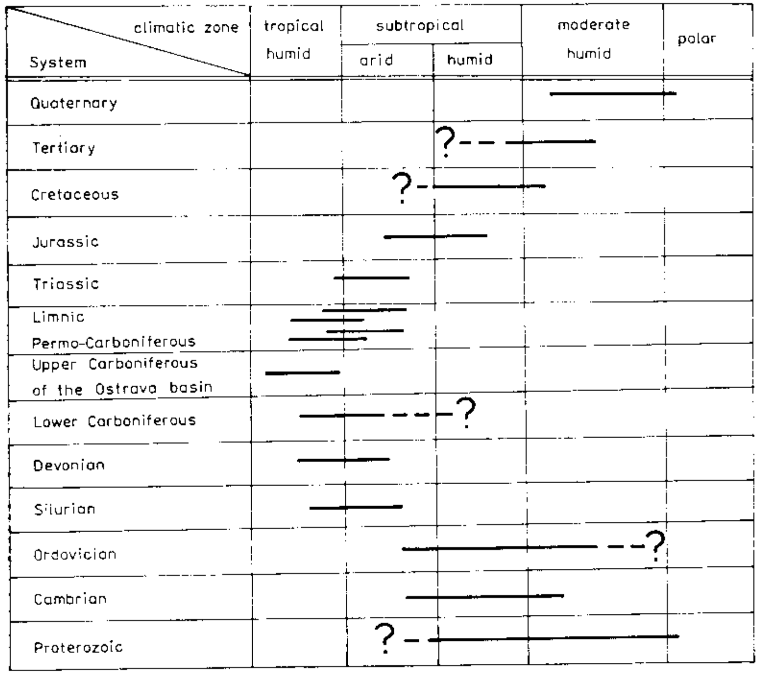
4.3 Palaeoclimate

The palaeoclimatic history of the Bohemian Massif region has been reconstructed on the basis of the composition of sediments. The data have been checked against the palaeomagnetic reconstructions of palaeo-poles and palaeo-equators for different stratigraphic units (mainly McElhinny 1975 and Morel-Irving 1978).

Our model is based on the assumption that the climatic zonation of the Earth did not change essentially during the geological history. It is plausible that the zones were periodically expanded and compressed (e.g. the polar zone in glacial periods or subtropical arid zones). In our reconstruction we used the following criteria:

1. The presence of so-called palaeoclimatic indicators such as coal, evaporites, bioherms, aggregate limestones, stromatolites;
2. The presence of desert sand and eolian dust (in the form of palaeoloess or as an admixture in limestones);
3. The existence of abundant alluvial fans of great thickness, which are typical of semiarid climate;
4. The presence of red beds. The primary red beds indicate alternation of the tropical humid and tropical acid climate.
5. The type of weathering residues. Unfortunately, although very abundant in the Bohemian Massif, the interval of their formation might have been very long. Moreover, red lateritic and kaolinitic weathering products can develop within a broad range of climate.
6. The composition of clastic sediments, chiefly their mineral and chemical maturity. Mature sediments are supplied with detritus from the source areas where humid climate prevails. The effect of climate may be effaced by a rapid erosion induced by greater differences in the relief. A mixture of weathered and fresh unstable components is regarded as one of the proofs of semiarid climate.
7. The presence of deltaic sediments. Perennial streams and major deltas indicate humid climate.

Table 4.3
Palaeoclimatic history of the Bohemian Massif. Palaeoclimate is reconstructed from the character of sediments and weathered materials (Z. Kukal, orig.). Tectofacies in the sedimentary history of the Bohemian Massif (Z. Kukal, orig.)



Our reconstruction of the palaeoclimatic history is in Tab. 4.3. We are well aware that the climatic conditions changed very rapidly during the geological history and therefore only average palaeoclimate patterns for individual periods have been reconstructed. During one period arid climate may have alternated with the humid one many times.

The reconstruction of the Proterozoic climate is the most difficult. During this long period the Bohemian Massif may have passed through several climatic zones. Immature sediments would attest rather to less intensive weathering in a moderate zone. The presence of glacial sediments not far from the Bohemian

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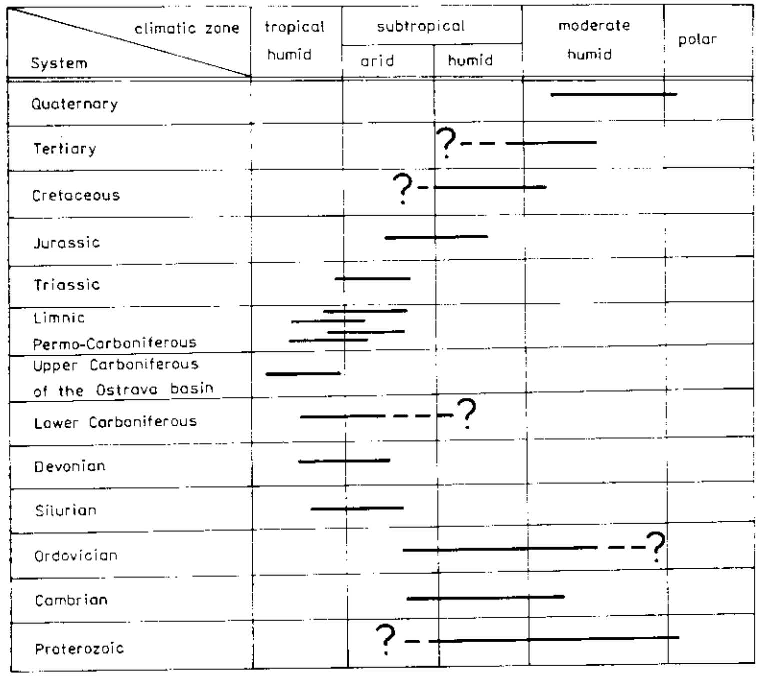

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Massif may imply the proximity of the polar zone, but on the other hand, stromatolites point to a subtropical or tropical climate. The reconstruction of the Cambrian climate lies on a more solid basis. The Lower Cambrian residual gravel and the mixture of ultrastable and unstable detritus is suggestive of semiarid climate. The presence of red beds is also indicative of warmer climate, both humid and arid. Similar conditions continued in the Ordovician. The Bohemian Massif occurred in the temperate zone, as is evidenced by intensive weathering of detritus and the presence of red beds. It is very likely that the Massif was moving alternately towards subtropical and polar latitudes. In the latest Ordovician there appear evidences of a warmer climate (increased production of biogenic limestones) and even of aridity (bimodal sandstones of the Kosov Formation). It can be presumed that the Bohemian Massif passed through the subtropical arid zone on its travel to the Silurian tropical latitudes. In the Silurian the sedimentation occurred in warm seas at the boundary between the tropical and subtropical zone. Clastic material was supermature and a rich association of benthic faunas, including biostromes developed. In the Devonian reefs, eolian dust and red limestones suggest sedimentation in the tropical zone and/or subtropical arid zone. The conditions may have changed frequently. Similar sedimentation persisted into the Early Carboniferous, but at that time cooling and aridization of the climate began (probably due to the uplift of the source area to great heights during Variscan orogeny). The paralic Upper Carboniferous is a product of tropical humid climate. During the latest Carboniferous and in the Permian the tropical humid conditions changed many times into subtropical arid and vice versa. Permian arid sedimentation continued into the Triassic. In the Jurassic subtropical humid and partly also arid subtropical predominated. Products of intensive weathering provide evidence of subtropical humid climate in the Cretaceous. The Bohemian Massif migrated still farther into the temperate zone, but weathering occurred in the subtropical zones even in the Tertiary. The conditions approached those of the Quaternary, when the Bohemian Massif was situated at the boundary between the temperate and polar zone.

4.4 Tectofacies

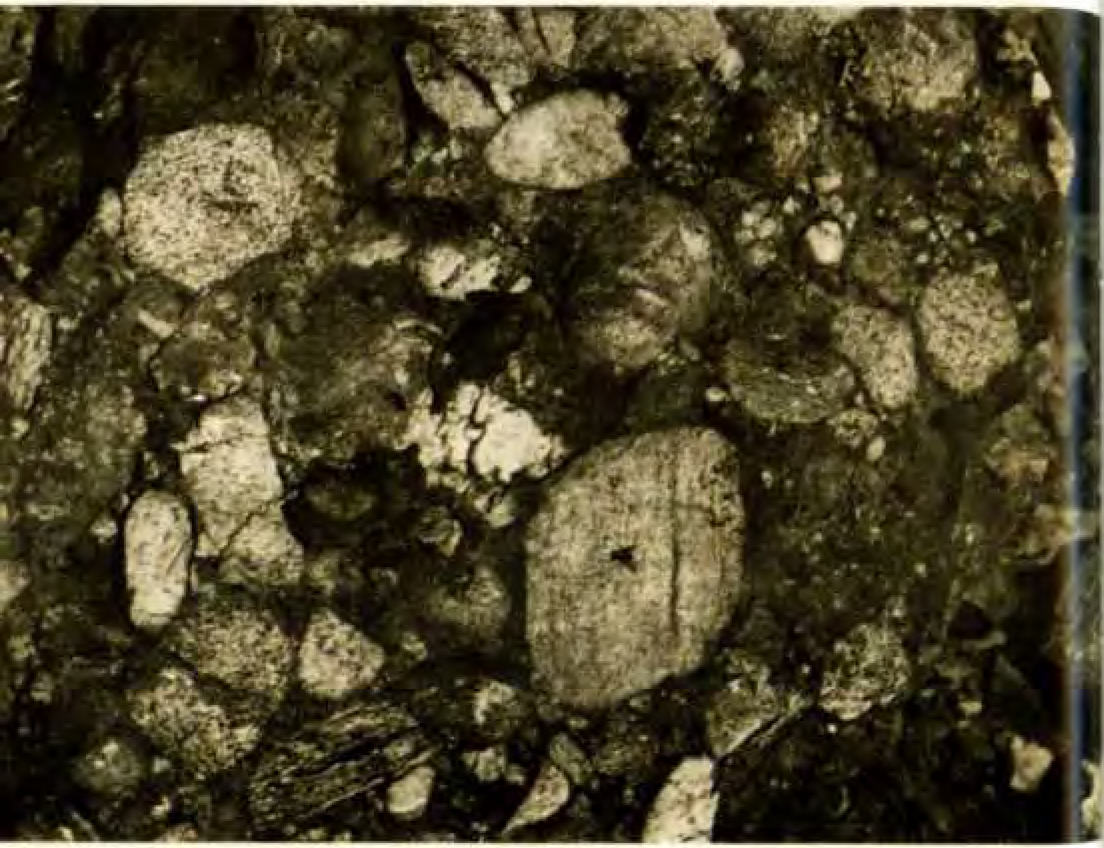
The tectofacies of the Bohemian Massif are reconstructed on the basis of the associations of sediments. Their history is depicted in Tab. 4.1. The term shelf is used here only in the tectonic and not morphological sense.

The Proterozoic rock associations are definitely eugeosynclinal and miogeosynclinal. The assignment of the Cambrian is rather uncertain. According to the mature quartzose sediments it would belong to the shelf, but the great thickness of the complex is suggestive of unstable shelf to intracratonic basin. The Ordovician—Silurian—Devonian associations occupy a broad range from the stable shelf to miogeosyncline. The Lower Carboniferous is evidently of eugeosynclinal character, whereas the Upper Carboniferous and Permian are to be ranged to the unstable shelf and intracratonic basin. From the Jurassic on the associations are typical of a stable shelf. Only on account of great thickness of sediments the Mesozoic and Tertiary complexes are partly assigned to the unstable shelf. From the above survey it follows that in the Bohemian Massif there are two typical geosynclinal tectofacies, i.e. Proterozoic and Lower Carboniferous complexes. Opposite are typical stable shelf sediments of the Mesozoic, beginning with the Jurassic. The transitional Upper Carboniferous to Triassic stands between unstable shelf and intracratonic basin. The associations of the Lower Palaeozoic, however, are so diverse as concerns the standard tectofacies that from some viewpoints they are geosynclinal, and intracratonic and of shelf nature from others.

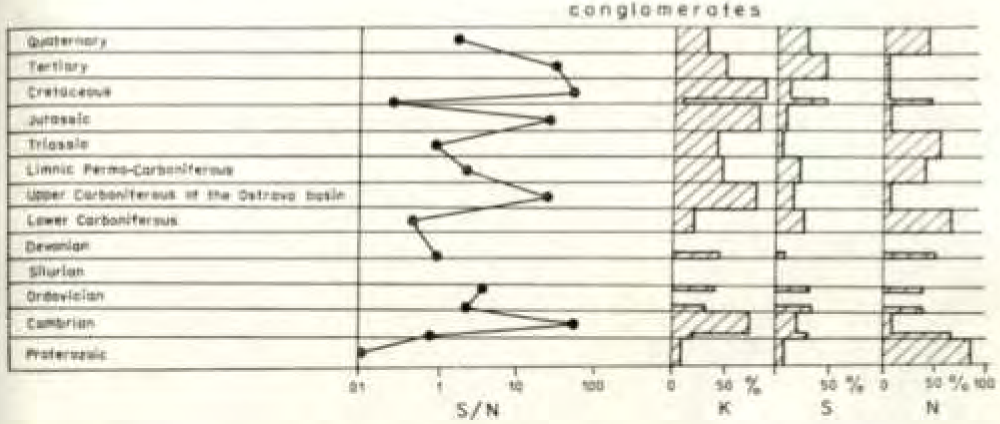
4.5 The development of conglomerates, sandstones and clayey sediments

Conglomerates

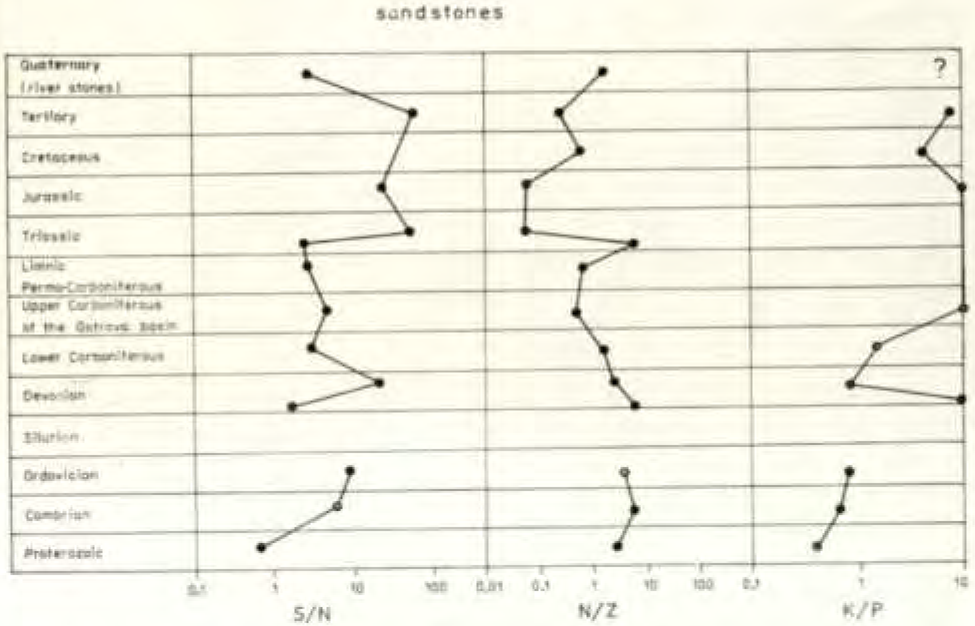
Conglomerates of the Bohemian Massif are very variable. The development of their composition is shown in Fig. 4.6, where the values of S/N ratio (i.e. percentage of stable pebbles to that of unstable pebbles), are plotted on the horizontal axis. This ratio indicates the maturity of conglomerates, which implies the degree of weathering in the source area, the length of transport, and reworking. Disregarding the special position of basal conglomerates, the trend of the curve indicates that the conglomerates are of several types. The Proterozoic and Culm conglomerates are least mature, the Cambrian, Cretaceous, Tertiary and, surprisingly enough, also the Upper Carboniferous conglomerates from the Ostrava basin are the most mature. Ordovician conglomerates and Permo-Carboniferous lacustrine conglomerates occupy a transitonal position. From the shape of the curve it is evident that in the Bohemian Massif the conglomerates do not show a clear-cut trend from the Proterozoic to the Quaternary. They rather fall into several minor units, in which a gradual change and maturation of pebble material is observable. The first sequence involves the Proterozoic—Cambrian, the second the Culm—Upper Carboniferous, and the third the Permo-Carboniferous—Triassic—Jurassic—Cretaceous. From the position of the Quaternary it appears that a new cycle from immature to mature conglomerates begins. The right-hand column in Fig. 4.6 complements this pattern. The stable material is divided into quartz pebbles (K) and pebbles of stable rocks (S). Peb-



4.5 Luleč Conglomerate with pebbles of Moldanubian rocks. Pístovice quarry, Drahanská vrchovina Upland Photo by J. Svoboda



4.6 Development of conglomerates of the Bohemian Massif. Curve on the left shows the variability of the S/N value (i.e. ratio of stable and unstable pebbles)
K — quartz pebbles, S — pebbles of stable rocks, N — pebbles of unstable rocks. Average values are computed for individual systems; conglomerates are specially indicated in some of them (Z. Kukal, orig.)



4.7 Development of sandstones of the Bohemian Massif. The development is based on the calculation of average composition of sandstones of all systems, using three parameters: S/N (ratio of stable and unstable components in sandy fraction), N/Z (ratio of unstable rock fragments to feldspars) and K/P (ratio of K-feldspars to plagioclases) (Z. Kukal, orig.)

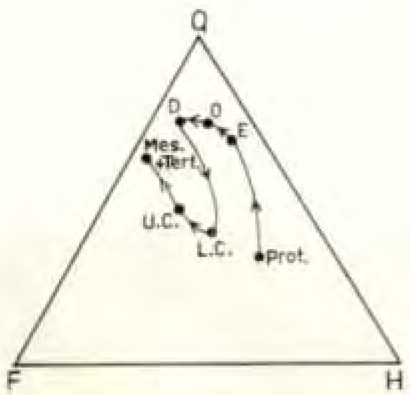
bles of unstable rocks are labelled N. The different composition of basal Cambrian, Cretaceous, and partly also Ordovician conglomerates is particularly well seen from this graph. The percentage of quartz is mostly positively correlated with stable pebbles, with the exception of fine-grained conglomerates of the paralic Upper Carboniferous, Cretaceous and Jurassic, in which the percentage of quartz rises to more than 90 %. The maxima of unstable clasts are in the Proterozoic, Culm, limnic Permo-Carboniferous, Triassic and Quaternary conglomerates.

Sandstones

The development of sandstones is illustrated by means of three parameters, which characterize the composition and maturity of these sediments. It is the S/N ratio (ratio of all stable and unstable grains in the sand fraction), the N/Z ratio (ratio of unstable grains to feldspars) and the K/P ratio (ratio of potassium feldspars to plagioclases). Even though the parameters change with the grain-size of sandstones, they are so characteristic that they maintain the fundamental properties of sandy rocks of the individual stratigraphic units. Average values of these parameters were computed and illustrated by a graph (Fig. 4.7) for all systems. The S/N curve markedly varies. The maturity increases from immature Proterozoic sandstones to the Palaeozoic. Basal Devonian clastics form an exception. In the Early Carboniferous an abrupt change took place and a long sedimentation of immature sandstones with low S/N values came into being. Another break has been established between the Triassic and Jurassic, this time a sudden reversal to mature sandstones. The period of their sedimentation lasted until the Quaternary, when the S/N value drops surprisingly (Quaternary is here represented by a minor set of fluvial sands). Similarly as with conglomerates, the sedimentary history of sandstones can be divided into two units, the first involving the Proterozoic to Devonian, and the second the Culm to Tertiary.

The curve of N/Z ratio is simpler. It shows that from the Proterozoic to Lower Carboniferous predominantly lithic sandstones were deposited (N/Z >1), in some systems even highly lithic (Cambrian, Ordovician, Devonian). Beginning with the Late Carboniferous feldspathic sandstones sedimented (with the only exception at the base of the Triassic) and only in the Quaternary sedimentation of lithic sands was renewed. High values of N/Z ratio imply a rapid sedimentation of undecomposed rock fragments but also, and in some places mainly, a lack of feldspathic material, i.e. a lack of granitoids and katazonal metamorphites in the source area. According to this indicator a sufficient amount of feldspathic material would have been available as late as in the Late Carboniferous, but the example of the Quaternary shows that it is not of universal validity and

4.8 Beds of nodular limestones belonging stratigraphically to the Třebotov Formation (Lower Devonian — Dalejan). Valley of the river Berounka, near Srbsko village
Photo by Z. Kukal



4.9 Triangular representation of the average composition of sandstones of individual systems, with end members Q — quartz, H — rock fragments, F — feldspar. Arrows show development trend from old to younger (Proterozoic—Cambrian—Ordovician—Devonian—Mesozoic—Tertiary) sediments (Z. Kukal, orig.)

4.10 Kotýs' Limestone. Kotýs near Koněprusy. The Lower Devonian of the Barrandian
Photo by J. Svoboda

that at accelerated erosion the feldspar detritus may be masked by another unstable detritus. This was obviously the case in the Early Carboniferous.

The K/P curve refines the data given above. In the Proterozoic, Cambrian, Ordovician and a large part of the Devonian and part of the Lower Carboniferous, plagioclases predominate over potassium feldspars. A break leading

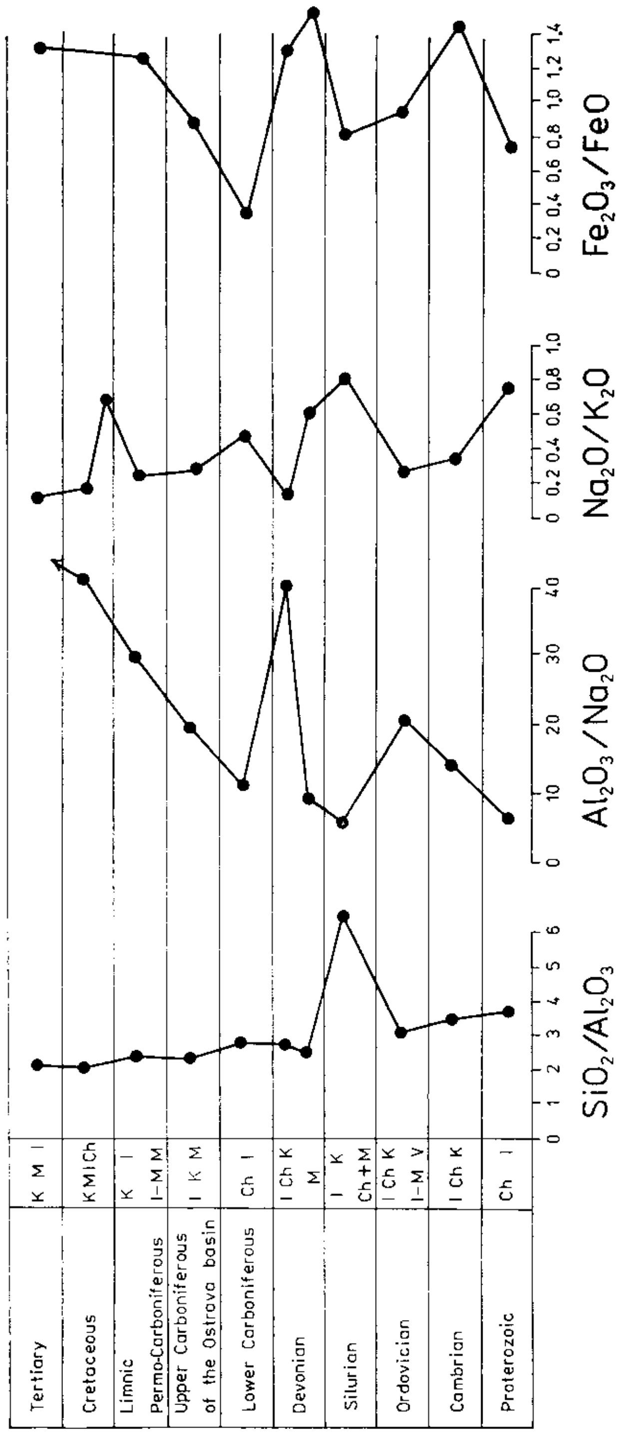
4.11 Typical graptolitic shales with intercalations of tuffitic limestone. Liteň Formation (Wenlock, Silurian). Barrandian Basin, near Karlštejn
Photo by Z. Kukal

towards the predominance of potassium feldspars has been established in the Upper Carboniferous and the K/P values attain their maximum throughout the Mesozoic. Granitoids and possibly orthogneisses are thought to be the main source of potassium feldspars. The N/Z curve, however, speaks for the interpretation of this high ratio in terms of the deficiency of feldspathic source rocks. According to K/P curve they began to be of greater extent as late as the Late Carboniferous. It is possible that the weathering processes also played a certain role because, as is well known, the unstable rock fragments (clayey shales, phyllites, aphanites, etc.) weather more readily than feldspars. During the Late Carboniferous and throughout the Mesozoic the weathering was doubtless of high intensity and consequently the enrichment with feldspar detritus may have occurred directly in the source area.

The development of sandstone composition is also illustrated in the triangle in Fig. 4.9. Average sandstones from all systems are plotted and the sequence is shown by an arrow. This curve also consists of two parts. The development from the Proterozoic to the Devonian, characterized by the increase in quartz and feldspar amounts to the detriment of rock fragments was interrupted at the beginning of the Early Carboniferous and the curve returns almost to the starting point. The development from the Early Carboniferous to the Mesozoic and Tertiary was analogous, with increasing amount of quartz-feldspar detritus. The development in the Mesozoic and Tertiary, however, is shifted considerably to the feldspar maximum.

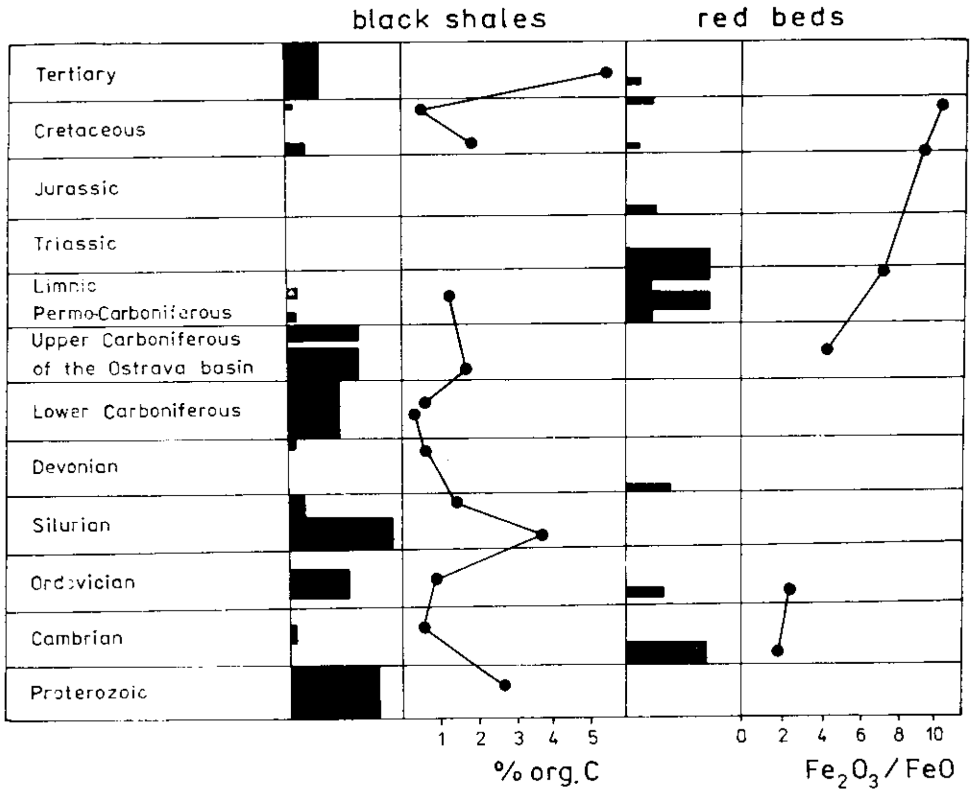
Clayey sediments

Chemical composition of clayey sediments is a very sensitive indicator of sedimentary conditions. Therefore, in the Bohemian Massif the vertical variability of characteristic parameters has been studied (see Fig. 4.12). The curve of SiO_2/Al_2O_3 ratio should indicate the percentage of coarser fractions, and possibly the admixture of authigenic quartz. Except for a great anomaly in the Silurian, a moderate decrease in the values is observable from the Proterozoic to the Tertiary. Of primary importance is the Al_2O_3/Na_2O ratio, which defines the chemical maturity of sediments. The value of 15 is usually considered to be the boundary between mature and immature claystones. The curve for the claystones studied rises from very low values in the Proterozoic to the Ordovician, dropping after a "Silurian anomaly" to very low values. Immature claystones sedimented still in the Devonian in the Prague basin. In contrast, almost supermature rocks sedimented in the Late Devonian of the Moravian region. The decrease of the values in the Early Carboniferous can be expected. Kukal (1980) explains it by a change in the relief configuration and a supply of a large amount of immature detritus on the one hand, and by the climatic



4.12 Evolution of clayey sediments of the Bohemian Massif. Curves illustrate their development characterized by the variability of four parameters. Essential clay minerals in second column are denoted by abbreviations: I — illite, M — montmorillonite, K — kaolinite, Ch — chlorite, V — vermiculite, I–M — mixed structures of illite-montmorillonite (Z. Kukal, orig.)

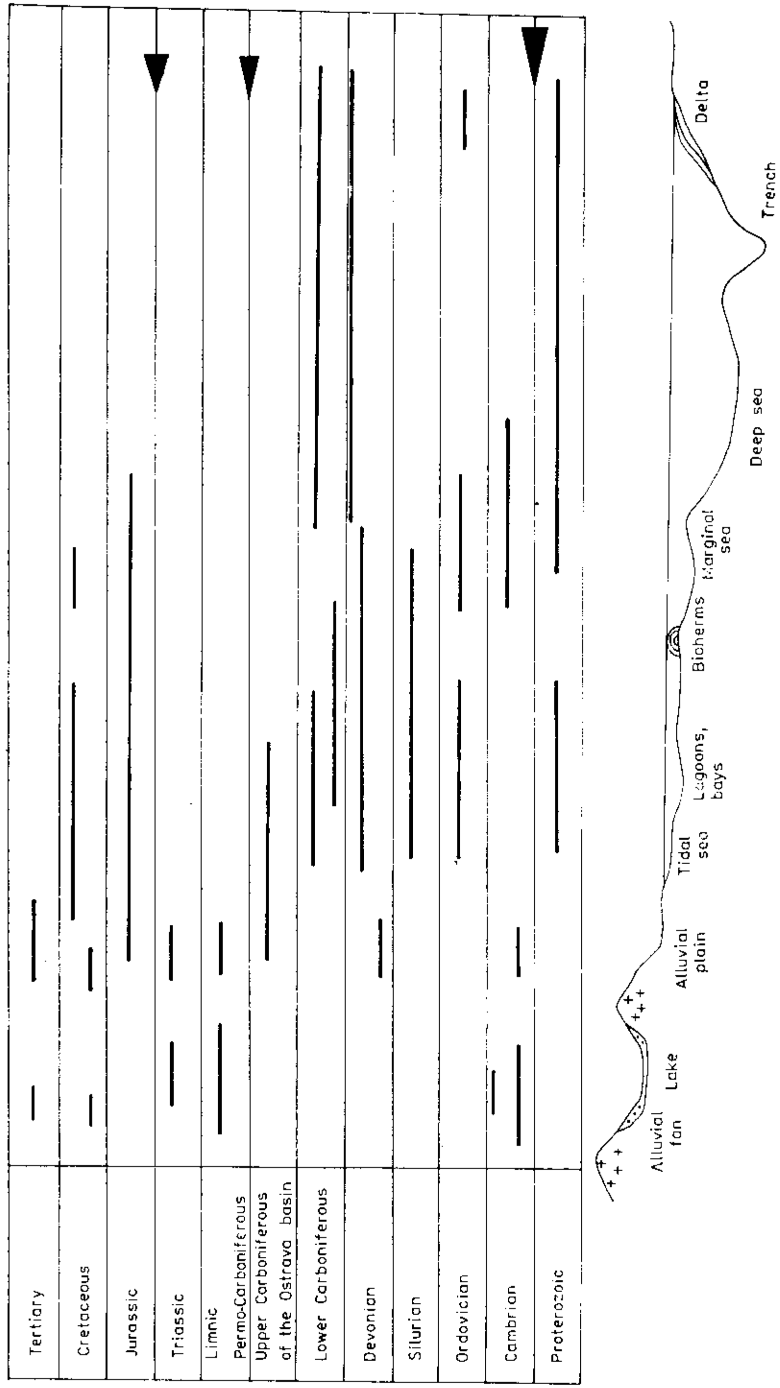
change, on the other. From the Early Carboniferous, clayey sediments of progressive maturity appeared, the Al_2O_3/Na_2O ratio attaining unusually high values in the Tertiary. The oscillations described by S k o č e k (1974) from the



4.13 Black claystones (shales) and red beds in the Bohemian Massif. Average contents of C_{org} are given for black claystones, and aver. Fe_2O_3/FeO ratios for red beds (Z. Kukal, orig.)

limnic Permo-Carboniferous, due to differences between the claystones of red and grey complexes, are not plotted on the curve.

The curve of Na_2O/K_2O ratio also reflects the development of maturity. The value of the ratio decreases with the increase in chemical maturity. In Fig. 4.12 (third curve from the left) the curve shows more irregularities than the previous curve. In the Proterozoic the values approach to 1.0, they decrease to the Cambrian and Middle Ordovician, to rise abruptly from the Upper Ordovician to Silurian (in the Silurian there is the greatest anomaly in the entire sequence). Until the Devonian the values rapidly decrease to a minimum. The increase



4.14 Tectofacies in the sedimentary history of the Bohemian Massif (Z. Kukal, orig.)

towards the Early and Late Carboniferous is easy to explain (by a supply of immature material), but the high values of the fresh-water Cenomanian are more difficult to interpret. Towards the marine Cenomanian, Turonian and Senonian the values decrease again and remain at a very low level up to the Tertiary. The curve shows broadly that after great oscillations in the Palaeozoic, mature detritus was being supplied beginning with the Late Carboniferous until the Tertiary, except for the fresh-water Cenomanian.

The curve of Fe_2O_3/FeO ratio (Fig. 4.12 curve on the right) displays great and irregular oscillations. The systems without a major amount of black shales show values above 1.0 (Cambrian, Devonian, Cretaceous, Tertiary). In contrast, the systems containing greyish-black or black clayey sediments possess values much lower than 1.0 (the lowest has been established for Upper Carboniferous, then Proterozoic, Ordovician and Silurian). The values of the Upper Carboniferous are near to 1.0 varying according to whether they belong to grey or red complexes. The relatively high value of typical black graptolitic Silurian shales is surprising. It is plausible that the trivalent iron has been preserved in undecomposed minerals and in the volcanic admixture.

Similarly as in sandy rocks, two cycles are distinguishable in the development of maturity of clayey sediments. The trend towards maturity appears strongly from the Proterozoic to the Middle Ordovician. In the Upper Ordovician sediments the degree of maturity decreases, which may reflect the beginning supply of immature material, which manifested itself so markedly in the Silurian. The Devonian clayey sediments are, on the contrary, supermature. The decrease in the Early Carboniferous could be expected and since that time regular and oustanding chemical maturing of clayey sediments continued until the Tertiary.

Black shales and red beds

These two sedimentary associations represent an important member of the sedimentary sequence. Their occurrences are shown in Fig. 4.13. The curve of average organic carbon content is adjoined to the black sediments. The fundamental condition for the formation of black clayey shales is the lack of oxygen needed for the oxidation of organic matter. In the Proterozoic the impoverishment in oxygen was universal and thus sediments richer in organic substances predominated. Black shales of Ordovician age are a product of anoxic sedimentation in semi-isolated basins of medium depth. The pelagic area into which the Prague basin passed eastwards also must have been a semi-isolated basin with oxygen-poor water. Anoxic sedimentation culminated by deposition of the Silurian graptolitic shales; an increased percentage of pyrite indicates that the water near the bottom had to be poisoned with hydrogen

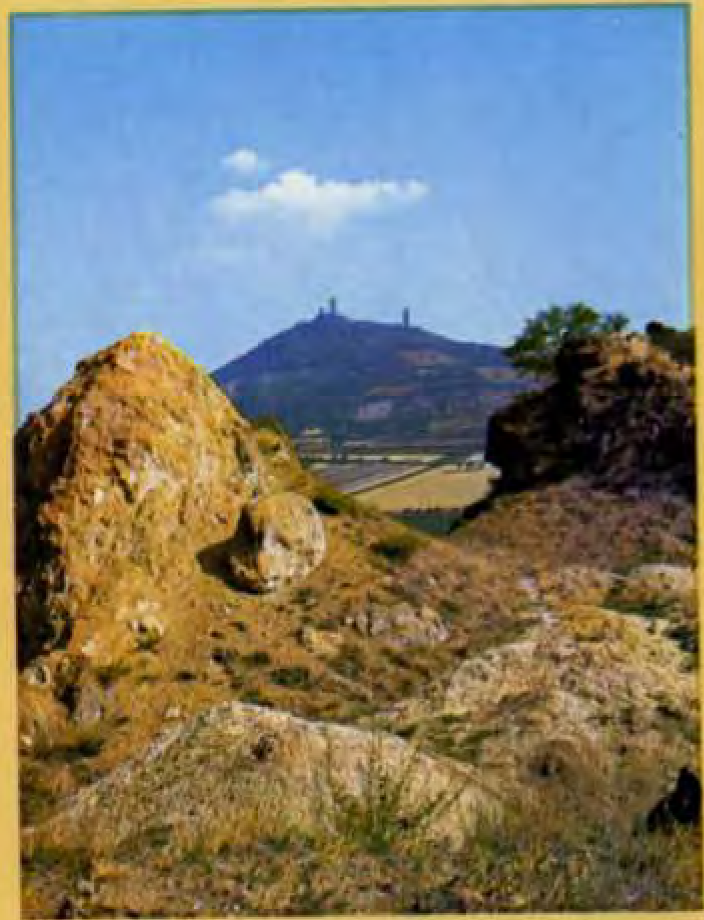
4.15 Devonian limestones SE of Hranice na Moravě. The central part of the karst chimney filled with Miocene sediments Photo by A. Zeman

4.16 Gently folded Silurian—Devonian boundary beds. The site represents an international parastratotype of the stratigraphic boundary between the Silurian and the Devonian. Barrandian Basin, Karlštejn, near the river Berounka Photo by Z. Kukal

sulphide. The water of the diversified Lower Carboniferous basin was poor in oxygen in all deeper parts. Black muds sedimented also in shallow bays. The coastal alluvial plains, marshes and submarine parts of deltas of the paralic Upper Carboniferous contained already primarily so much organic substances that the present oxygen could not oxidize the whole amount. In the limnic Permo-Carboniferous, fresh-water Cenomanian and Tertiary the more rarely occurring black clays sedimented locally in lakes.

The occurrences of red beds are plotted in Fig. 4.13 together with the average values of the Fe_2O_3/FeO ratio. There are two maxima of red beds in the Bohemian Massif: in the Lower Cambrian (continental sediments of Sádek and Holšín-Hořice Formations) and in the limnic Permo-Carboniferous (Lower and Upper Red Formations). Minor occurrences have been established in the lower part of the Ordovician (Klabava Formation), in the paralic Upper Carboniferous (part of Saddle-Seam Member) and in the Triassic, where sedimentation forms a continuation of the Upper Red Formation. The red beds are of a still smaller volume at the base of the fresh-water Cenomanian, in the Klikov Formation of South Bohemian basins and at the base of the sedimentary sequence in the Tertiary basins. The origin of almost all red beds is explained by the supply of red weathering material from the landmass, which was produced by intensive weathering processes of kaolinitic or lateritic type.

5. Magmatic history



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5.1 Hazmburk Hill — leucitic basanite. České středohoří neovolcanic area
Photo by J. Svoboda

The genesis of igneous rocks and especially their intrusion into the upper parts of the earth's crust, to date exposed by erosion, or to the earth's surface itself, is intimately associated with the tectonic history of the Bohemian Massif. Although Stille's conception of the relationship between tectonics and magmatism seems today too schematic in some aspects and cannot be brought into harmony with the principles of plate tectonics, it is still valid and most appropriate for the Bohemian Massif.

Magmatites are divided into initial (geosynclinal), essentially associated with the development of the subsiding sedimentary basin; plutonic rocks connected with the major orogenic processes; subsequent magmatites forming after the main folding phase during the fading out of folding events; and final (platform) magmatites associated with the platform tectonics. Volcanic rocks are mainly represented by effusive forms, relics of subvolcanic bodies may be identified only in places. Some plutonites may be very close in time to subsequent magmatites representing magma chambers of higher lying, at present worn away volcanic forms, which have been exposed by advanced erosion. This probability is indicated, for example, by pebbles of effusive and hypabyssal rock types in the Lower Carboniferous of Moravia, which are derived from the source area in the Českomoravská vrchovina Highland. The effusive rocks may be volcanic derivatives of today exposed granitoid massifs (Štelcl 1960, Dvořák 1969).

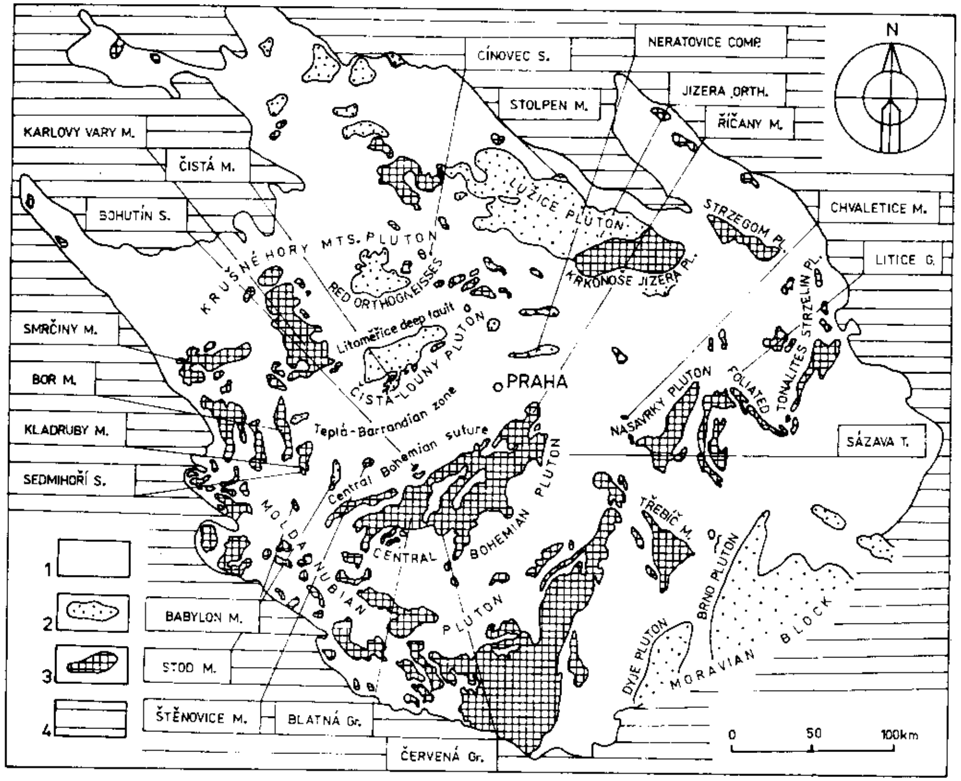
Superimposition of volcanic and plutonic activity has been evidenced unambiguously in the Krušné hory area by the relation of granite to the Teplice porphyry (rhyolite, Sattran 1966).

In the tectonic history of the Bohemian Massif the tectonomagmatic cycles are not always developed completely or are difficult to date. This relates particularly to the metamorphosed volcanic and plutonic rocks of the crystalline unit, in which the time of origin of primary complexes and their metamorphism have not yet been recognized with certainty. However, the stages of magmatic activity in the Bohemian Massif can be well identified within the scope of both Cadomian orogeny (initial volcanism, plutonism, subsequent volcanism) and the Hercynian orogeny (three stages, too). Only volcanism of the platform type did develop as a reverberation of the Alpine orogeny.

The relationship between the plutonic and volcanic activity has not been determined convincingly in most cases and, therefore, the plutonic and volcanic events will be discussed separately.

5.1 Plutonic complexes

The following plutonic complexes have been distinguished:
— metaplutonites of uncertain age in metamorphosed regions
— plutonites associated with Cadomian orogeny



5.2 Principal plutonic bodies of the Bohemian Massif (J. Klomínský, A. Dudek 1978)
1 — Bohemian Massif; *2* — pre-Hercynian plutonic rocks; *3* — Hercynian plutonic rocks; *4* — cover of the Bohemian Massif

— plutonites associated with Hercynian orogeny
— plutonites in Tertiary volcanic areas.

5.1.1 Metaplutonites of uncertain age

In the metamorphic units of the Bohemian Massif there occur orthogneiss bodies which evidently or with great probability formed by metamorphism of granitoid plutonites. Complexes of advanced migmatites of "orthogneiss" appearance are not classed with this group. This relates e.g. to most of the Gföhl Gneisses of the Moldanubicum (they are a product of several genetic processes — Dudek - Matějovská - Suk 1974, usually of recrystallization of granulitic rocks — Matějovská 1967), to the migmatized complexes of the Moravo-Silesicum (Keprník "orthogneiss" — Mísař 1960), Desná Orthogneiss, and Bechyně Orthogneiss (Fediuk 1977). These rocks are not normal stratigraphic members of metamorphosed units but they are associated with faults (indicated also by the presence of ultrabasites), which facilitated the supply of heat and the origin of ultrametamorphic processes. This concept based on the investigation of the Bechyně "orthogneiss" (Fediuk 1977) can be also applied to the Blaník orthogneiss and possibly to pegmatoid orthogneiss near Přibyslavice S of Čáslav. Bodies of these "orthogneiss" are located on ancient N—S and E—W trending faults.

True orthogneisses are represented by the so-called Krušné hory red orthogneisses, the Jizerské hory and Krkonoše orthogneisses of the West Sudetic crystalline complex and the Biteš Gneiss in the Moravicum.

The red orthogneisses are metagranites, in places with preserved porphyritic texture, in places with relics of contact metamorphism in the mantle (Scheumann 1932). They occur in an antiform of E—W strike, which trends diagonally to the younger structural direction of the Krušné hory region. They originated most probably during Upper Proterozoic folding, but they are somewhat older than the Cadomian granites.

The orthogneisses of the Jizerské hory and Krkonoše, also associated with the Cadomian orogeny, were probably partly produced by regional metamorphism of the Rumburk granite. Their genesis, however, has not been clarified convincingly, some authors ascribe Caledonian age to their metamorphism. These orthogneisses are also located in an E—W trending antiform. Interpretation of the orthogneisses in the Orlické hory-Kłodzko Dome as metagranitoids is questionable.

The Biteš Orthogneiss (muscovite biotite metagranitoid with augen structure) is the most significant member of the Moravicum sequence and a component of both the Dyje and Svratka Domes. Although the course of the body is highly diversified, it clearly follows a major NNE—SSW fault, which extends from the Danube up to the northern end of the Svratka dome over a length of almost 130 km. The Biteš Orthogneiss is prevalently thought to have been intruded between the Vranov-Olešnice Group and the Bílý potok Group (Mísař 1961, Dudek 1962, Jaroš - Mísař 1976). With regard to the stratigraphic position of these units, the orthogneiss was dated as Cadomian with great probability, but the recent radiometric Rb/Sr measurement has given an age of almost 800 Ma (Scharbert 1977).

Common features of the metaplutonites of the Bohemian Massif crystalline units are their connection with ancient structural E—W and N—S directions, a prominent granitic chemistry with a little increased sodium content, and pronounced leucocratic character of all types.

5.1.2 Plutonites associated with Cadomian orogeny

The existence of extensive Cadomian plutonism in the Bohemian Massif was controversial for a long time because there is no direct geological evidence for the age of most of the bodies, and the time of their origin can be inferred only from broad circumstantial evidence. However, recent detailed research and radiometric measurements have brought unambiguous proofs of at least Cadomian age for a number of bodies. According to assembled data and spatial analysis (Dudek - Melková 1975, Klomínský - Dudek 1978), the Cadomian plutonites are mostly confined to the structural units characterized by lower-grade metamorphism, absence of Hercynian plutonism, a smaller thickness of the crust (Beránek - Dudek 1972, Beránek et al. 1975) and positive gravity anomalies.

The Cadomian plutonites are located mainly in the Teplá-Barrandian block, the Železné hory region, the West Sudetic region, and the southern part of the Moravo-Silesian region. The following massifs can be justifiably considered as Cadomian units (Fig. 5.2):

a) some massifs connected with the West Bohemian fault zone
b) massifs in the Teplá anticlinorium and volcanic zones of the Teplá-Barrandian block
c) some massifs in the Železné hory region
d) the Lusatian massif and some minor massifs of the Orlické hory Mts. in the West Sudetes
e) Brno pluton and other bodies in the basement of the Carpathian foredeep and flysch nappes.

a) Basic bodies along the West Bohemian fault zone constitute a separate group of Cadomian magmatites. From NNW to SSE there occur minor basic massifs near Teplá, Mutěnín, Načetín and the large Poběžovice and Kdyně massifs. The massifs are connected with volcanic zones of the Barrandian Upper Proterozoic and the largest volcano-plutonic basic complexes — the Mariánské Lázně and Kdyně massifs — are emplaced at the intersection of the deep Ohře and Central Bohemian fault zones with the West Bohemian fault zone. The Mariánské Lázně complex consists almost exclusively of metavolcanics, whereas volcano-plutonic and plutonic complexes are represented in the more southerly massifs. The Mutěnín and Načetín bodies show a ring structure (Vejnar 1975, Tonika 1978) and were intruded only after the main phase of Cadomian regional metamorphism. The Poběžovice massif also displays a complex zonal structure. All the massifs contain a broad pattern of basic rocks, involving olivine gabbronorites, gabbros, olivine gabbros, hornblende gabbros to diorites.

In the zone of the Bohemian Quartz Lode there are also small ultrabasite bodies (Vejnar 1966b) which can be ranged to the Cadomian synorogenic plutonism only with reservation, as they may be older.

The group of Cadomian granitoids comprises the Lestkov massif (biotite granodiorite to quartz diorite), the Hanov massif (granite, granodiorite) and the Mračnice-Jeníkovice massif NW of Domažlice (muscovite-biotite granite). Although these bodies are connected with the West Bohemian fault zone, their intrusive form is markedly influenced by the structure of the Proterozoic: the bodies are greatly elongated in SW—NE direction, parallel to the trend of the Teplá anticlinorium. The Cadomian age of these bodies is very probable but has not been as yet evidenced radiometrically. Some rock types of the Bor massif are demonstrably of Cadomian provenience (556 Ma), and the Stod massif as well (510—530 Ma, Šmejkal - Vejnar 1965). The latter body is situated a little off the West Bohemian fault zone and is composed of hornblende-biotite quartz diorite and biotite-leucogranite (Tonika - Vejnar 1966).

b) In the north-western part of the Teplá-Barrandian block (showing positive gravity anomalies) there are granodiorite bodies near Polom and granitoid bodies, most of them buried by platform sediments. Minor basic bodies are closely related to the Proterozoic volcanic zones. Their structure is controlled by the structure of Proterozoic complexes and thus most massifs are elongated in SW—NE up to W—E direction (Chaloupský *in* Malkovský et al. 1974). The Cadomian age has not been evidenced by radiometric measurements for the large Louny massif formed of the Tis biotite granite, but it has been conclusively proved for the highly variable Neratovice massif (535—573 Ma) and the little massif near Bechlín built up of granite and pyroxene diorite (550 Ma, Cháb 1975).

c) In the basement of the Cretaceous Basin the structural directions indicated by the shape of Cadomian plutons turn from SW—NE to W—E and even NW—SE; the latter trend is well seen on the structural position of the Chvaletice granite massif in the Železné hory Hills and of the gabbro body near Týnec nad Labem. The Železné hory fault and its intersection with the Přibyslav fault zone of N—S strike was the site of the intrusion of Všeradov granite of the Železné hory pluton (Vachtl 1975) and of the complex gabbro-peridotite Ransko massif (Mísař et al. 1974), composed of serpentinized dunite, troctolite, olivine gabbro, gabbro, hornblende gabbro and anorthosite.

d) The most significant Cadomian pluton in the West Sudetes is the Lusatian massif, the major part of which is situated outside Bohemia. It is formed of a number of rock types of Cadomian age and additionally also of younger Hercynian "Stockgranits". The complex comprises biotite granodiorite (Lusatian granodiorite), muscovite-biotite (hybrid) granodiorite, and the Rumburk granite, which grades into the Jizerské hory orthogneiss in the E. The Cadomian age of the predominant part of the massif was proved for both the Rumburk granite (finds of pebbles in the Ordovician — Chaloupský 1962) and the Lusatian granodiorite (radiometric age of 560—570 Ma, Haake 1973).

In the Orlické hory-Kłodzko Dome, the pre-Hercynian plutonites are probably the Nový Hrádek albite-granodiorite massif, gabbro body at Špičák, and granodiorites to tonalites on the southern and eastern sides of the Dome, in the Zábřeh Group and the Staré Město mica-schists belt. The age of these rocks is uncertain; they have been regarded as Caledonian or early Hercynian intrusives.

e) The largest Cadomian body in the study area is the Brno pluton (550—600 Ma, Dudek - Melková 1975; 584 Ma, U-Pb, van Breemen et al. 1982). Besides the outcrops in the Brno massif itself and in the Dyje and Svratka massifs, it extends far eastwards in the basement of the foredeep and flysch nappes. Minor bodies occurring in the zone of the Upper Morava depression and north of it probably are connected with the Brno pluton at depth under the crystalline mantle. The pluton consists of a number of petrographical types ranging from basic to acid rocks (Štelcl 1963, Štelcl et al. 1973, 1976). Acid leucogranites to leucogranodiorites are more frequent in the granite massif beneath the Upper Morava depression NE of Prostějov (age of 470—540 Ma, Němcová 1969).

In the fault zone of the Upper Morava depression, gabbro with ultramafic pyroxenite and peridotite layers has been located in the Vlkoš-1 borehole and gabbronorite in borings at Rusava. In the Brno pluton, besides the basic zone of the Brno massif, diorite has been identified in the Mušov body and in a small massif near Dražovice. The biotite-hornblende granodiorite to tonalite forming an extensive buried body of E—W trend in the Ždánický les area is of a somewhat more acid nature. A substantially larger area is occupied by the biotite-hornblende leucotonalites of the Blansko and Slavkov types, biotite leucogranodiorites, and light-coloured granite building up the southerly part of the pluton at the Czechoslovak/Austrian boundary. The biotite leucogranite of a minor massif near Lubná is of a special type. The distribution of individual types has been studied on the basis of numerous borings and geophysical data (Dudek 1980). It is evident that the E—W and N—S directions played important role in the localization of intrusions and limitation of the bodies. The NW—SE strikes (the zone of Upper Morava depression, structures of Nesvačilka and Vranovice troughs) are later and disturb the pluton structure.

Besides a special structural geological position, the Cadomian plutonites show other characteristic features. The analysis of chemistry of the whole series and especially its comparison with chemistry of the Hercynian plutonites have revealed a sodium flavour of the Cadomian granitoids and some basic bodies (Dudek - Klomínský 1978), and a distinct leucocratic nature of granodiorite and tonalite types, in particular (Dudek 1977, 1980).

5.1.3 Hercynian plutonism and its relation to tectonics

The Hercynian plutonites are the most widespread magmatites in the Bohemian Massif. They make up large plutons in its nucleus and marginal parts, consolidating and cementing this structural unit, which after the Hercynian orogeny had assumed a markedly stabilized character. The occurrence of superficial plutonic bodies of Hercynian age is shown in Fig. 5.2; at no great depth, however, they are of a much greater extent, underlying the crystalline complex over vast areas, especially in the Krušné hory Mts. (Tischendorf et al. 1965) and in the Moldanubicum of southern Bohemia (Dudek - Suk 1965, Mottlová - Suk 1970). According to radiometric (mainly K/Ar) age data the Hercynian granitoids have been divided into three groups (Bernard - Klomínský 1975). Tonalites and related rocks are the oldest (about 360 million years). The durbachitic rocks (age of about 360—400 million years) also belong in this group. Granites of the marginal parts of the massif are younger (about 300 million years) and the group of tin-bearing granites of the Krušné hory Mts. are the youngest (about 260 million years).

On the basis of mineral and chemical composition, geological habit, spatial distribution and structural position, the following groups of Hercynian plutonites can be differentiated in the Bohemian Massif (Bernard - Dudek 1967, Sattran - Klomínský 1970, Klomínský - Dudek 1978):

a) group of granites
b) group of granodiorites
c) group of tonalites
d) group of diorites to gabbros
e) group of durbachites
f) alkaline plutonites.

a) Granites, mainly muscovite-biotite or biotite granite types, very often porphyritic, are the most widespread rocks of the Bohemian Massif. They occur chiefly in the Krušné hory and Šumava mountain ranges and in the Českomoravská vrchovina Highland. They were intruded predominantly from the late Viséan to early Westphalian. A characteristic member of the granite series is the group of younger autometamorphosed granites enriched in Na, Li and other elements, with which the vein and greisen Sn-W mineralization is associated. Tin-bearing granites had developed mainly in the Krušné hory block (the Krušné hory and Slavkovský les Mts.); in the areas of the Šumava and Českomoravská vrchovina only initial stages of autometamorphism are present.

The muscovite-biotite granites penetrate from the E into the northern part of the Central Bohemian Pluton, forming there the so-called Říčany type. Similar rocks underlie the Permo-Carboniferous of Český Brod and are presumed to extend as far as Kolín in the basement of the Kutná Hora crystalline complex

(Orel 1975). Hercynian granitoids of a small extent occur in the northern part of the Železné hory pluton, form several bodies beneath the Cretaceous and particularly the large Krkonoše-Jizerské hory pluton (Klomínský 1969). They also constitute the Žulová massif and the small Šumperk massif in the Moravo-Silesian region.

b) The group of granodiorites synchronous with granites is much smaller. They are predominantly biotitic, with a small amount of hornblende in some varieties. They usually occur together with granites, building separate massifs (minor stocks) only in the Teplá-Barrandian block, such as the Čistá massif (Klomínský 1963) and a major part of the Kladruby massif (Nežilová - Vejnar 1966). In the Central Bohemian Pluton they are represented by the Požáry type, and by the Weinsberg and Freistadt types in the Moldanubicum. There they are somewhat older and more intensely affected by tectonic events than the muscovite-biotite granites. They occur mainly in Austria whence they extend to the Šumava Mts. and Novohradské hory Hills on the Bohemian territory. Small massifs ascending from beneath the Cretaceous near Litice nad Orlicí and Rychnov nad Kněžnou also show granodioritic composition (Domečka - Opletal 1974).

c) The group denoted as "tonalite group" includes hornblende-biotite quartz diorites, tonalites to granodiorites. They are characterized by numerous inclusions of more basic diorite and gabbro, which in places have a size of small massifs and in places form long stripes. Tonalites are accompanied by a varied swarm of dykes and by Au-mineralization (Sattran - Klomínský 1970). They belong to the older group of Hercynian plutonites, which e.g. Chaloupský (1975) dates as Cadomian. Their most typical development has been recognized in the Central Bohemian Pluton, mainly in its north-western part (Sázava and related types). The large part of the Železné hory pluton and a conjoined massif beneath the Cretaceous sediments are also classed with this group (Chaloupský *in* Malkovský et al. 1974). Small tonalite stocks occur in the Teplá-Barrandian block (Štěnovice and Bohutín stocks), and others have been found by mine workings on fault structures parallel to the north-western margin of the Central Bohemian Pluton (Vlašímský 1973).

d) The mafic rocks usually form small bodies enclosed in granitoids of the tonalite group, such as basic bodies in the Central Bohemian Pluton between Březnice and Něčín in the Příbram area, and between Pecerady and Velké Popovice in the Sázava area. Enclosures of similar character are also abundant in the Železné hory pluton. Isolated minor bodies of mafic rocks are known from the neighbourhood of the Čistá-Jesenice massif (e.g. melagabbro at Petrovice — Ulrych et al. 1976). The age of these rocks has not been recognized with certainty (melagabbro — 380 million years).

e) Hercynian plutonites of a peculiar type are the so-called durbachites, which are melanocratic hornblende-biotite- or pyroxene-biotite granites to monzodiorites. They are characterized by a high biotite content, and a considerable amount of potassium, iron and magnesium. Their composition resembles that of lamprophyres. Durbachites occur in two zones of NNE—SSW direction: the zone at the eastern margin of the Central Bohemian Pluton is distinguished by the Čertovo břemeno and Tábor (syenite) bodies, a number of small bodies in the Písek and Vodňany area and the massif of Knížecí stolec in the Šumava Mts. The second zone follows the eastern branch of the Moldanubicum and consists of the Třebíč and Jihlava massifs in Moravia and the Austrian Rastenberg massif, in particular. Durbachites are often foliated, the K-feldspar phenocrysts in the marginal parts of the massifs are distinctly oriented (e.g. Bubeníček 1968). The Moldanubicum is the only unit of the Bohemian Massif where they occur. They are not found among the Cadomian plutonites either.

f) A short mention should be made of alkaline Hercynian plutonites, which were established in the Čistá massif (alkaline metasomatites — Klomínský 1961, Kopecký L. et al. 1970) and in the form of xenoliths in pipe breccia at Košťál SW of Litoměřire in the České středohoří Mts. (Kopecký L. 1966).

In the Bohemian Massif Hercynian plutons occur in other areas than Cadomian plutons and their spatial distribution is governed by a different structural plan. Large massifs are located in areas of negative gravity anomalies (Fig. 2.36) — the Krušné hory and Moldanubian blocks and part of the West Sudetic block. In the areas of positive gravity anomalies Hercynian granitoids occur rarely in the form of minor stocks (e.g. "Stockgranit" in the Lusatian massif, the Štěnovice, Čistá, Bohutín and Babylon massifs in the Teplá-Barrandian block) and they are probably absent in the Brno pluton area.

The axial part of the Hercynian orogen is characterized by a predominant presence of tonalite plutons of Central Bohemia and Železné hory. The Central Bohemian Pluton was intruded along the Central Bohemian suture of SW—NE trend, at the boundary between the Moldanubicum and Teplá-Barrandian block. Basaltoid and acid magmas ascended along this ancient fault as early as the Late Proterozoic (Jílové Zone): the tonalite rock types of the Central Bohemian Pluton are most abundant in the proximity of ancient basic volcanic complexes. The overall composition of the Central Bohemian Pluton is of tholeiitic character (Palivcová 1965, Steinocher 1969, Vejnar 1973), which points to the genesis of magmas very deep in the crust, possibly in the mantle, and to a great depth extent of the Central Bohemian suture.

In the marginal parts of the Massif, in areas more remote from the axis of the Hercynian orogen, plutons of more acid granodiorite and granite were emplaced, the composition of which was approaching the eutectic granite (Klomínský - Dudek 1978). Intrusions mainly follow NE—SW and NW—SE

5.3 Perched boulder, weathered-out hornblende-biotite granite of Čertovo břemeno type, Bratřejov near Petrovice in the Sedlčany area. Central Bohemian Pluton
Photo by J. Svoboda

5.4 Weathered muscovite-biotite granite of Karlovy Vary pluton. Svatošské skály in the Ohře-river valley near Doubí, western Bohemia
Photo by J. Svoboda

5.5 Moldanubian Pluton. Quarry in granite of the Eisgarn type, Mrákotín near Telč in the Českomoravská vrchovina Highland Photo by J. Svoboda

5.6 Diorite inclusions in quartz diorite (tonalite) of the Sázava type. Central Bohemian Pluton, quarry at Teletín in the Sázava-river valley Photo by J. Svoboda

5.7 Tourmaline aggregates in granite vein. Western slope of Jamník east of Písek. Southern margin of the Central Bohemian Pluton Photo by J. Svoboda

5.8 "Dívčí kameny" near Petrovka in the Krkonoše Mts. Weathered granite of the Krkonoše-Jizerské hory pluton Photo by J. Svoboda

trends, more rarely the N—S, NNE—SSW and E—W strikes. In the Krušné hory and the Českomoravská vrchovina the massifs intruded into anticlinorial structures bounded in the SE (E) by deep faults (Ohře and Přibyslav fault zones); in the Šumava they are located directly on fault structures.

The intrusions of durbachites followed a separate structural plan; they form two zones of SSW—NNE direction. The fabric of durbachite is markedly adapted to the structure of the mantle, at least in near-contact parts (Bubeníček 1968, Beneš 1971); they are evidently older than other Hercynian types (most probably late synkinematic).

The shapes of granite plutons are poorly known. The analysis of geological and geophysical data indicates that the Krušné hory massifs are most likely batholiths extending or widening to great depths (Polanský 1977). In contrast, the Krkonoše massif is of a thick-slab form, rooted mushroom-like at the southern side of the body (Klomínský 1969). The central massif of the Českomoravská vrchovina also shows rather a slabby shape (Suk - Weiss 1976). The areas of supply characterized by prominent negative anomalies occurred mainly in the southern part of the massif and in the neighbourhood of Melechov and Čeřínek.

Granite massifs obviously penetrated very near to the surface so that they disrupted their mantle in places. Such a contact is known chiefly from the northern part of the central massif (Krupička 1968). Young tin-bearing granites of the Krušné hory penetrated close to the surface, locally even into the effusive complex of Teplice porphyry; the Krkonoše massif is also a subsurface intrusion. The character of the inner structure of plutons is universally adapted to the structure of the mantle (Beneš 1971).

5.1.4 Neoidic plutonites

Plutonites of Alpine age are extremely scarce in the Bohemian Massif. We can range to them the subvolcanic bodies of alkaline plutonites in centres of volcanic activity in the Doupovské hory area (theralite and essexite at the site of central vent) and small stocks and dykes of essexite and sodalite syenite around Roztoky and Březno in the České středohoří Mts. These two occurrences are located at the crossing of major tectonic lines — the Ohře fault zone and the Labe line, or of the former with the Jáchymov fault zone.

5.2 Volcanic complexes

5.2.1 Metavolcanites of uncertain age in the crystalline areas

In the parts of the Bohemian Massif built up of crystalline rock complexes, the metamorphosed series contain an abundance of rocks formed by metamorphism of acid and basic volcanites. Some of the metamorphic complexes can be parallelized reliably enough with the Upper Proterozoic of the Barrandian (e.g. the Zábřeh Group, Letovice crystalline complex, Nové Město phyllites) or with the Palaeozoic (Železný Brod crystalline complex), but the stratigraphic assignment of the great majority of crystalline complexes is unknown. Their sedimentation, volcanism and probably also metamorphism occurred already before the Cadomian orogeny (Zoubek 1976, and many other authors).

Metavolcanites are most widely distributed in the Moldanubicum. They are initial volcanites, which developed in the sedimentary area at the time of its dissection into minor basins, when intensive basic and acid volcanism accompanied sedimentation of the Moldanubian Varied Group of diverse facies development. Volcanism began with basic (amphibolite) to ultrabasic (serpentinite) types and continued with a common ascent of basic and acid rhyolitic rocks (granulites) and ended again with basic rocks types (Zoubek 1976, Pletánek - Suk 1976). Metavolcanites occur in all three zones of the Varied Group of the Moldanubicum; amphibolites are present in the western zone between Klatovy and Český Šternberk, amphibolites together with the granulite formation of a large extent are developed in the central zone between Černá and Jihlava, and granulites with amphibolites in the eastern zone in Moravia. Granulites are most likely equivalents of rhyolite effusions and chiefly of tuffs and tuffites (Zoubek 1948, Matějovská 1967). The relatively little differentiated amphibolite series is divisible into two groups, which differ slightly in chemistry: amphibolites associated with the granulite formation, and amphibolites of the other parts of the Varied Group (Suk 1971). In the thoroughly studied parts of the Moravian Moldanubicum and in the Strážek Moldanubicum they correspond to tholeiitic basalt and alkali-calcic basalt (Klápová 1977, Šichtařová 1977). These two different trends are obviously also typical of the other parts of the Moldanubicum.

Metamorphosed basaltic volcanites are abundant in the Moravicum and Silesicum (in the Mica-schist zone, Vranov-Olešnice Group, Staré Město mica-schist zone and other units). Their association with the varied units suggest that they had originated under similar tectonic regimes as amphibolites in the Varied Group of the Moldanubicum.

In the pre-Proterozoic formation of the remaining crystalline units the metavolcanites are much scarcer; they occur in a small amount in the Krušné hory Crystalline. In the West Sudetic Crystalline they are part of Upper Proterozoic complexes.

5.2.2 Volcanism connected with the Cadomian orogeny (Upper Proterozoic—Cambrian)

Unusually abundant occurrences of volcanites of the Cadomian cycle come from the period of Upper Proterozoic sedimentation of the series developed typically chiefly in the Barrandian and in areas of metamorphosed Proterozoic complexes (the Český les, the Krušné hory, crystalline complexes of Krkonoše, Orlické hory and Letovice, Zábřeh Group, and parts of the Hrubý Jeseník crystalline complex). In the Teplá-Barrandian region volcanic rocks occur in five zones, which differ in composition of the rocks and overall variability (Fiala 1971b, 1977). The zones striking SW—NE are parallel to the fold structure of the Proterozoic, and are compared by some authors with recent island arcs. The rocks are typical submarine effusions and extrusions represented by lava flows, tuffs, tuffites, granulates and granulate breccias. The chemistry of volcanites and of the volcanic association differs from one zone to another (Fiala 1971b, 1977); it is predominantly tholeiitic in NW and in the SE part it shows a discrete tendency to alkali-calcic types. The zones are the following:

a) Central volcanic zone, 150 km long, extends between Kralupy n. Vltavou and Domažlice. It contains mainly metabasalts of tholeiite-basalt chemistry, spilites and sporadic keratophyres. Volcanic rocks are mostly affected by secondary alterations.
b) Zone of potassium spilite forms a belt of Slatina-Pavlíkov NW of the principal zone.
c) The Stříbro-Plasy zone displays a strong differentiation from ultrabasic types through metabasalts, keratophyre-spilites to quartz albitophyres (albite rhyolites).
d) The Mariánské Lázně metabasite complex consists of metabasalts associated with abundant ultrabasites, in places with gabbroic bodies (the whole set of rocks shows the character of an ophiolite complex, corresponding to it in metamorphism, too).
e) Southern volcanic zone stretches between Klatovy and Zbraslav and is formed of a typical metabasalt-spilite-keratophyre formation. The amount of acid volcanites increases to the NE.
f) Jílové zone containing abundant andesite and rhyolite in addition to basalt types.

The volcanic facies in the north-eastern parts of zone e) and in zone f) suggest that in this part the thickness of the crust in the Cadomian geosyncline was greater (Fiala 1977), and of the continental type.

In the Železné hory Hills the Proterozoic volcanites of the Prespilitic Group are of a more pronounced spilitic character than the allied rocks of the central Barrandian zone. The Postspilitic Group contains mainly intermediate and acid volcanics, which grade upwards into more alkaline types (Fiala 1971b).

The Cambrian volcanism is of a typical subsequent (in the sense of Stille), and subaerial character. The earlier infrequent extrusions have been established in the Cambrian of Brdy and Rožmitál p. Třemšínem, and they belong to the Lower Cambrian (Havlíček 1971). Their composition corresponds to that of andesite and rhyolite. In the linear Křivoklát-Rokycany zone, which is the main volcanic area, Waldhausrová (1971) differentiated four eruption phases: 1. palaeodacites, 2. palaeo-andesites, 3. pophyritic palaeodacites and palaeorhyodacites and 4. the youngest palaeorhyolites. In the more easterly Strašice zone, palaeo-andesites are accompanied by rocks of basalt chemistry. The volcanism is predominantly of Late Cambrian age but it might have continued until the Ordovician. Vidal et al. (1975), for example, give an age of 475 million years.

The Cambrian subsequent volcanites have not been found outside the Barrandian area, but Proterozoic volcanic rocks are widely distributed there. In the West Sudetic region basalt volcanism was active in all Upper Proterozoic series. Metabasalts are most abundant in the Lesczyniec unit in Poland, at the eastern margin of the Krkonoše-Jizerské hory anticlinorium, being appreciably scarcer in the Krkonoše and Ještěd crystalline areas.

Proterozoic metavolcanites of the Orlické hory Mts. are prevalently basic submarine initial volcanic rocks following the zones of NNW—SSE direction; acidic types are very subordinate. In chemistry, these basites correspond most probably to abyssal tholeiites (Domečka-Opletal, 1981) or tholeiite-basalts and are thus closely related to the Proterozoic volcanites of the Barrandian.

Upper Proterozoic volcanism is markedly distributed at the eastern margin of the Bohemian Massif, especially in the Zábřeh Group and the Letovice crystalline complex. Volcanics of metabasalt composition predominate, being locally associted with ultrabasites and gabbros (Letovice, the Svitavy area); acid types are very rare or absent altogether.

In general, Upper Proterozoic volcanism was centred to highly mobile sedimentary areas. It was of submarine, mainly effusive and extrusive type, and in places it may have even produced shallow intrusions. The rocks were chiefly tholeiitic basalts, more or less spilitized in some parts. Along the margins of major crustal blocks, the faults acting as supply channels reached to considerable depths and the volcanic associations are represented by basic-ultrabasic types

(Mariánské Lázně complex, Letovice crystalline complex). Inside the blocks, ultrabasic differentiates occur sporadically and basalts are associated with more acid types — andesites to albite rhyolites.

5.9 Spilite pillow-lavas. Abandoned quarry in the Úslava-river valley near Koterov (east of Plzeň). Upper Proterozoic of the Barrandian Photo by J. Svoboda

5.2.3 Volcanism related to the development of Lower Palaeozoic sedimentary areas

A partial cratonization of the Bohemian Massif after the Cadomian orogeny was reflected in the Barrandian area in the development of typical Upper Cambrian subsequent volcanism. In its closing phase the increasing consolidation induced transition to final volcanism; this is indicated mainly by the occurrence of more basic basaltic rocks with slightly alkaline tendency in the youngest members of the Strašice zone. This development, however, was brought to end by a new mobilization of the crust, by the subsidence of the Ordovician sedimentary area in the Barrandian and West Sudetic regions. Some

5.10 Spilite of the central zone in Barrandian Upper Proterozoic. Křivoklát, Čertova skála Photo by J. Rubín parts of the Moravo-Silesian zone were also mobilized, but much later, at the beginning of the Devonian.

Synchronously with the subsidence of the central part of the Barrandian, deep channels of supply were opened and submarine basalt volcanism had developed intensely (F i a l a 1971a,b). In the earliest phases the effusive rocks were of andesite-basaltic type, but on account of proceeding subsidence the ENE—WSW supplying faults had reached to increasing depths and the volcanites assumed basaltic character of steadily increasing basicity. Eruptions, mostly fissure eruptions, produced large amounts of lavals and tuffs, and the majority of effusives are autometamorphosed (diabases). The evolution towards more basic types continued in the Late Ordovician and Silurian, when even olivine basalts and ultrabasites appeared.

T h e S i l u r i a n v o l c a n i s m, which was developing especially during the late Wenlockian and early Budňanian (F i a l a 1970) is more basic and poorer in potassium than the Ordovician volcanism, and it was most intensive in the north-western limb of the Barrandian, between Loděnice and Beroun. Basic volcanics are spilitized and metasomatized at the import of sodium (essexitic and teschenitic diabases, sporadically up to egirine-augite syenites — F i a l a 1971b). Dykes of ultrabasic rocks, picrites and peridotites, are very characteristic.

T h e D e v o n i a n v o l c a n i s m is limited to a small area west of Prague. It is represented by submarine effusions of very basic vitric diabase, accompanied by tuffs and tuffites (F i a l a 1970).

Occurrences of Lower Palaeozoic volcanism are connected with deep WSW—ENE trending faults, which were channels of supply of basic magma from deep parts of the crust. Volcanic centres and areas of the most intensive volcanic activity moved during the Cambrian to Devonian gradually to the ENE (R ö h l i c h - Š ť o v í č k o v á 1968) simultaneously with the increasing alkalinity of basaltoid rocks (F i a l a 1971a,b).

Of great importance for the recognition of the structure of deeper crustal layers are the finds of diverse types of inclusions in Ordovician diabases W and NW of Beroun. Gabbro was identified at Krušná hora near Hudlice, altered ultrabasites and fragments of feldspars near Chyňava and Kařízek, and granitoid pebbles (probably fragments of Cambrian conglomerates) NE of Hořovice, S of Otmíče. These finds indicate that major complexes of older magmatic rocks may exist in the basement of the Barrandian Palaeozoic (F i a l a 1971b).

In the Krkonoše-Jizerské hory region the Early Palaeozoic volcanites are distributed randomly; they are more frequent only in the Železný Brod crystalline area and in the Rýchory Hills at the eastern margin of the Krkonoše-Jizerské hory dome. Volcanites of basaltic composition predominate in both these areas. In the former, volcanic activity followed the E—W structural trend and began in the Ordovician to develop with greater intensity in the Silurian; its products appear particularly above the graphitic phyllites (F e d i u k 1962). The earlier volcanic rocks of the Silurian complex have basaltoid composition, which changed abruptly in the later phase, the main products being keratophyres and quartz keratophyres (albite trachytes and rhyolites). In the upper part of the complex the succession of basic and acid types repeats once more, and the differentiation sporadically progressed up to ultramafic types (F e d i u k 1962). The volcanic complex is metamorphosed in greenschist facies.

Isolated peridotite dykes NW of Železný Brod display some chemical relations to the Silurian volcanism but they are somewhat later than the metamorphic foliation of the neighbouring sediments (F e d i u k 1971b). They seem to be in similar time relation to basaltoid volcanism as the intrusions in western Bohemia to the Upper Proterozoic volcanism.

In the Rýchory Hills the differentiation of the volcanic complex is substantially lower than in the Železný Brod area; the main rocks are basaltoid types, their tuffs and tuffites; the differentiates of higher acidity are lacking (F e d i u k 1958). Metamorphism is of a slightly higher grade than in the Železný Brod crystalline complex. Metavolcanites in the Krkonoše and Ještěd crystalline complexes are of the same type but of a much smaller extent.

Devonian volcanism of basaltic character is represented only in the north-western part of the Ještědské pohoří Mts.

In the Moravo-Silesian region the regeneration of the sedimentary area and the onset of a new geosynclinal regime began only at the beginning of the Devonian. The transgressive coarser-clastic sediments are followed by fine-grained pelitic-psammitic sedimentation, accompanied by intensive volcanic activity. The volcanic products are mainly basic lavas (pillow-lavas are frequent), tuffs and tuffites, and in the Middle Devonian acid volcanites, keratophyres and quartz keratophyres increased in amount. The whole rock set shows prominent features of initial spilite-keratophyre volcanism and low-grade metamorphism. The volcanic rocks occur in the Vrbno Group and stratigraphically equivalent units, in the Šternberk-Horní Benešov zone and subordinately in the Konice-Mladeč Devonian.

The effusive volcanism had a character of linear fissure eruptions and aligned volcanic centres (the strike of fissures SSW—NNE). Acid volcanic rocks were confined to separate centres located at the margins of elevation structures (B a r t h 1966). The Jeseník and Sobotín massifs can be assigned to the volcanism of the Vrbno Group as subvolcanic bodies (P o u b a 1962). The localization and development of Devonian initial volcanism suggest that the main supply channels followed deep fault zones of Červenohorské sedlo and the Šternberk-Horní Benešov zone.

5.2.4 Hercynian late-orogenic volcanism

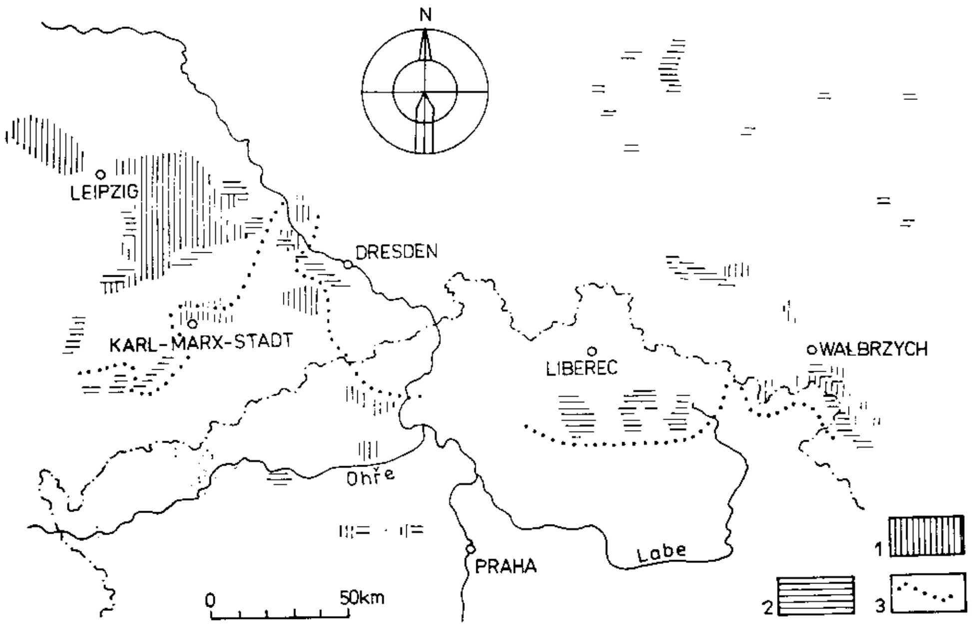
The Permo-Carboniferous of the Bohemian Massif extends at the southern margin of the occurrence of typical subsequent Hercynian volcanism in Central Europe. In the Permo-Carboniferous basins of central Bohemia and the West Sudetes and their close neighbourhood there are essentially two groups of volcanites: acid quartz porphyries and more basic melaphyres. In the "melaphyre" group effusive types predominate over tuffs; the character of rhyolite eruptions is mainly extrusive (tuffs, agglomerates, ignimbrites); effusions are scarcer.

The rocks of the "melaphyre" group are for the most part andesites or basalt-andesites, andesite-latites and latites and, to a minor extent, of basalt type (F e d i u k 1967). There exists a number of structural types denoted by special names. The extent and composition of volcanism somewhat differ in individual basins; the principal maxima of volcanic activity were concentrated into two phases, the earlier in the Carboniferous, chiefly in Westphalian B and C, and the later in the Late Permian, mainly in late Autunian. Regional distribution of the two phases is not equal: Upper Carboniferous volcanites predominate in the basins of central Bohemia, and Permian volcanites in the Mnichovo Hradiště, Krkonoše-piedmont and Intra-Sudetic basins.

In the basins of central Bohemia volcanic activity began before the onset of sedimentation, and the oldest volcanites thus form the basement of basin sediments. Explosive volcanism intensified especially in Westphalian C, occurring in depressions and ridges which separated them, and in their northern neighbourhood. Accumulations of ejecta are traceable in some horizons (whetstones) over a great distance (P e š e k 1975); on the basis of their habit the sites of volcanic centres can be reconstructed. They are assumed to occur between the Plzeň and Rakovník basins, near Nové Strašecí and Zlonice, and in the northern part of the Ohře valley, most probably in the area of Opárno volcanic rocks (M a š e k 1973, Fig. 5.12). Some of these centres are located on major deep faults. In addition to the predominating acid volcano-clastics and less abundant effusions, isolated effusions of basaltic rocks have been found in the southern part of the Kladno basin and in the Rakovník basin (K o p e c k ý L. - M a l k o v s k ý 1958, M a š e k 1973).

Beneath the Cretaceous basin the volcanic rocks are prevalently of Permian age. They are centred to the area north of the Maršovice-Bezděz elevation, where melaphyres constitute almost the whole filling of the Mnichovo Hradiště basin. To the south of the elevation, the proportion of volcanic rocks in the sedimentary complexes is very small and they are represented only by acid types (F e d i u k 1967).

Melaphyres in the Mnichovo Hradiště basin belong to three volcanic cycles. In the oldest cycle there are basaltic to olivine basaltic types (palatinites), in the middle cycle are rocks of basalt chemistry (tholeiites), and in the latest cycle



5.11 Schematic map of the occurrences of subsequent Upper Palaeozoic volcanites at the northern margin of the Bohemian Massif (J. Mašek 1973)
1 — quartz porphyries; *2* — melaphyres; *3* — line separating the northerly areas of predominantly Permian volcanism from the southerly areas of Carboniferous volcanism

5.12 Scheme showing the explosive centres of Westphalian age in Central Bohemian basins and their northern neighbourhood (J. Mašek 1973)
1 — Explosive crater at Nové Strašecí; *2* — pyroclastic cone near Zlonice; *3* — hypothetical eruptive centre of the whetstone horizon; *4* — hypothetical centre of other volcanic accumulations. *Dashed lines* — isolines of thicknesses of the whetstone horizon

andesites to dacites (navites); most of them are strongly secondarily altered. Rhyolitic types occur only in a small amount in a narrow stripe along the Lužice fault. Rhyolites (quartz porphyry) in the Mšeno basin are rare (they display nevaditic texture), but are common in the continuation of the Teplice porphyry and porphyry in the Opárno valley. They are represented mainly by ignimbrites, tuffs and tuffites. The chemical character of these rhyolites is slightly alkalic (F e d i u k 1967).

Volcanic rocks of the Krkonoše-piedmont basin are similar to those of the Mnichovo Hradiště basins and are present in all stratigraphic units. Intermediate and basic members (melaphyres) predominate over rhyolites. The basic types form effusions, sills and irregular intrusive bodies. In the Intra-Sudetic basin, the eruptive rocks locally occur as early as in Westphalian B and C and are represented (outside Bohemia) by both basic and acid members ("Křenov porphyry"). A later and substantially more significant volcanic phase occurred in the Permian; a lower and an upper eruptive series have been differentiated in the Permian rock complex. In Bohemia, the lower consists mainly of ignimbrites (H r d l i č k o v á 1966) and builds up the Javoří Hills in the Broumov area and the Vraní hory Hills in the Žacléř area. The rocks are of rhyolite type.

Outside the Permo-Carboniferous basins there is a notable body of the "Teplice quartz porphyry". It is a fissure volcano, which extruded along N—S trending faults and its development began in the late Westphalian, i.e. in the early phase of subsequent volcanism. It is formed of a series of effusions and tuff layers; rhyolites appear in a number of structural types (nevadites, felsites, pitchstone, fluidal types — S a t t r a n 1966). The Teplice porphyry is older than the latest phase of intrusive granites of the Krušné hory Mts.

Subsequent volcanism in the basins of central Bohemia was associated with the activity of radial fault tectonics, which led to the origin of subsiding basins. The location of main volcanic centres and of the Teplice porphyry shows that the faults of N—S direction played the most important role. In the Sudetic Permo-Carboniferous area, the NW—SE fault structures at the site of the present Lusatian fault and NE of it served as channels of supply, as is evidenced by the largest accumulation of basaltic rocks in the Mnichovo Hradiště basin and concentrated occurrences of less mobile quartz porphyry in a narrow zone along this line (F e d i u k 1967). Deep faults at the margins of the Intra-Sudetic basin had a similar function.

Thin layers of "tonstein" and some whetstones of the Ostrava-Karviná basin are interpreted as products of acid volcanism. The source areas of volcanic material are as yet unknown but they were obviously at a great distance from the sedimentary area.

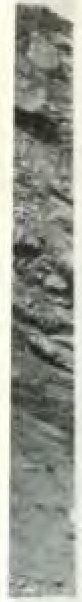
5.13 České středohoří Mts. viewed from Radobýl. Valley of the Labe in the centre, Mounts Milešovka and Kletečná in the background Photo by J. Svoboda

5.14 Vent breccia with fragments of altered marlstones, called "stony suns". České středohoří Mts., Hnojnice, north of Libochovice Photo by M. Malkovský

5.2.5 Neoidic volcanism associated with Saxonic tectonics

The whole Mesozoic era is in the Bohemian Massif a quiescent period completely devoid of the genesis of magmatites. Only at the beginning of the Tertiary the Alpine folding evoked rejuvenation of the ancient fault system of the massif, mainly in north-western and northern Bohemia. A system of deep faults of the Krušné hory graben originated as a component of the Ohře rift of ENE trend (Kopecký L. 1970, 1971). The principal structures are the Krušné hory fault in the NW, the Litoměřice fault in the SE and the central fault in the centre of the graben. The faults of NW—SE direction became the sites of scattered volcanic occurrences in the Bohemian Cretaceous Basin and in the Nízký Jeseník area. Each of these areas exhibits characterictic forms and types of volcanic bodies and characteristic chemical features of rocks.

According to Kopecký L. (1978), volcanic activity occurred in four separate eruption phases. The oldest is the Palaeocene phase (60—67 Ma), which is distinguished by melilitic magmatites emplaced along the marginal faults of



the graben and derived from the deepest magmatic sources. At the northeastern termination of the Litoměřice fault a number of dykes and concordant bodies of polzenites originated. Melilitic rocks also occur in the proximity of the Lusatian fault.

Of primary importance was the Oligocene phase (17—35 Ma) during which most volcanites of the České středohoří and Doupovské hory Mts. ascended to the surface. The big stratovolcano of the Doupovské hory occupies the southwestern part of the Krušné hory graben. The supply channel in the centre of the mountains is filled with essexite containing streaks of theralite. The characteristic rocks are basaltoids with leucite, in contrast to the České středohoří, where sodalite and nepheline are the principal foids. The České středohoří Mts. shows a structure of a volcano-tectonic horst. The following eruption stages can be distinguished in its development (apart from the oldest melilitic rocks); 1. the basalt-phonolitic, 2. essexite-tephritic and 3. trachyte-phonolitic. The last one is connected with the central fault, and all of them belong to the Oligo-Miocene phase of the Bohemian Massif (K o p e c k ý L., 1964). The formation of kimberlitoid breccias in pipes near the Litoměřice fault also falls in this period (K o p e c k ý L., 1971).

5.15 Columnar jointing of olivine basalt. Quarry at Podmoklice near Semily. Neovolcanic area of the Bohemian Cretaceous Basin — Photo by J. Svoboda

5.16 Distribution of plutonic bodies and dykes and sills of Tertiary volcanites in the České středohoří Mts. in the Labe-river valley (O. Kodym 1963)
1 — Essexite; *2* — sodalite syenite; *3* — mondhaldeite; *4* — the accompanying dyke suite of plutonic rocks

The younger, Miocene phase (9 Ma) is substantially less intensive and less extensive than the Oligocene phase. In the wider area of the Krušné hory graben, some volcanic bodies around Teplice and isolated occurrences (e.g. Vinařická hora near Kladno, Přišovská Homolka Hill NW of Plzeň) are products of this phase. The rocks are mostly alkaline olivine basalts, basanites and olivine nephelinites. In the Bohemian Cretaceous Basin most of the volcanic occurrences date from this phase. In this area of specific petrochemical character (with nepheline as a typical foid) the rocks usually form dykes and sills, and volcanic vents at the margin of the basin. The rocks are represented by olivine basalts and olivine nephelinites; ultrabasic types occur at the margins of the basin (e.g. in the Semily area).

5.17 Ropy lava. "Venušina sopka" near Bruntál, Quaternary volcano of the Silesian neovolcanic area in northern Moravia Photo by J. Svoboda

5.18 Fanwise arrangement of basalt columns on Vrkoč Hill, north of Vanov, the České středohoří Mts. in northern Bohemia Photo by J. Svoboda

5.19 Komorní hůrka-Hill. Quaternary volcano in West Bohemia Photo by J. Rubín

The Quaternary phase (0.8—2.8 Ma) is of the least extent; the volcanic occurrences are sporadic in the Cheb basin and the Nízký Jeseník Hills. The rocks in the surroundings of Cheb are of ultrabasic character, being transitional between olivine nephelinite and olivine melilitite. The localization of volcanoes in the Jeseník Hills was predisposed chiefly by the presence of deep NW—SE trending faults: the continuation of the Outer Sudetic fault (Bělsko fault) and its crossing with the Šternberk-Horní Benešov deep fault, and the fault running farther north between Krnov and Ostrava. The nepheline basanite near Kobeřice predates the late Tortonian, thus falling in the Oligomiocene phase. The volcanoes formed of olivine basalt and nepheline basanite that are located along the southerly line are of Quaternary age. They make up cinder cones and sporadic effusions between Budišov nad Budišovkou and Bruntál.

In the Ostrava-Karviná basin the neovolcanic activity was of limited extent. Minor dykes and fillings of small vents originated in the older, Oligomiocene phase.

5.2.6 Neoidic volcanism in the Moravian part of the West Carpathians

The traces of Neoidic volcanism in the south-eastern part of the Bohemian Massif are found in the Dogger. More intensive manifestations are observed in the Lower Cretaceous or the uppermost Jurassic of the Silesian unit and in the Senonian of the Magura unit (basites). Tuffs and tuffites in the flysch units and in the Neogene filling of the foredeep and the Vienna basin are products of intermediate to acid volcanism.

The earliest products of Neoidic volcanism in the foreland of the Outer Carpathians have been assessed in basal clastic beds of the autochthonous Jurassic in Austria. K a p o u n e k et al. (1965) described seven diabase (palaeobasalt) layers from clastic Dogger encountered in Porrau-2 borehole. These rocks may be associated genetically with the Lednice zone.

The oldest volcanites of the Carpathian Flysch in the area studied are the rocks of teschenite association in the Lower Cretaceous of the Silesian unit (effusions in the Hauterivian—Barremian Těšín-Hradiště Formation, hypabyssal forms in the lower part of the Těšín Formation of Malm age). The rocks occur in a broad belt extending from Hranice across Frýdek-Místek, Český Těšín to the neighbourhood of Bielsko-Biała in Poland. They are developed in the form of submarine sheets, pillow-lavas, agglomerate lavas, granulates, amygdaloids and dykes and sills of highly varied size. The principal occurrences are concentrated to dejection cones at the foot of the Baška slope of the Silesian sedimentary basin around Nový Jičín and Třinec.

The typical mineral of the teschenite association is analcime, accompanied by Ti-augite, Ti-amphibole and olivine. The amounts of feldspars vary. The association is composed mainly of teschenite and picrite and related rocks such as olivine diabase and diabase-picrite.

The petrography of picrite dykes found by boring Gbely H-6 in Upper Cretaceous marlstones of the Bílé Karpaty unit of the Magura Flysch was first described by Slavík (1930). By analogy with the Austrian occurrences the picrite effusions are placed in the Senonian (Eliáš 1976). In the adjacent part of the Magura Flysch this volcanism is indicated by increased contents of hornblende in heavy fraction (e.g. Jarošov-1 borehole, Eliáš 1976).

In recent years products of intermediate volcanism have also been established in the flysch sequence. Tuff and tuffite layers occur, for example, in the Godula Formation (probably in its Senonian part), in the Senonian of the Istebna Formation of the Silesian unit and in the upper Eocene Zlín Formation of the Rača unit of the Magura Flysch. Such occurrences have been recognized some time ago in the Polish Carpathians, the Ukrainian Carpathians and in eastern Slovakia.

Basic volcanism of the Flysch Carpathians is connected especially with the pelitic facies, which preceded the development of typical flysch. Within the framework of individual basins the occurrences are rather sporadic. Intermediate volcanism is more widely distributed but because of poor exposure it is difficult to follow in flysch sediments.

Palaeogeographical reconstructions permit us to assume that basic volcanism (compared with initial volcanism by some authors) was associated with deep faults of the fault systems which separated the basin subsiding before the origin of true flysch from the relatively rising cordilleras. Intermediate volcanism is thought to be localized in cordilleras, although there is no direct evidence available.

Scarce layers of vitric tuffs and tuffites have been found in Badenian sediments of the Carpathian foredeep in southern Moravia. Rhyolite tuffs are known from the Badenian of the Ostrava area and the Moravian Gate and from the Karpatian of the Vienna basin.

6. Metamorphic history

6.1 Garnetiferous muscovite-biotite gneiss (metatuffite), Zbyslav near Kutná Hora
Photo by M. Suk

On the territory of the Czech Socialist Republic regional metamorphism mainly affected the units of the Bohemian Massif; the Alpine metamorphism did not reach there from the Carpathians. The Cadomian and Hercynian metamorphic stages are of primary importance; the question whether or not the pre-Cadomian regional metamorphism and Caledonian metamorphism were separate metamorphic stages still remains to be settled.

The distribution of metamorphic alterations and polymetamorphic units permits to distinguish not only metamorphic zones but also the units of higher order, i.e. metamorphic regions and metamorphic provinces in the sense of Zoubek (1948). The following metamorphic provinces (viz. associations of metamorphic regions of the same position in the orogen within which the last metamorphism occurred) have been established: the Moldanubian-Thuringian, West Sudetic and Brno provinces. The last one is separated from the other two by the independent Moravo-Silesian belt (Fig. 6.2).

The Moldanubian-Thuringian province involves four regions (consisting of zones of the same origin): the Moldanubian, the Krušné hory, the Teplá-Barrandian and the Thuringian regions with series of prevalently low- and medium-pressure facies.

In the West Sudetic metamorphic province there are two regions i.e. the Krkonoše and the Orlické hory regions, with facies predominantly of medium and higher pressures.

6.2 Metamorphic division of the Bohemian Massif and the Brno unit in the territory of the Czech Soc. Republic (J. Cháb, M. Suk 1976)

In the Moravo-Silesian zone, F r a s l et al. (1968) discriminated the Old Moravian (Cadomian, of medium pressure), Middle Moravian (synkinematic, early Hercynian) and Late Moravian (Hercynian retrograde) phases.

The Brunovistulicum represents a separate B r n o m e t a m o r p h i c p r o v i n c e.

6.1 Pre-Cadomian metamorphism

The existence of the continental crust forming the basement of the volcano-sedimentary series of the Cadomian orogenic stage in the Bohemian Massif is demonstrated by unquestioned evidence which, however, is not interpretable unambiguously.

The low-grade metamorphosed Upper Proterozoic greywackes of the Barrandian have provided clastic minerals and rock fragments coming from plutonic and effusive rocks and metamorphites showing low to medium grades of alteration (phyllite, mica-schist, greenschist). The principal minerals established are garnet and staurolite (B e r n a r d o v á 1966, B e r n a r d o v á - C h á b 1968, C h á b - F i a l a 1970) and the association of clastic pyroxene, hornblende and garnet, described by J a k e š et al. (1978). Notable is the presence of pinkish zircon which is usually thought to be characteristic for the older Proterozoic of the Fennosarmatian Shield. The primary age of the zircons corresponds to the Karelian orogeny (2000—2100 Ma, G r a u e r t et al. 1973, G e b a u e r - G r ü n e n f e l d e r 1977), which suggests that they may have been transported from the shield. This interpretation, however, is debatable because isometric oval forms of zircon may hardly originate from elongated crystals during the transport in water; the zircons may also be metamorphogenic and, consequently, formed in situ.

In most of the Precambrian units of the Bohemian Massif were also found metaconglomerates in which, despite strong metamorphism (up to higher amphibolite facies, Fig. 6.3) the original material of pebbles is well distinguishable. In these metaconglomerates occurring in the Moldanubicum near Hluboká nad Vltavou (V r á n a 1977, 1982), in the Pacov area (N ě m e c 1979), in the Krušné hory Mts. (S a t t r a n 1963), in the Barrandian (F i a l a 1972, 1980), the "Islets zone" (S v o b o d a 1931), and the Železné hory Hills (F i a l a - S v o b o d a 1956), there are pebbles of metavolcanites, basalt and rhyolite, plutonites (granodiorite, quartz diorite, plagiaplite), tourmaline quartzite and hornfels, calc-silicate metamorphites, mica-schist and leucocratic gneiss. This material is also considered to be derived from the Fennosarmatian Shield (W a t z n a u e r 1968, L o s e r t et al. 1977) or from a hypothetical ridge formed of older Upper Proterozoic units in the Upper Proterozoic sedimentary basin (C h á b - P e l c 1973, S a t t r a n 1963).

Less substantiated for timing the pre-Upper Proterozoic metamorphic stages are various unconformities or thrust surfaces of nappes referred to from the Proterozoic of the Bohemian Massif, and analyses of the genesis of tectonic elements; they reveal the sequence of alteration events but provide only exceptionally evidence for dating the metamorphism, although they are often used for such interpretation without sufficient criticism.

6.3 Metaconglomerate (sillimanite zone, Monotonous (?) Group of the Moldanubicum. Těchobuz quarry near Pacov, central Bohemia. Material of D. Němec

Photo by B. Matoulková

Very interesting in view of the existence of the Precambrian basement is the find of the transgression of Upper Proterozoic metaconglomerate on the metatonalite near Ondřejov (V r á n a - C h á b 1981), which is equivalent to the transgression of the Brioverian on the granodiorite-orthogneiss in the Armorican Massif (C o g n é 1972).

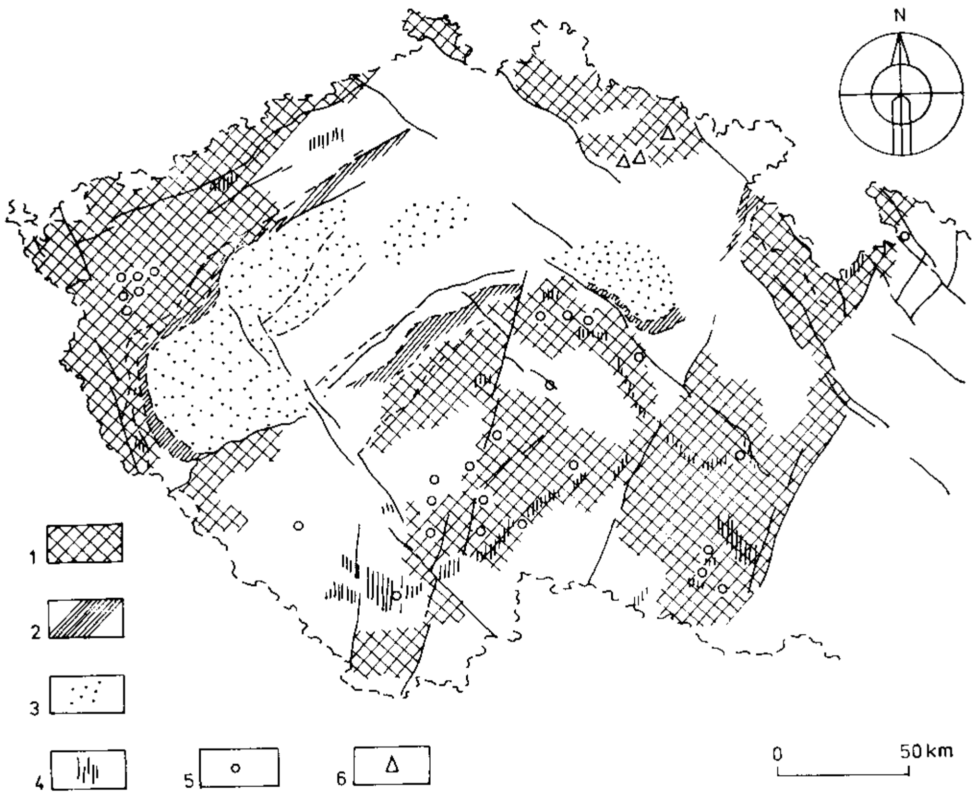
Significant indications of the existence of pre-Cadomian elements exist in the Brunovistulicum. Most of the radiometric data from this unit correspond to the Cadomian stage (650—580 Ma, D u d e k 1980), but despite repeated measurements also earlier ages appear (1100—1400 Ma — amphibole from the tonalite at Dražovice, D u d e k - M e l k o v á 1975). The occurrence of the pre-Cadomian elements in this unit is very probable with regard to its interpretation as a projection of the East-European Platform. Moreover, the Upper Proterozoic of the Moravicum and the eastern part of the Jeseníky Mts. showing a shallow-water development, points to the existence of an older landmass in the E and SE, i.e. in the Brunovistulicum (Mísař 1959, Dudek - Weiss 1963, Suk 1969). The metamorphism in some parts of the Brunovistulicum also differs from the character of the Cadomian metamorphism in the Bohemian Massif. In the southern part of the Brunovistulicum phyllites of greenschist facies prevail (the boundary of biotite isograd is reached), but because of the complex block structure (Štelcl - Weiss 1976) rocks of the epidote-amphibolite facies (e.g. near Krhovice, Dudek 1960) and granulite facies (in the Miroslav horst, Dudek 1963) occur jointly with them. In the northern part gneisses of the higher amphibolite facies are represented (rocks of the quartz-muscovite-kyanite subfacies pass eastwards into sillimanite gneisses and migmatites (Tomšík 1972). According to Štelcl - Weiss (1978) the migmatites terminate in the Lednice zone. Intervening between this zone and the Peripieninian lineament are greenschists and, in the basement of the West Carpathians, the rocks of the epidote-amphibolite facies. Geologically, the Precambrian age of this metamorphism is evidenced by the transgression of the Lower Palaeozoic in Moravia.

6.2 The Cadomian metamorphic stage

In most crystalline units of the Bohemian Massif the distribution and character of the metamorphism of the Cadomian fundament of the Hercynides are traceable. The Cadomian age of this metamorphism is substantiated geologically, especially by the transgression of the Lower and Middle Cambrian and Ordovician on the folded and metamorphosed Upper Proterozoic in the Barrandian and the Železné hory Hills (Fiala - Svoboda 1956), Dudek - Fediuk 1955, Havlíček 1971, 1980). Identical conditions exist in other parts of the Hercynides, e.g. in the Schwarzwald and the Armorican massif. In some sectors (e.g. in the Saxothuringicum) the Proterozoic/Cambrian boundary is obscure, but even there a striking change in the tectonic regime and the configuration of source areas is inferable from the lithology of sediments (Fiala - Svoboda 1955).

An important source of information is the material of pebbles and clastic minerals in Lower Palaeozoic rocks. Pebbles of cataclastic granite and orthogneiss were described from the Cambrian and Ordovician conglomerates of the Barrandian and the Železné hory Hills (Zelenka 1925, Fiala 1948, Fediuk 1959). According to Fiala (1980) these granitoids differ prominently from the granitoids in the Proterozoic pebbles and markedly agree in petro-

6.4 Pencil gneiss of Doubravčany. Leucocratic muscovite-biotite (Kouřim) gneiss, Kutná Hora crystalline complex east of Prague Photo by J. Svoboda chemistry with the pre-Hercynian magmatites of the Železné hory Hills, the Lusatian massif and red gneisses of the Krušné hory Mts. Pebbles of these, partly schistose, have been found in other Lower Palaeozoic conglomerates (C h a l o u p s k ý 1962). Pebbles of phyllite and dynamically metamorphosed



6.5 Distribution of Cadomian metamorphic zones in the Bohemian Massif (M. Suk, orig.) *1* — Kyanite-staurolite zone; *2* — chlorite zone; *3* — prehnite-pumpellyite zone; *4* — occurrence of granulitic rocks; *5* — eclogite occurrences; *6* — occurrences of glaucophanic rocks

greywacke are known from the Barrandian (K e t t n e r - D u d e k 1956, F e d i u k - R ö h l i c h 1960); finds of pebbles of kyanite-bearing mica-schists are reported by F i a l a (1948, 1980) and K u k a l (1966); the latter established their supply from the SE, i.e. from the "Islets-zone", to which the rock associations and their petrographical types are very similar. Finds of pebbles of calc-silicate rocks and marble (the Železné hory), metavolcanites and greenschists are less frequent.

The minerals in the association of clastic minerals (P e t r á n e k 1952, K u k a l 1962, 1966) correspond exclusively to the assemblage of garnet-kyanite-staurolite, with epidote, tourmaline, anatase, monazite, etc. For the time being, minerals common at the present-day denudation level of the Hercynian metamorphism have not been found and no marked changes in the composition of clastic minerals have been established which would suggest a progressive uncovering of deeper, more intensely altered layers of Cadomian orogeny.

Radiometric data provide important evidence for the timing of the Cadomian metamorphic cycle. The data obtained on volcanites and metavolcanites universally confirm Upper Proterozoic age of the educt (Bíteš Gneiss 796 Ma — S c h a r b e r t 1977; spilites of the Barrandian 660 Ma — J ä g e r 1977). The data corresponding to the Cadomian metamorphism were established by G r a u e r t et al. (1973) and G e b a u e r - G r ü n e n f e l d e r (1977) as ranging from 600 to 550 Ma. J ä g e r (1977) considers the value of 670 Ma determined for the spilites from the Barrandian Žitec Conglomerates to be the limit for the beginning of the Cadomian metamorphism.

The age of late tectonic and posttectonic massifs is about 550±30 Ma (K l o m í n s k ý - D u d e k 1978). This date is in good agreement with the frequently reported age of 544 Ma for the culmination of the Cadomian metamorphism in the whole region of the European Hercynides.

All these data are at variance with the geological conditions in the Bohemian Massif at the Proterozoic—Palaeozoic boundary. They presume, namely, a synchronous formation of the Cambrian molasse (Lower Cambrian in the Barrandian dated biostratigraphically and radiometrically) and the regional metamorphism associated with the emplacement of plutonites. It is the same situation as in the Hercynides: in northern Moravia the rocks altered by Hercynian metamorphism occur in pebbles in the Upper Viséan, whereas in other sectors (e.g. in the zone adjacent to the Kouty belt at the western boundary of the Nízký Jeseník) metamorphism and emplacement of plutonites continued beyond the boundary of the Late Carboniferous.

According to geological and radiometric data the beginning of metamorphic activity must be placed in the Late Proterozoic (650—630 Ma) and its culmination at the onset of the Palaeozoic at about 570 Ma. The Cadomian orogeny closed by the late tectonic phase (550—530 Ma) and final tectonic movements at the Cambrian/Ordovician boundary. The radiometric data on the metamorphites and magmatites from the Barrandian Proterozoic, the Moldanubicum (G o r o c h o v et al. 1977), the Lusatian massif and the Orlické hory and Krušné hory Mts. range within this interval.

The origin of late-tectonic magmatites, which usually imply the close of regional metamorphism is thus placed in the Early Cambrian (Neratovice, Kdyně, Ransko massif, Stod, and others). Somewhat younger Late Cambrian volcanites in the Křivoklát-Rokycany zone (470 Ma, V i d a l et al. 1975), already show

Table 6.1
Isograds in the Upper Proterozoic of SW Bohemia after J. Cháb - Z. Vejnar - J. Zoubek

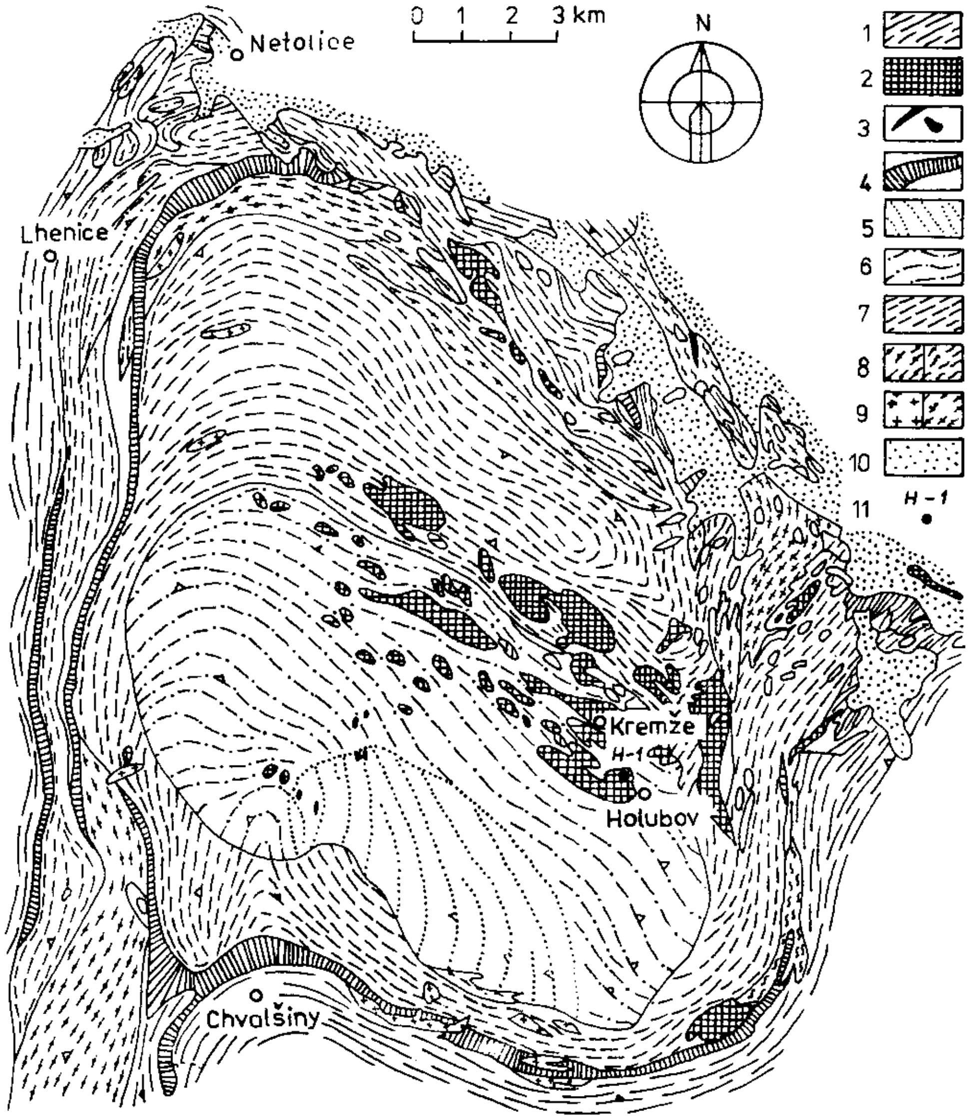
Average grain size	Typomorphic minerals of metapelites	Typomorphic minerals of metabasites prehnite+pumpellyite	Geological unit
0.01–0.03 mm		prehnite+pumpellyite	
0.02–0.08 mm	chlorite	pumpellyite chlorite	Barrandian Upper Proterozoic
0.03–0.01 mm	biotite	epidote actinolite	
0.01–0.6 mm	garnet	hornblende+albite	
	staurolite	hornblende+oligoclase	Domažlice crystalline unit
0.5–1.5 mm	kyanite	hornblende+andesine	
1 mm <	sillimanite	hornblende+labradorite	
	cordierite	labradorite+pyroxene+hornblende	Moldanubicum in the Šumava Mts.
		pyroxene+hornblende+garnet	

subsequent features (W a l d h a u s e r o v á 1971, F i a l a 1971a), and tectonic events in the Ordovician may be regarded either as the last manifestations of the Cadomian orogeny or as first events of the beginning Hercynian cycle. Geosynclinal (initial) character of the Ordovician magmatism in the Bohemian Massif speaks for the second alternative (R ö h l i c h 1966, F i a l a 1971a).

A similar age of the Cadomian orogeny can be derived from radiometric data also for the Moldanubicum, chiefly for orthogneisses (A r n o l d et al. 1974,

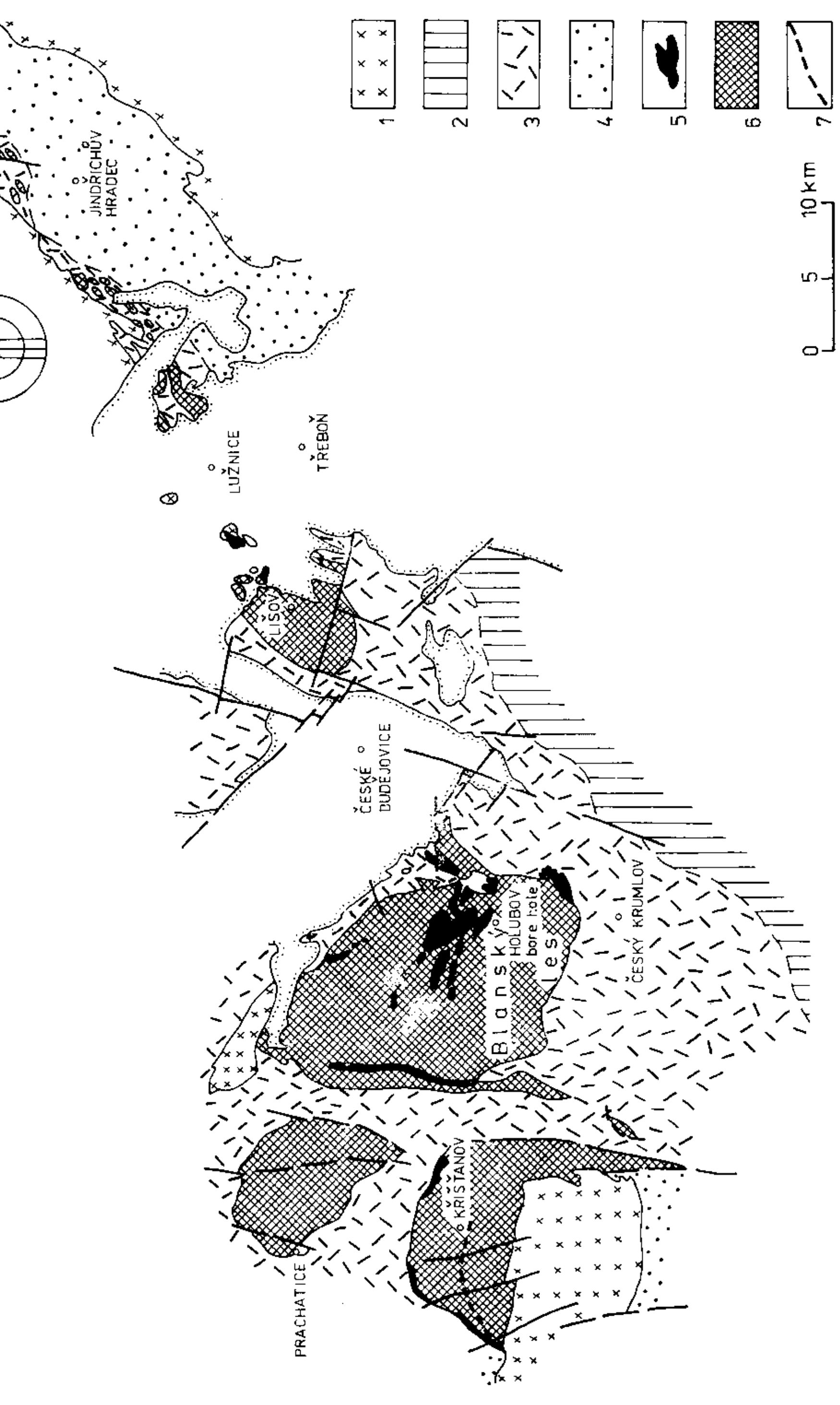
6.6 Eclogite lens in muscovite-biotite (Kouřim) gneiss. Vrbův Mlýn near Kutná Hora. Kutná Hora crystalline complex
Photo by B. Matoulková

6.7 Folded serpentinized garnet peridotite. Bořetice near Kutná Hora. Kutná Hora crystalline complex
Photo by B. Matoulková



6.8 Granulite body of the Blanský les and its inner structure (O. Kodym, jun. - P. Jakeš - P. Schovánek 1978)
1 — paragneiss encircling the massif; *2* — ultrabasites; *3* — metabasites of the granulite massif (mainly pyribolites); *4* — amphibolites in the rim of the massif; *5* — granulites of the massif core; *6* — partly recrystallized biotite granulite of transitional zone; *7* — recrystallized biotite granulite in the outer parts of the massif; *8* — orthogneisses and migmatites; *9* — granites and granodiorites; *10* — Tertiary and Cretaceous; *11* — Holubov borehole

Gorochov et al. 1977, Grauert et al. 1973, Köhler - Müller - - Sohnius 1979, Gebauer - Grünenfelder 1974). The only ex-

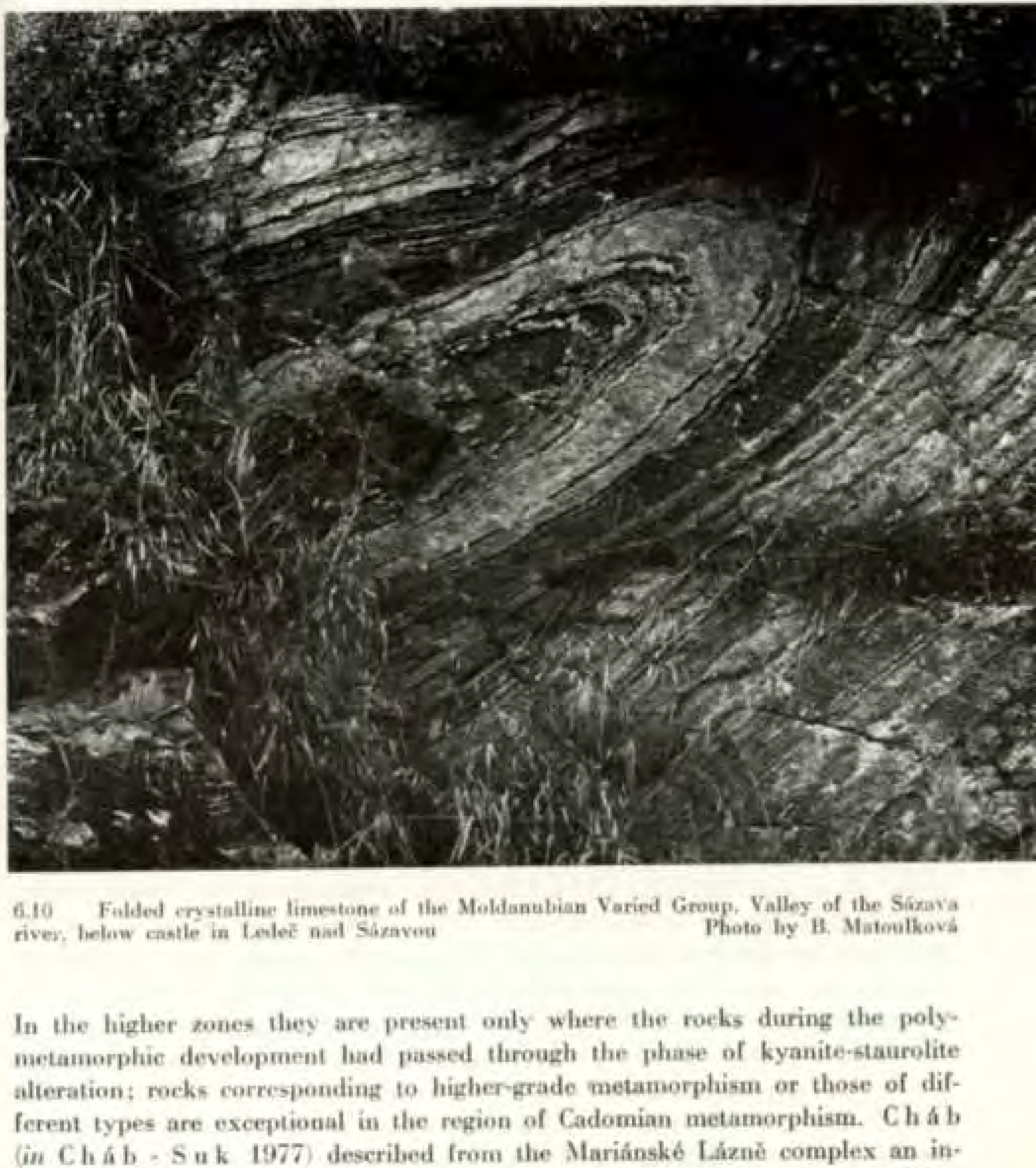


6.9 South Bohemian granulite belt (M. Suk, orig.)
1 — Hercynian plutonites; *2* — Kaplice Group; *3* — Varied and Monotonous Groups; *4* — cordierite-biotite migmatites; *5* — ultrabasites; *6* — granulites and leptynites; *7* — metamorphic boundaries

ception is the age of about 470 Ma obtained for the primary homogenization of granulites. An interpretation of these data would require a long persistence of the Cadomian metamorphism in the Moldanubicum until the Ordovician. We think therefore these data to be questionable (comp. Z o u b e k 1980).

On the assumption that the Bohemian Massif is a relict of the Cadomian structure, the extension of the Cadomian metamorphic zones into the other units of the European Hercynides cannot be reconstructed. In the Bohemian Massif itself only a fragmentary reconstruction is possible. Nevertheless, their zonal course and regular distribution can be evidenced (Fig. 6.5). According to fully consistent data from the different parts of the Bohemian Massif, the character of this metamorphism corresponds to the Dalradian type, i.e. to the metamorphic series of medium pressures. In the higher grades the influence of higher pressure is generally more pronounced than in the lower ones. Characteristic is the extremely rapid sequence of metamorphic zones; this feature is well known from the Teplá-Barrandian region, where a series of higher pressure has been recognized in the Teplá area and a sequence of lower pressure in the SW, in the area of the Domažlice crystalline complex (Tab. 6.1). The lowest alteration grades established S of Prague in the central part of the Bohemian Massif are in the area of the weakest deformation. Hence metamorphism rises continuously as towards NW and N so towards SW and E, into the mantle of the Central Bohemian Pluton (S u k 1974).

The zonation in the Kutná Hora Crystalline, Domažlice Crystalline, in the Moravicum and Lugicum corresponds to the Cadomian metamorphism of medium grades. The kyanite-staurolite assemblage appears as typomorphic minerals of the Cadomian metamorphism in all areas of the Massif and in the European Hercynides in general (D o r n s i e p e n 1979). In the Moldanubicum these minerals are in many cases preserved as relicts of earlier metamorphism. From numerous observations of the superimposed mineral assemblage typical of the Hercynian metamorphism it can be inferred that the granulite kyanite-garnet assemblage in the Moldanubicum, the Kutná hora crystalline complex, the Lugicum and in the Krušné hory region belongs to the Cadomian metamorphic stage, and probably the formation of the omphacite-garnet assemblage in eclogites, too (U d o v k i n a et al. 1977), particularly where they are equivalent to granulites (D u d e k 1971). There is, however, a question whether these are true granulites (and eclogites) or whether these mineral assemblages originated in the rocks involved owing to a low primary water content in the original rocks or owing to local ratios of partial pressures of CO_2 and H_2O (Z o u b e k 1965, 1980, L o s e r t 1971). The Austrian geologists (F u c h s 1979, T h i e l e 1971, F r a s l et al. 1968) and V r á n a (1979) favour the first hypothesis, the other is supported by, among others, M a t ě j o v s k á (1975). These authors advance as principal argument a common alternation of these "granulites" with amphibolites, hornblende-biotite and biotite paragneiss (Fig. 6.8), which are typical of the amphibolite facies. Another fact of no small importance is the presence of "granulite" mineral assemblages in the Bohemian Massif together with amphibolites in the rocks of the kyanite-staurolite zone (D u d e k - S u k 1971), for example, in the Moldanubicum, the Kutná Hora Crystalline (K o u t e k 1966), the Domažlice Crystalline (V e j n a r 1981) and in the Krušné hory Mts.



6.10 Folded crystalline limestone of the Moldanubian Varied Group. Valley of the Sázava river, below castle in Ledeč nad Sázavou — Photo by B. Matoulková

In the higher zones they are present only where the rocks during the polymetamorphic development had passed through the phase of kyanite-staurolite alteration; rocks corresponding to higher-grade metamorphism or those of different types are exceptional in the region of Cadomian metamorphism. C h á b (*in* C h á b - S u k 1977) described from the Mariánské Lázně complex an increase of Cadomian metamorphism in eclogites, amphibolites and serpentinites up to the rutile zone. A relict rutile zone is also reported by M a t ě j o v s k á (1975) from the West Moravian granulite belt. Z o u b e k (1951, 1980) associates the so-called Gföhl migmatization in the Moldanubicum with the Cadomian metamorphism, but the association with migmatites is not usual for the Dalradian type of metamorphism. The pressure plays such a great role that migmatization does not develop up to the highest-grade regional metamorphism. The Gföhl migmatization in the Moldanubicum originated during Hercynian metamorphism by superposition of migmatite structures on the educt, the two components of which are really Cadomian. Zoubek's assumption relates to these very components. The connection of the origin of migmatite structures with the Hercynian metamorphism has been proved in both the Gföhl Gneiss of western Moravia (M a t ě j o v s k á 1975) and the equivalent Popovice and Podolsko complexes (D u d e k et al. 1974). As far as the Cadomian migmatites occur, the migmatization is invariably linked with contact effects (or emplacement of late-tectonic magmatites, such as red gneiss in the Krušné hory Mts. or orthogneisses in the Moldanubicum (A m b r o ž 1935, F e d i u k 1976). In many rocks, formerly denoted as migmatites, banding originated by another process (e.g. in the Bíteš Gneiss, F r a s l et al. 1968; the Sněžník Gneiss in the Orlické hory Mts., O p l e t a l et al. 1980; in the Kouřim Gneiss of the Kutná Hora Crystalline).

Relict manifestations of c o n t a c t m e t a m o r p h i s m o f C a d o m i a n a g e are also known from the Moldanubicum, for example, from the border of the Stráž Orthogneiss near Jindřichův Hradec, or from the Pacov Orthogneiss, from which greisen was reported by N ě m e c - T e n č í k (1976). Dislocation metamorphism of Cadomian age is known from the granulites of the Krušné hory Mts. (B e h r et al. 1965) and the Moldanubicum (S u k 1979).

6.3 Problem of Caledonian metamorphism

In the Bohemian Massif an extensive Caledonian metamorphism was presumed above all in the Lugicum, where Caledonian deformations have been reliably substantiated (K o d y m O. sen. - S v o b o d a 1948, C h a l o u p s k ý 1966). The Lugicum was therefore regarded as a separate branch of the Caledonian orogenic zone and is still separated from the Bohemian Massif by some authors (W a t z n a u e r 1968). However, no independent metamorphism could be proved in this area, and neither magmatites nor flysch and molasse sediments that would correspond to the effects of Caledonian orogeny in the Bohemian Massif have been recognized. Also in other parts of the European Hercynides the low-pressure metamorphic features can mostly be ranged to the Cadomian metamorphism and the low-pressure phenomena to the Hercynian metamorphism. This, of course, does not alter the fact that the Bohemian phase is an essential divide in the history of the Hercynides, representing the rejuvenation of the Epicadomian platform and the onset of Hercynian development.

Only sporadic opinions were put forwards on the activity of the Caledonian metamorphism in other parts of the Bohemian Massif. For example, S t e j s k a l (1925) and Z o u b e k (1946) considered the Moldanubian granulites to be of Caledonian (i.e. Late Cambrian) age. This hypothesis was unexpectedly supported by radiometric Rb/Sr data, which for granulites and orthogneisses of the Moldanubicum range from 420 to 530 Ma (D o r n s i e p e n 1979).

The discrepancy between the geological situation and these data is explained by some authors in terms of heterogeneous rocks, which had been brought up from depth during the Hercynian orogeny (Z w a r t 1969) or of extensive nappes (T h i e l e 1971). Z o u b e k (1980) proved by a detailed analysis that we are not able to decipher convincingly these data which are in essence enigmatic (one of the possible explanations is that they belong to the Cadomian stage rejuvenated by Hercynian events). This is also suggested by their great scatter and the fact that all of them have been obtained on polymetamorphosed rocks (D o r n s i e p e n 1979).

Another explanation assumes that the Cadomian and Hercynian metamorphisms belong to one continuous megacycle which, according to data given above, began in the Late Proterozoic and ended with the late Hercynian magmatism (Š k v o r 1970, F i s c h e r - T r o l l 1973). This interpretation would agree with the idea that the European Hercynides originated as a result of collision of the southern (Gondwana) and northern (Laurasian) blocks, but it does not correspond to basic geological data:

a) Whereas the Caledonian stage is substantiated only by geochronological data and tectonic events, both the Hercynian and Cadomian metamorphic stages display a regular and complete sequence of phases from the syntectonic dynamic metamorphism through high-temperature periplutonic metamorphism (which is more prominent in the Hercynian metamorphism than in the Cadomian) up to the phase of retrograde alterations. Evidence exists e.g. in the Barrandian (C h á b *in* C h á b - S u k 1977), and for the Hercynian metamorphism at the Moldanubicum/Saxothuringicum boundary (e.g. S c h r e y e r 1965).

b) In both stages there is also a complete succession of magmatic types, from the "geosynclinal" through syntectonic abyssal to the "subsequent" acid and basic volcanism.

c) The extent and gradation of the metamorphic zones of the two stages differ sharply (zonal course of Cadomian metamorphism and domal of the Hercynian metamorphism).

These arguments against a separate Caledonian stage of regional metamorphism and uninterrupted existence of metamorphic conditions in the upper crustal layers from the Cadomian to Hercynian stage do not exclude that the fundamental cause was a continuous trend of Gondwana and Laurasia towards collision, or as presumed by Krebs - Wachendorf (1973) or Zwart - - Dornsiepen (1980), a secular vertical supply of masses and energy in places of the mantle hot spot.

6.4 The Hercynian metamorphic stage

The second principal process of regional metamorphism is the Hercynian stage, which was active to a large extent in the whole Bohemian Massif. It is evidenced geologically by the transgression of the Lower Carboniferous on the folded and metamorphosed Lower Palaeozoic in Moravia, by the fading out of metamorphic alterations during the sedimentation of the Lower Carboniferous, and by metamorphism of biostratigraphically proved Lower Palaeozoic sediments in the mountain ranges of the Krkonoše, Jizerské hory and Krušné hory (in some parts) and in the "Islets zone".

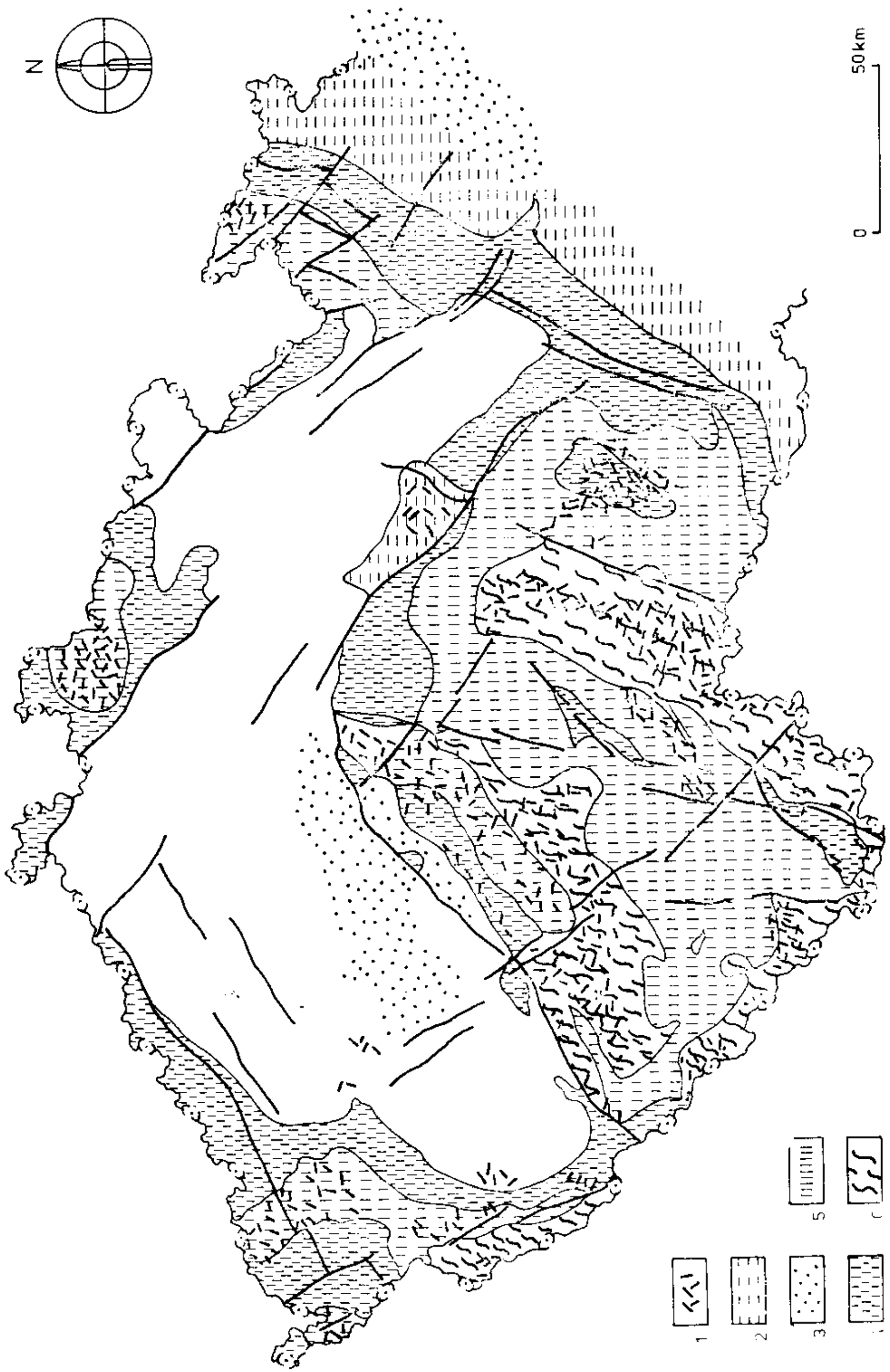
The onset of the Hercynian metamorphic stage is difficult to determine. Kodym sen. - Svoboda (1948) and Škvor (1970) have proved that the beginning of the Hercynian stage must be placed in the Ordovician, when isothermal solutions began to ascend. It is therefore possible that in the areas of higher-grade metamorphism, e.g. in the Moldanubicum, there are exposed layers in which Hercynian alterations had started in the Ordovician, whereas in other areas which represented higher layers of the Hercynian orogen, sedimentation continued still in the Devonian (Jeseníky Mts., Barrandian). Radiometric data and their scatter from 400 Ma to about 270 Ma would correspond to this interpretation; the latter value compares with the closing phase of heating in the late tectonic magmatism. The Late Devonian can be regarded as the period of culminating Hercynian metamorphism. The time succession is complicated by the typical migration of maximum metamorphism in the Hercynian zone from the south, i.e. from the Moldanubicum northwards into the Saxothuringicum and the Rhenohercynian zone during the Devonian to Early Carboniferous. This migration can be substantiated as in the Bohemian Massif (the Bretonian phase in the Moldanubicum, Sudetic phase in the Krušné hory Mts.) so at other places in the Hercynides, for example, in the Rheinisches Gebirge (radiometrically).

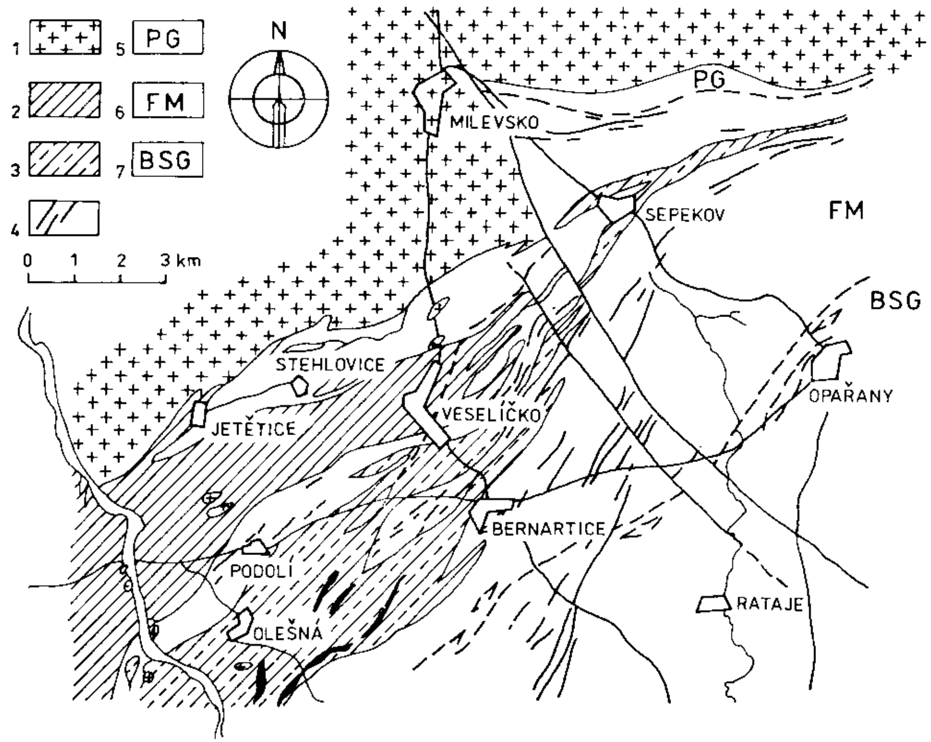
The termination of this metamorphic phase is also asynchronous owing to the origin of autonomous blocks. Whereas in the Lower Carboniferous, molasses of Moravia already contain pebbles of typical Moldanubian rocks (Štelcl 1960, 1969), in the Krušné hory region and northern Moravia alterations had occurred still in the Late Carboniferous.

The Hercynian metamorphism is thought to be a low-pressure metamorphism of the periplutonic cordierite-sillimanite type. However, it shows this character chiefly in the Moldanubian zone, in other sectors it is rather of the Barrovian

Table 6.2
Metamorphic stages and their phases on the territory of the Czech Soc. Rep.

Name of stage	Name of metam. phase	Approximate interval at present denudation level in million years	Type of metam. phase	Typical examples in the Czech Soc. Rep.
Hercynian metamorphic stage	Saxonian		platform phase	contact met. in Bohemo-Silesian volcanic arc, Pb:U re-equilibration
	Late Moravian (Frasl et al. 1968)	300—280	retrogressive phase	albitization, epidotization of Hercynian intrusives, Teplice porphyry
	Bohemo-Moravian	330—300	late tectonic phase	Central Bohemian + Moldanubian plutons, periplutonic metam. (cordierite migmatites)
	Ligurian (Kornprobst et al. 1980)	370—330	syntectonic phase	andalusite-staurolite alterations in cryst. units (Jeseníky Mts.)
Cadomian metamorphic stage	Bohemian (early Caledonian)	520—450	platform phase	Křivoklát-Rokycany Belt
		540—420	retrogressive phase	alterations in the Jílové Zone
	Norman (Kornprobst et al. 1980)	570—540	late tectonic phase	Lusatian pluton, Proterozoic basic massifs of Barrandian, Islets Zone + Železné hory Hills
	Early Moravian (Frasl et al. 1968)	630—570	syntectonic phase	reg. metam. of Barrow type in Barrandian, boundary of granulite facies in Moldanubicum
Pre-Cadomian (Assyntian) metamorphic stage		?	platform phase	
			retrogressive phase	higher-temp. alterations of basic rocks of Brno Massif
	Icartian phase (Kornprobst et al. 1980)	?	late tectonic phase	Brno pluton (800 Ma?) reg. met. to granulite facies in Brno unit
		1800 (900?)	syntectonic phase	?





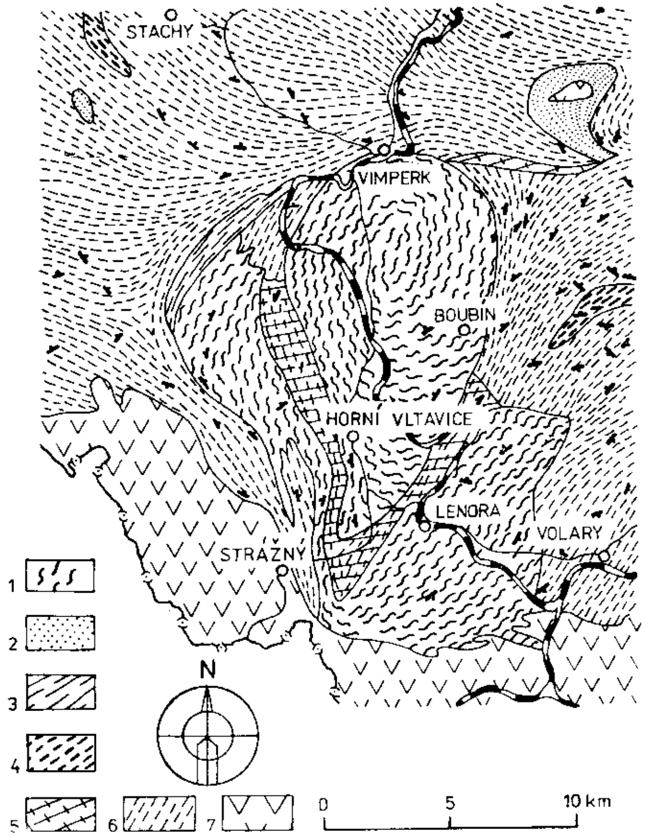
6.12 Zones of periplutonic migmatization at the southern margin of the Central Bohemian Pluton (M. Suk. 1981)
1 — Central Bohemian Pluton; *2* — hornblende-biotite gneiss; *3* — nebulitic migmatite; *4* — quartzite, erlan and amphibolite of the Varied Group of the Moldanubicum; *5* — zone of pearl gneiss (PG); *6* — zone of stromatitic migmatite (FM); *7* — zone of sillimanite-biotite paragneiss (BSG)

type, and in the Krkonoše Mts. at the northern margin, it bears features of a series of medium or higher pressures (F e d i u k - M í s a ř 1968, R y k a - - Z n o s k o 1978, Š t e l c l 1968, C h á b - V r á n a 1979). Some characters of higher pressure are, of course, found even in the cordierite metamorphism of the Moldanubicum (F e d i u k 1971a).

6.11 Zones of Hercynian metamorphism in the Bohemian Massif and the Brno unit (M. Suk. orig.)
1 — Hercynian plutonites; *2* — low-grade metamorphism (predominantly chlorite and epidote isograds); *3* — very low-grade metamorphism (muscovite isograd and increased coalification); *4* — medium-grade metamorphism (garnet, staurolite-andalusite and staurolite-muscovite isograds); *5* — medium-grade metamorphism (+sillimanite and +K-feldspar isograds); *6* — zones of high-grade metamorphism (predominantly cordierite-K-feldspar)

A typical feature of the Hercynian metamorphism in the Bohemian Massif is its polymetamorphic character, because the younger high-temperature Hercynian stage is usually superimposed on the Cadomian metamorphic assemblages or even earlier (Acadian) higher pressures phases (F e d i u k 1971a, V e j n a r 1966a).

The mutual influencing of the Cadomian and Hercynian metamorphic stages is exceptionally intimate and their relations are much closer than is usual e.g. in the zones where Caledonian metamorphism is superimposed on the Precambrian one in Scandinavia or of Alpine on the Hercynian metamorphism in the Alps. Characteristic overprinting of earlier assemblages with kyanite, staurolite and garnet by younger alterations with sillimanite and cordierite has already been described by W a l d m a n n (1927) and it is repeatedly confirmed in different units and on different rocks, such as granulites (F e d i u k o v á - F e d i u k 1971), eclogites (F e d i u k o v á - D u d e k 1979) or in cordierite gneiss. The formation of exotic rocks with saphirine (F i š e r a 1977) and corundum (S u k



5.13 Domal structures of km-order in the Moldanubicum of southern Bohemia (according to 1 : 200 000 map, Strakonice sheet)
1 — cordierite-biotite migmatite; *2* — pearl gneiss; *3* — biotite paragneiss; *4* — leucocratic gneiss; *5* — retrograde-metamorphosed rocks; *6* — sillimanite-biotite paragneiss, partly migmatized; *7* — Hercynian plutonites

6.14 Domal structures in the Bohemian Massif (O. Kumpera, orig.). Volcano-sedimentary depressions connected with them are shown in black
1 — Münchberg zone; *2* — Smrčiny Dome; *3* — Sächsisches Granulitgebirge; *4* — Krušné hory domal system; *5* — Slavkov cupola; *6* — Teplá dome; *7* — dome of the Krkonoše and Jizerské hory; *8* — dome of the Orlické hory and Kłodzko; *9* — Velké Vrbno dome; *10* — Keprník dome; *11* — Desná dome; *12* — Oskava dome; *13* — Rohle dome; *14* — Nemilky dome; *15* — domal system of Kutná Hora crystalline; *16* — Oheb dome; *17* — Svratka dome; *18* — Olešnice dome; *19* — Jihlávka dome; *20* — Dyje dome; *21* — cupola in the Nízký Jeseník Culm

et al. 1975), which appear sporadically in the crystalline complex of the Bohemian Massif, can also be accounted for by polymetamorphism.

The Hercynian metamorphism is associated with regional migmatization. The following types have been discriminated:

a) the infiltration of rocks by granitic material is usually connected with tectonically predisposed zones. This can be exemplified by the formation of the granodiorite of the Kozlovice type (with cordierite and transitions into agmatite-like migmatite), which is associated with the Klatovy fault zone (K o d y m jun. - S u k 1961); the Sázava type in the Central Bohemian Pluton, interpreted as tectonically disturbed series of basic volcanites infiltrated by granitic material, in the zone of the Central Bohemian suture (P a l i v c o v á et al. 1967, Fig. 7.8); and the origin of some migmatitic orthogneisses in western Moravia (D u d e k et al. 1974), in the zone of the Moravicum and Moldanubicum. A foreign analogue are pelites and migmatites in the zone of the Bavarian Quartz Lode;

6.15 Garnet-bearing migmatite. Contact between hornblende-pyroxene-biotite syenite (Tábor type in the Central Bohemian Pluton) and gneisses of the Moldanubian Varied Group. South-eastern margin of the Central Bohemian Pluton. Tábor in the Lužnice-river valley
Photo by B. Matoulková

b) dehydration and genesis of migmatite textures developed by inner migration of substances, without supply of material from outside (S u k 1964, F e d i u k o - v á - S u k 1979);

c) mobilization of the material of leucocratic gneisses with synchronous supply, which is known mainly from the southern margin of the Central Bohemian Pluton (S o u č e k 1974, S u k 1979). This type of migmatization is connected spatially with the emplacement of magmatites, but the formation of migmatite structures invariably preceded the intrusion at a certain denudation level. Pearl gneisses are formed nearer to the granitoid, passing into banded migmatite towards the more remote zones. Linked with these processes is also the migration of metal elements, especially gold and uranium, the concentrations of which are very often at the margins of the migmatization zones.

The zones of Hercynian metamorphism do not have a zonal course as have the zones of the Cadomian metamorphism. The alterations are most intensive in the domal structures, in places of diapiric character (Fig. 6.11), associated with granitoids and migmatites (Fig. 6.12) in the Moldanubicum, the Krušné hory and Jeseníky Mts. Between the domes there are sectors of lower-grade metamorphism, in which rather alterations of foregoing stages are preserved (e.g. relics of the Cadomian metamorphism in the Chýnov Mica-schists between the antiform structures of the Central Bohemian Pluton and the Central Massif).

As in the closure of the Hercynian orogeny the entire plate of the central and southern parts of the Bohemian Massif had been inclined to the north (D u - d e k - S u k 1965), the levels exposed by denudation at the present-day surface differ by several kilometres (e.g. according to the dip of lineations the difference between the northern and southern margins of the Moldanubicum amounts to at least 12 km), and the zones of higher-grade metamorphism widen towards S and SW. At the southern margin of the Moldanubicum near Passau, for example, occur anatexites with spinel, and muscovite-biotite gneisses prevail at its northern margin. The intensity of migmatization also increases southwards and the individual granitoid bodies have a pronouncedly widening zone of contact metamorphism at southern margins (e.g. in Central Bohemian Pluton, Karlovy Vary massif, Babylon massif.

6.5 Alterations of the platform stage

The following fundamental geotectonic units build up the region of the Czech Towards the end of the Hercynian metamorphism the conditions in the initiating blocks became markedly differentiated. While flysch deposits of the Lower

6.16 Degree of coalification in the Permo-Carboniferous of the Bohemian Massif (V. Skoček 1975)
1 — gradation of coalification; 2 — reflectance of vitrinite in oil; 3 — degree of coalification; high, medium, low; 4 — distribution of Permo-Carboniferous rocks

Carboniferous sedimented in some segments, metamorphic conditions still existed in others. The delimitation of blocks in which overheating still persisted in the Late Carboniferous and Permian has been facilitated by the study of zones showing different degrees of coalification of organic substances (Dvořák - Skoček 1975, Skoček 1976, Dvořák - Wolf 1979). In consistence with the inclination of the Bohemian Massif to the north, coalification in the Carboniferous units intensifies towards the south (in the Palaeozoic of Moravia, in the Blanice and Boskovice Furrows, where increased temperature dominated still in the Permian). The greatest heat flow in the Upper Carboniferous has been determined in the western part of the Upper Silesian basin, where the metamorphic grade definitely rises from east to west, and in the Krušné hory Mts. (Brandov), where an increased heat flow has persisted up to date.

Various alteration types were produced by the ascent of basic magmas in the Tertiary, in the Bohemo-Silesian volcanic arc (thermal shock metamorphism at the contacts, formation of spilosites and desmosites). Of relatively wide range, however, are also the "anomalous" radiometric data, thus far not interpretable, which suggest a re-opening of the systems in the Tertiary (Legierski - Vaněček 1965, Gebauer - Grünenfelder 1977).

7. Tectonic development

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7.1 An example of Hercynian folding. Silurian of the Barrandian, Budňany rock, Berounka valley W of Prague Photo by J. Rubín

The following fundamental geotectonic units build up the region of the Czech Socialist Republic:

The oldest is the Precambrian basement consolidated by Cadomian folding. It consists of the Brno unit (Brunovistulicum), and some parts of the Crystalline of the Bohemian Massif, incorporated into the Hercynian structure. Besides the Cadomian orogeny, also earlier, pre-Cadomian orogenic processes (Dalslandian) contributed to the consolidation of some parts of the Massif. The Upper Proterozoic in the Barrandian and in the areas of the Krkonoše Mts. and the Krušné hory Mts. was only affected by the Cadomian orogeny.

The Lower Palaeozoic unit was consolidated jointly with the basement units by Hercynian folding.

The platform cover is formed of the Mesozoic and younger units, which were subjected only to the Saxonian tectonic processes. These three geotectonic units are structural layers of the Bohemian Massif.

The projections of the West Carpathians, extending to eastern Moravia, were consolidated by the Alpine folding; their cover mainly occupies the northern part of the Vienna basin.

7.1 The development of the principal geotectonic units of the Bohemian Massif

7.1.1 Precambrian basement of the Bohemian Massif

The Precambrian basement of the Bohemian Massif is represented by the Brno unit (Brunovistulicum) and its equivalents incorporated into the Cadomian and Hercynian structure, such as the Moldanubian structural layer (which, in the opinion of some authors, is quite separate) or the Upper Proterozoic (Cadomian) structural layer.

The Brno unit displays a number of features which indicate that it originally belonged to the East European Platform, a projection of which it probably represents (Fig. 2.3). Therefore, the earliest W–E and N–S trends are dominant in its structure, being less common in the younger structural layers. These trends are also manifested in the deeper structure (e.g. the N–S magnetic anomaly extending transversely to the surface structure between Pohořelice and Svitavy). The plutonic rocks and metamorphic isograds also have the E–W strike (Fig. 6.3). The later but still pre-Devonian NW–SE trend mainly influences the distribution of the Palaeozoic sediments, and the subsequent SW–NE and SSW–NNE trending faults disrupt the overall structure (after Dudek 1980). The Brunovistulicum forms the basement of the West Carpathians and of the eastern margin of the Bohemian Massif, into which seeral blocks of the Brunovistulicum are incorporated. These are, for example, e Brunides of Tišnov (J a r o š - M í s a ř 1976), and probably some parts of e domal structures in the Jeseníky Mts.

The Moldanubian structural layer is the most important Pre- mbrian structural unit of the Bohemian Massif. According to Z o u b e k (1976) nd C h a l o u p s k ý (1980), it is older than the Upper Proterozoic of the Bar- ndian, and probably corresponds to the Dalslandian structural layer in Scandi- avia and its equivalents in France and Great Britain; its age would thus be 200—850 million years. In the Bohemian Massif it involves the Moldanubicum, hich occupies the Šumava and the Český les Mts., the southern part of central ohemia and the Českomoravská vrchovina Highland; in Poland the Góry owie Mts., and the Granulitgebirge in Saxony.

The Cadomian (Baikalian) structural layer, although fficult to date and differentiate stratigraphically, represents the tectonic evelopment of the Proterozoic geosyncline with typical Cadomian folding, here the filling of intramontane depressions with molasse sediments had ntinued until the Early Cambrian. The age of the Cadomian structural layer estimated at 850—550 to 500 million years and covers beneath the Hercynian ructural layer virtually the whole region of the Bohemian Massif, including its der reworked Dalslandian parts. Indisputable is the first intra-Proterozoic ctonic "Železné hory" phase (S t i l l e 1958, K o d y m, Sen. 1963), which stinctly separates the Proterozoic Spilite Group from the Eocambrian. The cond, infra-Cambrian phase separates the Eocambrian from the Lower ambrian.

The Cadomian structural layer is characterized by the SW—NE ends, discernible in the Precambrian of the whole Bohemian Massif; in many ses (e.g. the Barrandian Palaeozoic) they are reflected in the Hercynian ructural layer. This influencing of the Hercynian structural layer by the tectonic ructure of its Precambrian basement is one of the most relevant features of e Hercynian orogen in Central Europe.

A major tectonic line of the Precambrian basement of the Bohemian Massif the Central Bohemian suture trending NE—SW, which forms the boundary etween the Moldanubicum and the Barrandian and is a component of Zoubek's e-Moldanubian lineament. The granulite and ultrabasite zones in the Molda- ubicum, in whatever way they are interpreted, also indicate important tectonic nes. The existence of the Cadomian nappe structure is questionable. Some in- cations have been recognized in the Lugicum (F a j s t 1976) and in the roterozoic of the Barrandian (K o d y m, Sen. 1926, P e r t o l d 1964), but eir interpretation is not unambiguous.

7.1.2 The Hercynian structural layer

The final character of the Bohemian Massif has been defined by its annexing to Meso-Europe: the Hercynian history in the Palaeozoic was closed by Hercynian folding associated with the emplacement of numerous plutons and extensive regional metamorphism. This folding had reworked the whole region and often obscured the earlier, Precambrian and probably also some Caledonian structural units. From this point of view, the Bohemian Massif has a tripartite structure, consisting of these vertical components: the Precambrian (Cadomian) basement, Hercynian Palaeozoic units, and the post-Hercynian platform cover.

The presence of the Caledonian structural layer is still subject of discussion. In the area which should have been folded and consolidated by Caledonian orogeny, C h a l o u p s k ý (1967), has proved that only the Hercynian folding was of primary importance. The Caledonian orogeny had caused mainly epeirogenic movements, which resulted in hiatuses and facies changes. The end of the Cambrian and beginning of the Ordovician is demarcated by a hiatus due to the Bohemian phase. As it is shown by a slight unconformity, K o d y m, Jun. - S u k (1961) thought it to represent the aftermath of the Cadomian orogeny. The end of the Ordovician and beginning of the Silurian are also indicated by a stratigraphic hiatus caused by the Taconian phase.

In the Hercynian structural layer three main stages are differentiated (M á š k a *in* B u d a y et al. 1961). The lower stage involves the Devonian and older sediments and magmatites of the Hercynian geosyncline. In this stage the first phase of Hercynian folding, the early Bretonian, was active. In the central part of the Bohemian Massif and in the Jeseníky Mts. it was in places alpinotype and associated with regional metamorphism.

The middle Hercynian stage includes the Carboniferous except the upper Stephanian. This structural stage was locally affected by the Sudetic phase between the Viséan and Namurian, and by the Krušné hory phase between the Namurian and Westphalian; it was closed by the Asturian phase in the late Stephanian. Between the Bretonian and Asturian phases structural substages can be discriminated on the basis of orogenic subphases.

The upper Hercynian structural stage covers, according to M á š k a (1961), the uppermost Carboniferous and the Lower Permian. As this stage is postorogenic and is represented by the fillings of intramontane basins of the Hercynian mountain range, the deposits of the Upper Permian can also be assigned to it (M a l k o v s k ý 1974a,b). On the basis of tectogenetic criteria we believe that this stage in Meso-Europe also includes the Lower Triassic in the facies of variegated sandstone, which lies on the Upper Permian without a distinct hiatus. In this Hercynian structural stage, which is characterized by germanotype tectonics, there are in places manifestations of the Saalic phase between the Middle and Upper Rotliegendes and of the Pfalzian phase etween the Upper Rotliegendes and Early Triassic. The filling of intramontane epressions of the Hercynian mountain range in the Bohemian Massif was de-nitively closed by the Montenegrin phase between the Early and Middle riassic.

The following geotectonic regions have been differentiated in the Bohemian assif according to the position in the Hercynian orogen: Moldanubicum, Lu-cum, Moravicum, Silesicum, Bohemicum and Saxothuringicum.

The Moldanubicum had been folded by the Cadomian orogeny; aledonian folding is probably lacking, and the Hercynian folding is associated ainly with vertical movements of masses connected with extensive remo-lization of the granitic material. There is a characteristic predominance of ntiforms (diapirs) and a marked inclination of the whole block towards NNE, ving to which deeper levels had been exposed by denudation in the south-n parts than at the NE margin (Dudek - Suk 1965). Stille (1951) nged to the Moldanubicum exposed parts of the Assyntian block as it was elimited by Kodym, Sen. (1963). In this concept, the Assyntian block cludes, from W to E: the Domažlice crystalline, the Teplá crystalline complex arrandian, Lower Palaeozoic of Chrudim and the Hlinsko zone, and the Kutná ora, Čáslav, Železné hory and Svratka crystalline complexes (Chlupáč et . 1976), viz. it extends up to the Moravicum. Kodym, Sen. thus differentiated e intensely metamorphosed Moldanubicum block and low-metamorphosed ssyntian block. Naturally, the assignment of some minor blocks at the contact the Moldanubian and Assyntian blocks with respect to the grade and intensity Hercynian intrusions is questionable.

The tectonics of the Moldanubicum is polyphasic; in some parts as many as x well defined tectonic phases can be distinguished, which had developed ring two orogenic processes at least, i.e. the Cadomian and Hercynian, the fects of which cannot be safely stated everywhere.

The most striking structures are synclines and anticlines, many kilometres in ce. Their axes generally dip moderately to NE, only in the Šumava Mts. and the neighbourhood of Žďár nad Sázavou the structures are broadly vertical. ey are predominantly of rotational type and had developed in the plastic ate of rocks; planar elements prevail only in lower-grade metamorphic mica-hist-gneisses. Diapir structures increase in amount towards the more intensely igmatized parts of the Moldanubicum.

Beneš (1964) differentiated five systems of B axes in the Moldanubicum d considered the oldest NE—SW system to be pre-Cadomian. He found its tension into the neighbouring units only in places, which he explains by heritance of structures. In his opinion, the following (NW—SE) system is Ca-mian, and the subsequent deformations late Cadomian up to Hercynian.

The stratification is parallel to the principal metamorphic schistosity. Diagonal ike has been observed in some granulites (Kodym, Jun. 1972). A separate inner structure of large granulite bodies is known from both the Bohemian and Austrian parts of the Moldanubicum (Scharbert 1962, Kodym, Jun. 1972).

7.2 Horizontal fold in Moldanubian paragneisses of the Želiv group, 10 km SW of Černovice near Tábor, South Bohemian Moldanubicum Photo by J. Svoboda

The nappe structure of the Moldanubicum is postulated particularly by the Austrian geologists (Thiele 1976). Stettner (1972) believes the whole Moldanubicum to be a vast nappe. In the Bohemian part a number of syn-metamorphic to late metamorphic faults have been established, which often run at the boundary between the competent and incompetent units. Intrusions of granites, more intense migmatization, chloritization and other alterations took place along them. The changes in the strike of foliation and termination of rock belts, however, is not of such a degree to substantiate a presumption of the nappe structure. Some geologists think it more likely that granulites and associated basites, ultrabasites and eclogites had been brought up from deeper parts of the earth's crust along Precambrian structural lines.

The Saxothuringicum is of a similar geotectonic character as the Moldanubicum. It also has the basement folded and consolidated by the Cadomian orogeny, geosynclinal development of the Palaeozoic and alpinotype

Hercynian folding. Towards NW it passes into the Rhenohercynicum (the Harz Mts.). In this region the latest Hercynian phases were most intensive.

The crystalline complex of the Krušné hory and Smrčiny builds up a compound anticlinal belt, which is divided transversely into several minor domes and anticlines: the Smrčiny Dome, Klínovec anticline, Měděnec anticline, Hora Svaté Kateřiny Dome and others. The overall structure of the anticlinorium is asymmetric. The southern limb is steeper, and towards ENE primarily deeper, more intensely metamorphosed units are exposed at the surface. The well defined zonal structure has been studied by Škvor (1975). He divided the upper structure into two layers. The upper layer which corresponds to the muscovite-chlorite zone, is characterized by steep folds, and by schistosity differing in strike from the original bedding. In the lower layer (biotite zone) there is usually bedding cleavage. In the overall structure a slight undulation with a slight curvature and amplitude of folds is perceptible.

The mica-schist part (under the conditions of the epidote-amphibolite facies and amphibolite facies) is intensely folded. The folds show a great curvature and small amplitudes.

The migmatite complexes are characterized by structures of cupola- to domal shapes, whose development were completed by the ascent of underlying granitoid bodies.

The differences in the tectonics of the lower, middle and upper zones are also interpreted as structural discordances.

The linear structure of the western part of the region was studied by Holubec (1966). The lineations (point of intersection of schistosity with cleavage, preferred orientation of micas and small folds) are usually parallel to fold axes and generally trend E—W, with inclination to the W. Holubec presumed on the basis of fabric analysis a structural discordance between the Cadomian and Hercynian structures in the Smrčiny Mts. above the Arzberg group, but Škvor considers its existence as questionable.

Sporadic observations provide evidence of a very complicated structure, comprising, for example, recumbent folds in the Hammerunterwiesental limestone quarry and blocks of Ordovician (?) phyllites directly overlying the higher-metamorphosed basement near Hermsdorf, Rehefeld and Vápenice. Nowadays, they are mostly regarded as transgressive, having a different orientation of B-axes than their basement.

The Lugicum makes up the north-eastern margin of the Bohemian Massif and of the Hercynian orogenic belt in Europe in general. Consequently, it shows some different features and a very complex structure with the Precambrian basement and manifestations of the Hercynian folding as well. The oldest, Devonian phase is of primary importance. Stille (1951) assumed the principal folding and final consolidation to be Caledonian. The unit, however, is not a component of the Caledonian orogenic belt but, in our opinion, the revival of tectonic activity (Chaloupský 1967) and palaeogeographic changes in the Early Palaeozoic were doubtless a repercussion of the origin of the Caledonian orogenic belt in north-western Europe.

The Krkonoše-Jizerské hory crystalline complex displays an asymmetric domal structure with the Hercynian pluton in the core. The views on the structure of this unit are not unanimous. The alleged Caledonian nappe structure (Kodym, Sen. - Svoboda 1948) has not been confirmed by recent investigation, but an unconformity between the Upper Proterozoic and Ordovician—Silurian units has been substantiated. The Cadomian folding and metamorphism gave rise to folds of N—S trend (Chaloupský 1967), and the later (Caledonian after Chaloupský (l.c.), and Hercynian, after Chlupáč 1964) reworking produced structures with axes predominantly of E—W strike.

The Orlické hory-Kłodzko crystalline complex shows a well-defined domal structure. The core is formed of the rocks of the Strónie Group and associated orthogneisses. In the W it is rimmed by the Nové Město Group and in the E by the Staré Město mica-schist belt. Fajst (1976) claimed a tectonic phase between the sedimentation of the Strónie Group and the Zábřeh Group but Domečka. Opletal did not find satisfactory evidence for its existence and regard the boundary between the two units as tectonic. The Strónie Group is folded isoclinally with folds overturned to the E. The fold structure of the Nové Město Group is relatively simple, with flat-lying megafolds whose axes trend E—W. The principal NNE trend in the Staré Město mica-schist belt is parallel to the Ramzová overthrust.

The Moravo-Silesicum underwent a different pre-Devonian development (the Upper Proterozoic basement was forming in a tectonically mobile zone) and the Hercynian evolution as well (the Palaeozoic transgression probably occurred as late as the Silurian, the Devonian is of a typical geosynclinal development, and the Hercynian folding of the alpine type). Dvořák (1968) separated "the Sudeticum" as an individual geotectonic unit, and ranged to it those parts of Stille's Moravo-Silesicum that belong to the Hercynian structural layer. In this sense, "the Sudeticum" is a Hercynian unit, formed predominantly of Devonian and Carboniferous rocks; it occurs at the eastern margin of the Bohemian Massif and in the mantle of the Brno unit (Brunovistulicum).

The Moravicum builds up a strongly tectonically disturbed zone between the Moldanubicum and Brunovistulicum, whose original relation to both these units was completely effaced. The limitation against the Moldanubicum is primarily metamorphic (Cháb - Suk 1977) but the metamorphic boundary was considerably influenced by tectonic movements. Suess' opinion that the tectonic and metamorphic processes in the Moravicum are of Hercynian age, being connected with a vast overthrust of the Moldanubicum on the Moravicum has not been accepted by the Czech authors. They think the Moravicum metamorphites to be pre-Devonian, probably Cadomian, and do not exclude the Caledonian age either.

The Moravicum occurs in the Svratka and the Dyje Domes, which extend to Austria. The Dyje Dome is overlain by the Brno igneous massif, and the strongly dectonized granite in the Svratka Dome bears relics of its mantle. The transgressive Devonian locally preserved on the Svratka granite is divided into two tectonic slices (J a r o š - M í s a ř 1976). The Bílý potok unit (Inner Phyllites) sets on them tectonically, and is followed upwards by the intrusive body of the Bíteš Orthogneiss and the Vranov-Olešnice Formation (Outer Phyllites). The boundary between the Bíteš Orthogneiss and the Bílý potok unit is not tectonic.

The Nedvědice unit (the Moravian mica-schist zone) in the basement is primarily of a lower metamorphic grade than the Moldanubicum, and not its part altered by retrograde metamorphism.

The Moravicum shows two vergencies: the western, Cadomian or Caledonian in age and the eastern, which is later and affecting the Devonian. The Moldanubicum/Moravicum boundary is often followed by later faults of different character and genesis.

The Silesicum has a similar tectonic position and structure as the Moravicum. It makes up two principal anticlinoria, the Keprník and the Desná Domes; they are separated by the geosynclinal zone of Červenohorské sedlo, which is a significant gravity boundary. The overall vergency is to the E, and the very intensive Hercynian reworking considerably obscures the earlier structures.

In the region of the Moravo-Silesicum (and "Sudeticum") the Hercynian tectonics affected most strongly the western part, i.e. the zone of Červenohorské sedlo. The overthrust of the rocks of the Keprník Dome was accompanied by a strong slicing (imbrication) of the Palaeozoic and its Proterozoic basement (M í s a ř 1960).

The intensity of deformation decreases to the ESE. From the apex of the Desná Dome to the Šternberk-Horní Benešov zone (inclusive) the fold structures are of western vergency (with very few exceptions). The westernmost part represented by the Vrbno zone, was affected by low-grade metamorphism and very complex folding. Three deformation phases have been reliably discriminated (O r e l 1975); they occurred before the sedimentation of the upper Viséan (D v o ř á k 1978a). The sizes of folds of phase 1 are of hundreds of metres to kilometre order and their axes trend NNE—SSW and usually dip to the NNE. Folds of phase 2 are coaxial with the preceding folds but only of dm to m dimensions, with almost horizontal planes. The youngest phase is represented by open folds of cm to dm dimensions and with rounded crests; their axes strike SW—NE and dip moderately to the NE at the apex of the Desná Dome, and more steeply in the area of Palaeozoic formations. The level of folds rises westwards.

The eastern part of the Nízký Jeseník (Oderské vrchy Hills) is characterized by overturned folds of m- to km dimensions, with eastern vergency and eastern inclination of the fold level. The more easterly coal-bearing molasse of the Ostrava Group as far as the Orlová Fold shows a similar character of deformation. East of the Orlová Fold in the basement of the Flysch Carpathians the Palaeozoic complex is no more folded.

The block of the Drahanská vrchovina Upland situated farther to the S is separated from the Palaeozoic of the Jeseníky Mts. by the NW—SE trending horst-like structure of the Upper Morava depression. The Konice-Mladeč anticlinorial zone (Devonian in limestone development) separates the westerly Boukov synclinorium filled with Lower Carboniferous greywackes and shales from the larger easterly synclinorium in the northern part of the Drahanská vrchovina Upland.

The southernmost block of the Moravian Karst is folded less intensely (D v o ř á k 1973); a stronger deformation is observed in places of ancient fault zones in the basement, which were active already during sedimentation (D v o ř á k et al. 1976). At the western margin of the Moravian Karst the folds and thrust faults show a western vergency and in the eastern marginal part an eastern one. In both instances a strong axial-plane cleavage is locally developed. Devonian limestones between these zones are almost unaffected by folding.

East of the Moravian Karst the Lower Carboniferous was not folded; it was deformed into two large Luleč and Olšany brachysynclines at the south-eastern margin of the Drahanská vrchovina Upland.

The term B o h e m i c u m was used by M a l k o v s k ý (1979) to denote the Assyntian structural layer. Proterozoic sediments of the Barrandian are folded in the NE—SW to NNE—SSW direction, i.e. diagonally to the fold axes in the Barrandian Palaeozoic. The main syncline lies in the area of Lower Palaeozoic sediments and the anticline in the Teplá crystalline complex. The transverse Český les elevation bounds the Bohemicum in W. In the southern limb near Davle, folds of hundreds of metres to several km amplitudes and with medium dip of limbs and a small amount of transverse fractures are well traceable. In other parts of the Barrandian the rock complexes are tectonically disturbed more intensely.

Particularly strong transverse schistosity related with the Central Bohemian suture is developed in the "Islets zone" and the adjacent part of the Barrandian.

There is no evidence available for extensive nappe structure whose indications were described by K o d y m, Sen. (1926), J i n d ř i c h (1960) and P e r t o l d (1961).

H o l u b e c (1973) differentiated the tectonic history into four stages: in the first stage schistosity s_1 but no folds originated. Clasts became aligned, quartz grains were re-oriented and minerals arranged linearly. Metamorphism and the main crystallization occurred in the second stage, and folds and schistosity s_3 developed. The original alignment was partly preserved. The third stage is characterized by post-crystalline minor faults and chevron folds. In the fourth stage the fold structure was completed; it appears to be the youngest although it was initiated in the second stage.

The Železné hory region is tectonically very heterogeneous. The Proterozoic is divided into at least two sedimentary cycles separated by a hiatus and orogenic phase, which was accompanied by low-grade metamorphism. It builds up the southern limb of a complex syncline of WNW trend, in the northerly part of which there are Palaeozoic complexes. The structure is strongly disrupted by strike faults, which caused substantially greater shifts in the Proterozoic members than in the Palaeozoic complexes (Fig. 7.8), and brought the blocks of different chemistry and metamorphic grades together. Under these conditions it is possible that some of the disconformities recorded (U r b a n 1972) are in fact younger tectonic features (e.g. discordant folding or boudinage).

The Hlinsko zone is limited tectonically against the surrounding crystalline complexes. It had been overthrust and the rocks are intensely mylonitized along the thrust plane. The structure consists of N—S trending, steeply inclined isoclinal folds with slight western vergency.

The structure of the Zábřeh Group and its equivalents (Polička and Letovice crystalline complexes) is little known because of an extensive cover. It has a synclinorial structure of WNW strike, being linked up with the structure of the Barrandian Proterozoic.

7.1.3 The Neoidic structural layer

The Neoidic structural layer — the platform cover of the Bohemian Massif — is the uppermost structural element. M a l k o v s k ý (1971b,c, et al. 1974, 1976a) discriminated in it besides Triassic (which are still a genetic component of the Hercynian structural layer) five structural stages of sediments. The oldest platform stage (Upper Jurassic) corresponds to the platform development of the West Carpathian region (R o t h 1977). The following structural stage (Upper Cretaceous) compares with the principal folding in the Eastern Alps and in the Carpathians. The middle structural stage (Palaeogene) is distinguished by the peneplanation of the Bohemian Massif. Sedimentation did not reach great thicknesses, mainly after a slight folding in the Inner Klippen Belt of the West Carpathians (Eocene—Oligocene). A younger structural stage (lower and middle Miocene) was associated with folding in the Flysch Belt of the West Carpathians. The youngest structural stage (upper Miocene to Quaternary) represents the development of the platform cover after the close of folding processes in the West Carpathians.

The platform cover of the Bohemian Massif is not fully developed because the Massif was almost continuously rising during the platform history. Therefore it was for the most time dry land amidst the Mesozoic and Cenozoic seas or continental basins. It was flooded partly by epicontinental sea only in the Late Jurassic, Late Cretaceous and middle Miocene. Denudation during the Mesozoic and partly the abrasion of Mesozoic seas gave rise to the flat surface forms (K o d y m , Sen. 1963). The process of the rejuvenation of the relief of the Bohemian Massif began at the onset of the Neogene, when its close neighbourghood, viz. the Flysch Belt of the West Carpathians was the site of folding. The mega-elevation uplift of the Bohemian Massif and its block disintegration was intensified in the Quaternary.

After the close of the Hercynian orogeny the Bohemian Massif became a consolidated block. The platform cover, which was formed by impersistent sedimentation of Middle and Upper Jurassic, Upper Cretaceous, Palaeogene, Neogene and Quaternary deposits, covers only parts of the Massif and is not of such thicknesses and regular development as are some other European large basins on the platform. Nevertheless, it provides important evidence of the vertical movements of the blocks of the Massif and their time correlation with folding stages in the Alpine-Carpathian orogen, mainly in the West Carpathians.

The tectogenesis of the platform cover of the Bohemian Massif can be divided into two periods. There are very scarce data on the function of major faults during the period of the Mesozoic—early Badenian; from the beginning of the Badenian until the Recent vertical movements on ancient faults created its present-day geomorphological configuration. Most of the faults plotted in geological and tectonic maps functioned in this period. However, we cannot conclude from this finding that the first period was tectonically at rest. Extensive marine transgression onto the Bohemian Massif in the Late Jurassic and Late Cretaceous, the ascent of neovolcanic masses, chiefly at the beginning of the early Miocene, for which there are no analogies in any other epoch, give evidence against it.

Sedimentation which had been interrupted between the Permian and Triassic because of the Pfalzian phase of the Hercynian orogeny, was renewed in the Early Triassic in north-eastern Bohemia, in the Intra-Sudetic basin and in the eastern part of the Krkonoše-piedmont basin. The Lower Triassic belongs to the southeastern part of the German-Polish basin, which was situated north of the Vindelic landmass. The Vindelic landmass to the core of which also the Bohemian Massif belonged, separated this basin with epicontinental marine and continental development of the Triassic from the Alpine-Carpathian sedimentary area. The sedimentation of the Lower Triassic was closed by the Montenegrin phase, which affected the southern parts of the Eastern Alps between the Early and Middle Triassic.

The absence of younger Triassic and older Jurassic rock complexes indicates a continuing upheaval of the Bohemian Massif due to isostatic movements. This interval is a period of definitive consolidation of the Epihercynian platform.

At the time of late Kimmerian phases, the Callovian and early Malm phases in particular, the north-eastern part of the Bohemian Massif was flooded by the ocean in the late Callovian. As a result, a connection of the epicontinental sea of the German-Polish basin with the Alpine-Carpathian geosyncline was realized.

The late Kimmerian Deister phase, which separated the Kimmeridgian from the Portlandian, brought about the end of Jurassic sedimentation in these parts of the Bohemian Massif. The movements on the Lusatian fault and faults of the Blansko graben caused the subsidence of Jurassic sediments in blocks NE of them, and thus also their preservation. In the other parts of the Massif, Jurassic sediments of small thicknesses had succumbed to intense weathering and denudation already before the Cenomanian transgression.

During this period of denudation vast nappe movements occurred in the Central Alps induced by the Austro-Alpine and early Austrian phases in the Early Cretaceous. They were responsible for the sinking of the Bohemian Massif; after the late Austrian phase at the Albian/Cenomanian boundary, its north-eastern part submerged below the ocean level in the middle and late Cenomanian. In the Late Cretaceous the emerged part of the Massif reached its minimum extent.

The Late Cretaceous sea was most widespread in the middle Turonian, but towards the end of it and in the late Turonian the sea began shallowing or receded altogether from various parts of the Massif.

In spite of this event, the sinking tendency in this part of the Bohemian Massif was maintained until the Coniacian (except for several marginal sectors) owing to the formation of nappes in the Central Carpathians and Limestone Alps in the late Turonian Mediterranean phase. Subsequently to orogenic processes in the Alps (in the Early Cretaceous) and the Carpathians (in the Late Cretaceous) the Bohemian Massif began again to rise. As a result of the Ilsede phase, one of the group of the Subhercynian phases, marine sedimentation in the Bohemian Massif was terminated between the early and middle Santonian.

In the Palaeocene the peneplanation of the Massif continued, being accompanied by block disintegration of small intensity. It was a period of strong waethering, which produced kaolinic residues in the Karlovy Vary area and silicification of the surficial layer of Upper Cretaceous sediments in the Most area (V a c h t l 1952), and in the Kadaň (K a m a r á d - M a l k o v s k ý 1955), Teplice (F e n c l - Z á r u b a 1955), Žatec and Podbořany areas (M a l k o v s k ý 1979).

Continental limnic sediments were deposited as late as the Late Palaeogene, probably in the late Eocene to Oligocene (M a l k o v s k ý 1979). They are represented by the Staré Sedlo Formation in the Sokolov basin and its equivalents in the Podbořany area and the České středohoří Mts. The Lipnice Formation in the South Bohemian basins is thought to be of the same age. In the flysch belts of the Alps and Carpathians sedimentation began again in the Eocene and Oligocene. Whereas in the West Carpathians nappe movements began in the late Palaeocene, in the Northern Limestone Alps they occurred later, between the Illyrian and Pyrenean phases of the Alpine orogeny. In case the Staré Sedlo Formation is of late Eocene age, it had sedimented between these two phases, if it is of Oligocene age, sedimentation occurred between the Helvetian and early Savian phases (M a l k o v s k ý 1979).

In north-western and northern Bohemia the basins at the foot of the Krušné hory Mts. and the České středohoří Mts. were developing as tectonic blocks between the Palaeogene and Neogene, after the early Savian phase. Intensive volcanism was active within a zone extending through the whole Bohemian Massif from NE to SW, and the Underlying complex of clays and sands sedimented during the Aquitanian (late Egerian) (Č t y r o k ý - F e j f a r - H o l ý 1964). During the late Savian phase between the Aquitanian (late Egerian) and Burdigalian (Eggenburgian) when the Subsilesian unit of the West Carpathians had been folded, the subsidence in the area of Krušné hory basins was temporarily interrupted and the Main coal seam was forming. The subsidence was renewed here towards the end of the Burdigalian, after the latest Savian phase. The Overlying complex in various facies developments sedimented in all Neogene basins in northern Bohemia, including the Žitava basin extending to Bohemia near Hrádek nad Nisou. Sedimentation was brought to end between the early Helvetian (Ottnangian) and late Helvetian (Karpatian) as a result of the early Styrian phase of the Alpine orogeny.

Similarly as in the Late Cretaceous, the termination of the lower Helvetian (Ottnangian) sedimentation in northern Bohemia was followed by subsidence and by limnic sedimentation in the South Bohemian basins, i.e. after the early Styrian phase. It is uncertain whether it had begun in the late Helvetian (Karpatian) but it certainly occurred in the early Tortonian (this is the only instance when it can be well correlated with the lower Badenian of central Paratethys). At this time the fluvial-limnic Mydlovary Formation sedimented, showing traces of intermittent ingressions of the sea. Tectonic history of the South Bohemian basins is identical with the development of the Alpine and Carpathian foredeeps, whence the lower Badenian transgression extended to south-eastern and southern parts of the Bohemian Massif. Sedimentation ended in the latest Styrian phase between the early and late Tortonian (Badenian) when the marginal nappes were translated for the last time. The sea retreated from the foredeep, and the whole Bohemian Massif in its present surface configuration became a landmass in the late Badenian.

In the late Miocene and in the Pliocene no orogenic movements occurred either in the Eastern Alps or in the Western Carpathians (M a h e l' 1974). The development is characterized only by epeirogenetic movements and palaeogeographical changes. Fluviatile and limnic sedimentation covered the region of the Bohemian Massif.

Stratigraphically younger than the lower Badenian is the Domanín Formation in southern Bohemia (Řeháková 1969) and its sandy equivalents such as the Vrábeč Member (Žebera 1967b). It rests on the silicified surface of the Mydlovary Formation (Lipnice, Borovany). Most authors agree that the Domanín Formation may be of Sarmatian s.s. age (see also Fejfar 1974). This opinion is also supported by absolute age of moldavites, which occur at the base of the complex (moldavites of strewn field). The age was determined as 14.7±0.7 Ma (Gentner et al. 1967).

From the palaeogeographic view, the presence of the Sarmatian s.s. in the South Bohemian basins is not illogical. With the Sarmatian are grouped the fluviatile sediments not only in the Alpine foredeep in the Federal Rep. of Germany and Austria but also in the Naab valley, where they are believed to occur as far as north of Schwandorf (Tillmann 1964), i.e. at the same geographic latitude as the northern margin of the South Bohemian basins near Tábor. Sarmatian sediments also occur at places of the presumed discharge of the South Bohemian basins into the Eggenburg area, not more than 90 km distant. The distribution of the Sarmatian in the Vienna basin in Moravia also fits in this palaeogeographic pattern (Špička 1972).

The Pliocene, palaeontologically not well defined so far, is known from the Cheb basin (Vildštejn Formation) and from the South Bohemian basins (Ledenice Formation). The oldest river terraces in the Ohře valley and in the northern course of the Vltava valley are indisputably of this age, too. In Moravia, Pliocene sedimentation spread from the Vienna basin into the Carpathian foredeep and farther on to the Bohemian Massif along the tectonically predisposed Upper Morava depression (Špička 1972).

The Quaternary is characterized by intensive tectonic movements, by a predominance of uprising over subsidence, which gave rise to the marginal mountain ranges (Kopecký A. 1972, Malkovský 1975).

The Mesozoic in the Bohemian Massif was, after the preceding Hercynian orogeny, an explicitly anorogenic period, free of volcanism and with only fault-tectonic manifestations. The Massif was an island rising above the level of the world ocean and its extent changed depending on orogenic phases in the Alpine-Carpathian region. During the Triassic and Jurassic the reverberations of the unrest in the Eastern Alps affected the area of the Massif, and the Cretaceous folding in the Alps and Carpathians obviously increased the loading of this block outside its present-day surface limits and caused its general subsidence. Among the faults originated at that time, there are e.g. the Lusatian fault, the Jílovice fault and the Blansko graben (Triassic, Jurassic, Cretaceous), all of which are parallel to the Krušné hory fault. The Mesozoic tectonic structures are characterized by elements of NW—SE trend; the remaining strikes are of minor importance.

In the Tertiary the Savian phases played an important role in the Bohemian Massif, especially the early Savian phase between the Palaeogene and Neogene, when further movements of flysch nappes occurred in the Alps. Beginning with the early Savian phase the Bohemian Massif was again strongly uplifted as a whole and the individual blocks were affected by differential movements. This intensive block disintegration with great vertical movements on major faults, accompanied by basic volcanism and genesis of a system of anticlines and synclines in the Cretaceous of eastern Bohemia has continued in essential up to date. In contrast to the Mesozoic tectonics, the most significant tectonic structures of the Cenozoic are of SW—NE direction, corresponding to the younger structural plan of the western sector of the Czechoslovak Outer Carpathians.

Tectonic movements have continued in the latest stage of the Neoidic tectonic development. The isolines of annual rates of the vertical component of recent movements follow the pattern of the Neoidic block scheme.

The horizontal component of recent tectonic movements has been evidenced by shifts of young relief forms — the drainage network along three fault zones of NW—SE trend.

The shift from the middle Pleistocene to the Recent is estimated from the size of sigmoids in river valleys at 6—10 km/690,000 years. Geodetic measurement of this component indicates that the Carpathians move away from the Bohemian Massif at a rate of 8—10 mm/year (Vyskočil P. - Zeman A. 1980), which is in agreement with the tendency established geodetically in the German Democratic Republic (Thurm et al. 1977). Two lines of horizontal shift between Brno and Mladá Boleslav show, in addition to the shifts in the drainage pattern, a widening of the Boskovice Furrow from average 6 km to 11—18 km. The structures located between the lines of horizontal shift in the eastern part of the Labe-Svratka block beneath the Cretaceous show indications of rotation (mentioned by Pokorný - Šťovíčková 1980). These rotational structures are partly identifiable on satellite images.

7.2 Tectonic development of the West Carpathians on the Moravian territory

In the eastern part of the Czech Soc. Republic, in Moravia, the Western Carpathians are represented by the Carpathian foredeep and the Flysch Belt (part of the Outer Carpathian allochthon), on which the northern (Moravian) part of the Vienna basin is located.

The principal tectonic elements of the Bohemian Massif submerge from NW to SE into the deep structure of these units. Their extension beneath the Outer Carpathians can be followed reliably on the basis of the gravity and magnetic fields up to the axis of the gravity low, stretching from the Vienna area in Austria to Hodonín, Valašské Klobouky and farther towards Kysucké Nové Mesto and Námestovo in Slovakia, and then to Poland (Roth 1957, 1980, Ibrmajer - Doležal 1959, Dlabač - Menčík 1964). This part of the deep structure belongs to the platform block of the foredeeps in Moravia (Roth 1964). It is separated from the exposed Bohemian Massif proper by the Neoalpine fault-flexural margin of the foredeep, which broadly follows the line connecting Znojmo—Vyškov—Hranice and Ostrava (Dlabač - Menčík 1964).

7.2.1 The basement of the West Carpathians in Moravia

The block of the Moravian foredeep comprises the structural units consolidated in the Asturian phase of the Hercynian orogeny, which are closely linked with the exposed part of the Bohemian Massif and experienced a common development with it still in the Palaeozoic. The crystalline basement belongs to the Brno unit — the Brunovistulicum. The Palaeozoic, which begins prevalently with the Devonian transgression, is a constituent part of the Sudeticum. During the Mesozoic, the block of the Moravian foredeeps was, as part of the West European platform, flooded by the sea showing relations to both the Alpine-Carpathian geosyncline and the epicontinental platform. The spatial distribution of Mesozoic sediments on the Epihercynian platform in the block of the Moravian foredeeps attests to the influence of the NW—SE tectonic trends on their palaeotectonic position (Roth 1957, 1960, 1980).

In southern Moravia (and the adjacent part of Austria) up to 2000 m thick Liassic—Tithonian sediments have been preserved in the sandy, carbonate and carbonate-pelitic facies (Eliáš 1979). This Jurassic complex crops out at the surface only in the neighbourhood of Brno (Oxfordian—Kimmeridgian carbonates) and Olomučany (Callovian—Lower Malm). Younger Mesozoic sediments have not been preserved. Transgressive Albian calcareous breccia lying directly on crystalline rocks has been found near Brno on a very small area (Krystek - Samuel 1979). The major part of the Jurassic basin is buried by the foredeep and the overthrust Outer Carpathian nappes. It is composed of Liassic—Tithonian sediments, partly covered transgressively by Campanian—Maastrichtian marly facies (Řehánek 1978). The extension of the Jurassic basin from the NW to SE into the basement of the Outer Carpathians is indicated by the allochthonous position of the klippen of the Tithonian limestones in the Pavlovské vrchy Hills, in front of the Ždánice unit. Their upper Turonian sedimentary mantle still demonstrates a palaeogeographic relationship to the Cretaceous of the Bohemian Massif.

In northern Moravia the Epihercynian platform was flooded only by the Upper Cretaceous sea. Denudation remnants of glauconitic sandstones and conglomerates with *Exogyra columba* Lam. beneath the Outer Carpathian nappes near Oldřichovice and beneath the Miocene in the Opava are of early Senonian (the latter of the earliest Senonian) age; their development is similar to that of the Upper Cretaceous in northern Bohemia (Petrascheck 1928, Roth et al. 1962, et op. cit.).

Except for this Mesozoic sedimentary mantle, the Hercynides of the block of Moravian foredeeps in the part adjacent to the Bohemian Massif remained dry land until the initiation of the Oligo—Miocene foredeep.

There are no reliable data available on the preservation and nature of the autochthonous sedimentary envelope of the Hercynides in the inner parts of this block. Some authors admit the existence of the Mesozoic (mainly Jurassic) envelope series (Dlabač - Menčík 1964) or of "light sedimentary masses" saturated with fluids, as e.g. old molassoid sediments of the deep part of the foredeep (Tomek - Švancara - Budík 1979). From the analysis of the amplitude of the overthrust of the Subsilesian unit and from the stratigraphic assignement of clasts in its sediments, Roth et al. (1962) and Roth (1980) do not exclude that the outer part of the Subsilesian sedimentary area might have originally extended on the part of the Epihercynian platform that lies at present NW of the gravity minimum.

The final pre-Tertiary structure of the block of Moravian foredeeps in the region linked with the Bohemian Massif is divided into three transverse segments. In the South Moravian segment the Dyje and Brno plutons and the preserved folded Palaeozoic (Devonian—Upper Carboniferous) complex are overlain with extensive Mesozoic sedimentary cover (Jurassic, Upper Cretaceous). The Central Moravian segment is characterized by the ascent of granitoids in the Ždánice-Chřiby elevation from beneath the Palaeozoic of the Drahanská vysočina Upland, and of granitoids with ultrabasite bodies mantled with epizonal phyllites in the transverse horst of the Upper Morava depression. The North Moravian segment is distinguished by Palaeozoic sediments of a large extent, including the Upper Carboniferous filling of the Upper Silesian coal basin extending to Czechoslovakia. The crystalline basement of the Palaeozoic is built up of paragneisses and migmatites with sporadic granitoid intrusions.

7.2.2 The Flysch Belt (Outer-Carpathian allochthon)

In the geotectonic history of the Outer Carpathians the block of Moravian foredeeps formed the primary Palaeo-alpine foreland bordering the area of the Outer Carpathian geosynclinal system (see also Roth 1980).

The modern opinions on its palaeogeographic and palaeotectonic configuration and the degree of its preservation in the present-day structure are based on different geological and geophysical criteria (A n d r u s o v 1958, 1959, 1968, B u d a y et al. 1961, 1967, R o t h 1980). The tectonically reduced or subducted parts of the outer Carpathian geosyncline of the Flysch Carpathians in the Moravo-Silesian region may be assumed to extend from the axis of gravity low (Námestovo line in the sense of A n d r u s o v l.c.) south-eastwards to the Peripieninian lineament or into the deep basement of the Central Carpathian structure (R o t h 1980 et op. cit., R o t h - L e š k o 1974, 1975).

The analysis of clasts of flysch sediments gives evidence that the basement of the predominant part of the Outer Carpathian geosynclinal system was the remobilized Epihercynian platform composed of plutonites, Cadomian crystalline complex and Devonian—Upper Carboniferous sediments. Only the Bílé Karpaty unit, on account of its post-Palaeogene structural-tectonic conjunction with the Klippen Belt, shows that the inner part of the Magura Flysch sedimented on the Central Carpathian basement reworked by Palaeo-alpine orogeny (A n d r u s o v 1930, M a t ě j k a 1956, et seq.).

The diversity in the development of the Outer Carpathian geosynclinal system is manifested first in the relationship of the Jurassic and Lower Cretaceous sediments to the overlying beds. This sedimentation occurred continuously from the younger flysch only in the Silesian unit (Beskydy trough — graben, R o t h 1980). In the remaining units the Jurassic—Lower Cretaceous sediments are found either in redeposited clasts (or olistostromes) or klippes. Their lithofacies development indicates that the palaeogeographical conditions were independent of the following development of the Upper Cretaceous to Palaeogene flysch filling. The facies development was most strongly differentiated, in dependence on the palaeotectonic history of the existing nappe units, in the late Senonian. At the beginning of the Palaeocene, the development concentrated into two principal palaeogeographical areas, which correspond to the Menilitic-Krosno group of flysch units and the Magura flysch group.

In the Outer Carpathian geosynclinal system, the sedimentary areas were gradually rejuvenated towards their external margin. In the units of the Magura Flysch the stratigraphic range of the youngest sequence involves the upper Eocene—(? lower) Oligocene. Sedimentation in the Ždánice-Subsilesian unit ends in the Subsilesian part with the (? lower) Oligocene, and in the Ždánice part it continued above the Menilitic Formation until the Egerian. Only in the Pouzdřany unit the stratal sequence also contains the lower Miocene, affected by alpinotype tectonics (S t r á n í k - M o l č í k o v á 1980).

These conditions suggest a progressive folding of the outer Carpathian geosyncline. The older forms of folding can only be delimited as areas of denudation according to stratigraphic hiatuses or termination of sedimentation in single tectonic zones (R o t h 1980). Only the younger forms of folding of the Outer Carpathians (in the old and young Styrian phases) permit to define the structural boundary between the outer Carpathian allochthon of nappes and their autochthonous foreland (R o t h - L e š k o 1974).

The earlier forms of folding from the (?) Pyrenean phase are exhibited as redeposition of rocks of the denuded front of the Magura flysch into the conglomerates of the Ždánice-Hustopeče Formation. The pre-Miocene folding forms (? Helvetian—Savian phases) are preserved owing to the transgression and unconformable deposition of the Eggenburgian and Ottnangian onto the folded Magura flysch (the Rača and Bílé Karpaty units), at the margin and beneath the Vienna basin. In southern Moravia a moderate angular unconformity separates the denudation remnants of the lower Miocene-Karpatian in the southern part of the Hustopečská pahorkatina Hills from the folded basement formed by the Ždánice unit (personal communication of Z. Stráník).

The nappe movements of the Styrian phase showed themselves in Moravia in all units of the Outer Carpathians by the overthrust on the Oligo-Miocene filling of the Outer Carpathian foredeep. The intensity of the old Styrian horizontal movements increases from SW to NE along the Carpathian arc, which was accompanied in tectonic bodies by rotation of the original sedimentary filling of the Outer Carpathian foredeep. The intensity of the old Styrian and Silesian units, including the frontal anticlinorium of the Magura nappe (the Rača unit). From Hranice towards the NE continues the subhorizontal overthrust (in late Styrian phase) over the inner margin of the lower Badenian foredeep. It has been also established in the Subsilesian, Silesian, Fore-Magura units and the frontal zone of the Magura unit. The old Styrian nappe forms (in the Subsilesian and Silesian units) began to be destructed by a two-phase movement of this nappe system. The differentiation of the Silesian unit into the Těšín and Godula nappes (M e n č í k 1960, 1973), dragging of parautochthonous Karpatian slices into the nappe structure, and the covering of denudation remnants of the early Styrian nappe fronts by the lower Badenian (J u r k o v á 1967, 1976) were other results of this event. In the core of the late Styrian Godula nappe there are conserved elements of the earlier folding, differing in direction from the late Styrian movement of nappes in the foreland (M e n č í k 1979).

The resulting structure of the Flysch Carpathians in Moravia consists of thrust nappes translated far from their root zone. Their internal structure is controlled by different competence of rocks, different maturity of tectonic style (R o t h 1980) and by the total thickness of the nappe body depending on the depth of the autochthonous basement. All the units of the Menilitic-Krosno group, including the frontal Rača anticlinorium in the Magura nappe, whose autochthonous basement rises nearer to the surface, are therefore distinguished by flat, platy bodies. With the increasing thickness of the Magura nappe (the Rača and Bystrica units) the inner structure of the nappes becomes steeper and is accompanied by the formation of a system of elongated anticlinal and synclinorial zones. The overthrust of the Bystrica unit on the Rača unit is also steep. The Bílé Karpaty unit with the Klippen Belt incorporated in post-Palaeogene times has a shape of flat plate body at least in the marginal part.

The total amplitude of the nappe overthrust on the foreland is about 20—30 km, as evidenced by deep borings. With regard to the position of the interior margin of the block of Moravian foredeeps, which is indicated by the axis of gravity low, it amounts at least to 50 km.

7.2.3 The Carpathian foredeep

Depending on the progressive folding of nappes the area of final sedimentation of the Outer Carpathians moved into the Oligo-Miocene foredeep. The oldest sedimentary group comprises the Oligocene filling of the Nesvačilka and Vranovice troughs, which Pícha (1968) and Pícha - Hanzlíková - Cahelová (1978) consider to be the filling of submarine canyons extending to the exposed margin of the Bohemian Massif. The lower Miocene sedimentation (Eggenburgian, Ottnangian) was concentrated to the South Moravian segment of the block of Moravian foredeeps. The relics of lower Miocene sediments on the Ždánice unit points to the palaeogeographic connection of the foredeep with the lower Miocene of the present Vienna basin. The palaeogeographic position of the occurrences of lower Miocene on Jaklovec and in the Dětmarovice Furrow in northern Moravia is not clear.

Longitudinal foredeeps following the margin of the developing nappe structure of the Flysch Carpathians, came into being only in the Karpatian and early Badenian. The sedimentary Karpatian filling occupies the interior partial basin in the foredeep, and the lower Badenian partial basin is situated at the external margin of the foredeep. Under the influence of the late Styrian folding the Miocene foredeep was translated into the foreland. The filling also contains sediments of upper Badenian in the Opava area, the foredeep of which occurred on the territory of Poland.

In relation to the foredeep in Austria and Poland, the foredeep in Moravia was of embryonic character, as concerns both the extent and thickness of sediments. Their maximum thickness of about 1000 m was attained in the Ostrava area in early Badenian.

During the Neoalpine history, when the nappes were overthrust and foredeeps initiated, the block of the Moravo-Silesian foredeeps had become a lower structural layer; the pre-Tertiary relief of its structure and the newly differentiated depth position were only secondarily modified. The dominant elements of the new longitudinal and transverse structural forms are the longitudinal ones, which created the relief of the basement of the lower Badenian foredeep (Dětmarovice Furrow — Ostrava-Karviná ridge, the central lower Badenian depression including the Bludovice Furrow in the Ostrava area — and the Slavkov-Těšín ridge, which limits the lower Badenian foredeep on the inner side). In contrast, the Karpatian basin does not show any regionally marked parts and its margin is not known reliably everywhere. It is probable that in general it does not exceed the morphotectonic step which divided the Epihercynian platform longitudinally into a deep and a shallower part. In the surficial structure, this step is copied by the frontal anticlinorium of the Magura nappe. The ancient surface of the Epihercynian platform plunges from its interior margin towards the main gravity low to depths of 5—12 km.

It is unknown to what extent the alpinotype nappe movement had affected the ancient structure of the block. Roth (1980) presumes that it had been secondarily incorporated into the Outer Carpathian nappes in the deep part adjacent to the gravity low. In the shallow part the translation of nappes caused only truncation and tearing off of minor surface blocks, which were then dragged as klippes along the base of the main overthrust surfaces (Krásná-1, Čeladná SV-6 boreholes, see Roth 1980, Jurková 1981).

7.2.4 The Vienna Basin

The Vienna Basin is an interior molasse basin formed in the structural elements of the Outer and Central Carpathians, affected by alpinotype folding. The Moravian part of the Vienna Basin is beneath the Neogene complex built up chiefly of the Magura group of Outer Carpathian nappes. The stratal sequence of the sedimentary filling begins with the lower Miocene (Eggenburgian, Ottnangian) to Pliocene in the marine, brackish to fresh-water facies with lignite seams.

Palaeogeographic extent of the lower Miocene and partly also of the Karpatian differed from the modern shape of the basin, which began to develop during the Badenian. The gradual filling of the basin during the Miocene, the individual transgressions, regressions, hiatuses, angular unconformities and disconformities reflect the single orogenic phases, which took part in the development and forming of the Outer Carpathian system in Moravia (Buday et al. 1969). In Moravia the lower Miocene attained the greatest thickness in the Lužice depression, and the Badenian, Sarmatian and Pliocene sedimentation in the central Moravian depression. This evolution was affected by synsedimentary and postsedimentary radial tectonics. It formed the principal structural elements of the Vienna basin, such as the Rakvice block, central Moravian depression, the Hodonín-Gbely horst to the SE of it, and the Hradiště graben extending to the NE. This is one of the youngest parts of the Vienna basin, which were flooded as late as the Sarmatian and Pliocene. In the N, the Hradiště graben is separated by the Napajedla gap from the fresh-water Plio-Pleistocene filling of the Upper

Morava depression, which closes the genetic cycle of sedimentation in superimposed basins in Moravia.

One of the most important elements of radial tectonics in the Moravian part of the Vienna basin is the system of Steinberk-Stratenberk faults at the northwestern margin. The buried continuation of the Outer Carpathian nappes and their autochthon of the South Moravian segment of the Hercynides with the Mesozoic sedimentary mantle sink deep into the Neogene basement along them.

7.3 Opinions on the global causes of the origin and differentiation of the tectonic units

The introduction of the global tectonic theory led to a wide differentiation of opinions on the origin of the geotectonic units.

7.3.1 The geosynclinal model

The geosynclinal model is still currently applied to the explanation of the development of the Hercynides in both the Bohemian Massif and the West Carpathians.

The geosynclinal model for the Central European Hercynides was elaborated by Stille (1949, 1951) and Aubouin (1965). According to this concept, towards the end of the Devonian a cordillera had developed in Central Europe, forming the axial zone of divergence (Stille's "Alleman threshold"). In the Bohemian Massif it is represented by the Precambrian Moldanubian zone with the Cambro-Devonian mantle (Barrandides). This median mass also comprises the Moravicum and Lugicum, in which the Moldanubian zone terminates. In this sense the Moravicum has its equivalent in the Arvenian-Vosgesian Massif, where the overthrust of the Cevennes is equivalent to the contact between the Moldanubicum and Moravicum. Towards the north, the Moldanubian zone is thrust over the Saxothuringian zone which, beyond the Bohemian Massif, is linked to the Rhenohercynian zone and the zone of Hercynian foredeeps. The activity of the Hercynian orogen occurred with increasing delay towards the north to appear in the northernmost part as late as the end of the Carboniferous. The metamorphic gradient and intensity of granitic plutonism also decline rapidly towards the northerly zones.

This model is a basis on which most of other interpretations have been developed, for example, the theory of Thiele (1971) who, however, regards also some parts of the Moldanubicum as Externides, or of Dvořák - Paproth (1969), who claim the termination of the Hercynian orogenic zones to be at the tectonic boundary of the East European platform. Inside the Bohemian Massif they delimited the Moldanubian zone (to which they range all Precambrian units of the Bohemian Massif), Saxothuringicum, Barrandium, Sudeticum and Lugosudeticum (as intervening between the Labe and Odra lineaments) comprising both Precambrian and Palaeozoic structures.

The Saxothuringicum and Barrandium occur as inner stationary minor geosynclines (without polarity — Aubouin 1965) within the Hercynian median mass, and end on the Labe lineament. In addition to the lack of polarity, a great thickness of the Lower Palaeozoic (including Silurian) and rudimentary development of the Devonian and Carboniferous, compared with the Rhenohercynicum and Sudeticum, are typical of these units. A foredeep filled with molasse is also absent (Dvořák 1968). The Saxothuringicum and Barrandium have a similar development as the NW—SE trending geosynclinal furrow between the Labe and Odra lineaments (Lausitzer Schiefergebirge, and others).

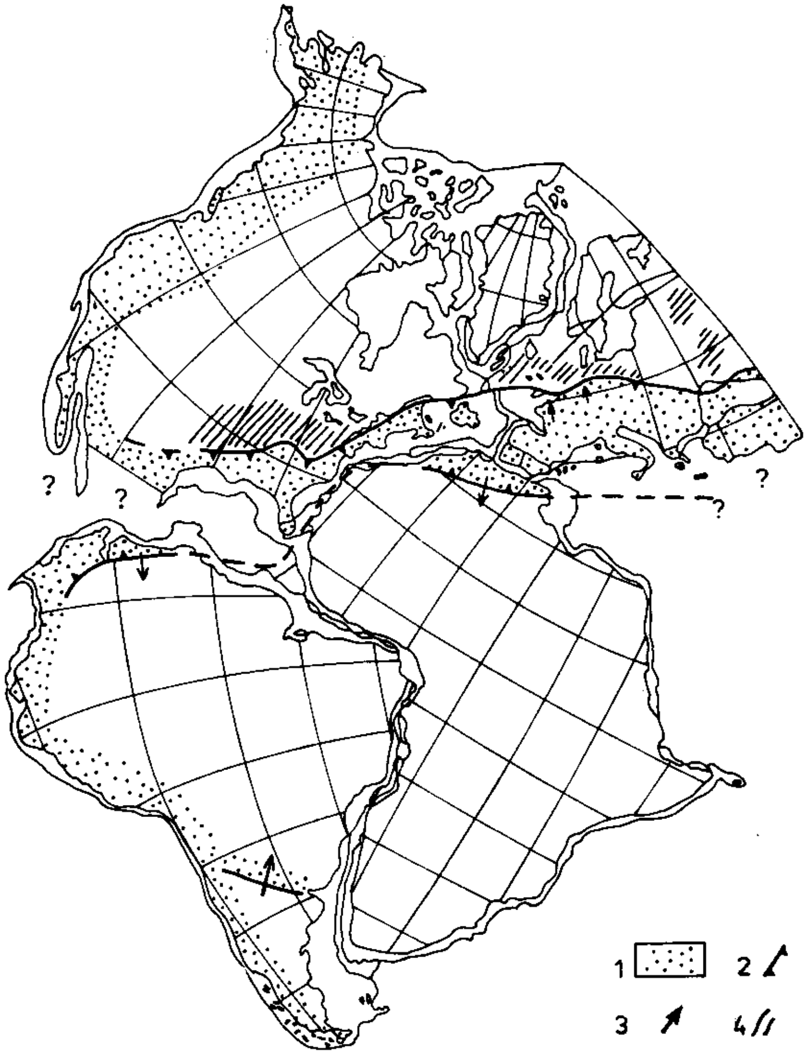
The Rhenohercynicum (NW of the Bohemian Massif) and the Sudeticum are uniaxially symmetrical external geosynclines, which border on the Hercynian forelands (the Netherland platform in the NW and the pre-Carpathian platform in the SE). They have a prominent complete polarity and their outer part is rimmed by a foredeep filled with coal-bearing molasse. The polarity is gradually disappearing towards the SSW in the transverse blocks.

In the NE the Hercynian orogenic belt is terminated by the Odra lineament (Dvořák 1968, 1973a, 1981). From this lineament the mobile margin of the East European platform with predominantly platform development of the Devonian and Carboniferous extends up to the Tornquist line. Between the Luby depression and the southern neighbourhood of Rügen there is a dilatational rift structure, filled with the Devonian platform sediments and coal-bearing Carboniferous. It runs parallel to the Donetz aulacogen. At that time it probably was an aulacogen or initiating rift structure. The SW vergency of most Hercynian structures located along (or between) the Odra and Labe lineaments provides evidence that the NW—SE trending marginal structures of the East European platform were thrust to the SW on the Hercynian orogen.

In the transverse SSW-trending blocks of the Sudeticum and Rhenohercynicum, where miogeosynclinal (carbonate) development of the pre-flysch formations predominantes, the flysch is developed only rudimentarily. The molasse formation, however, sets on sooner and is often of a great thickness (e.g. upper Viséan conglomerates of the Drahanská vrchovina Upland are up to 3000 m thick and contain pebbles of Moldanubian rocks as much as 2 m in size). The pebbles prove that at that time the Moldanubicum already suffered Hercynian metamorphism.

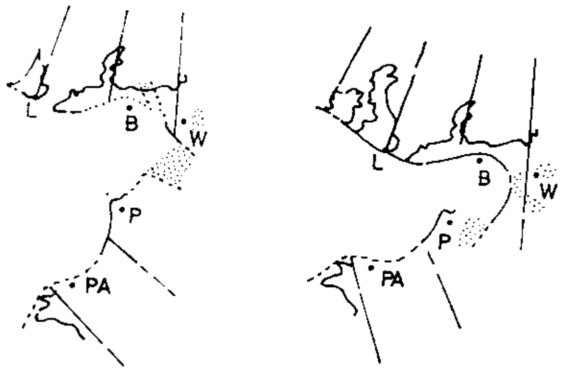
The late stage of the Hercynian orogeny (Westphalian—Permian, in places from the late Viséan) is characterized by the formation of intermontane depressions, which were gradually filled with terrestrial, locally coal-bearing molasse (Holub - Skoček - Tásler 1975).

The fundamental problem of all these interpretations is the mode of termination of the Hercynian orogenic zone at the north-eastern margin of the Bohemian



7.3 Correlation of European Hercynides and North American Appalachides. Situation before the opening of the Atlantic in the Jurassic (J. Krause - M. Pilger 1977)
1 — Hercynian geosynclines; *2* — margin of interior Hercynides; *3* — trends of folding; *4* — Subhercynian coal-bearing foredeeps and shelf areas with coal deposits

Massif. Stille (1951) assumes an axial wedging out, but other authors, who issue from Kossmat's original hypothesis explain it by arcuate bending and convergent structure of the belt. But this concept is at variance with the structure of the Lugicum and therefore Aubouin (1965) and Dvořák (1973a, 1975a) claim a tectonic termination on the Odra lineament and a divergent structure of the Hercynides in the Bohemian Massif.



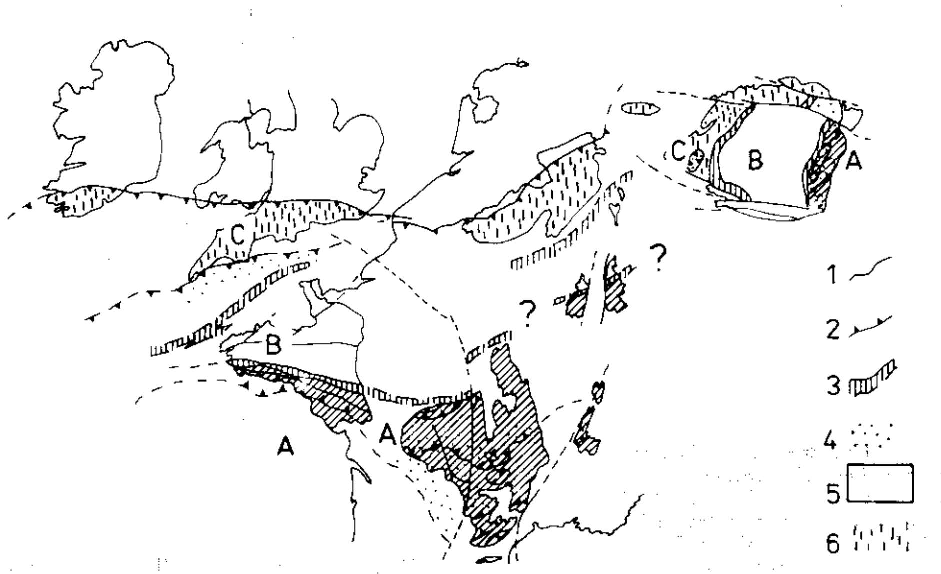
7.4 Hypothetical configuration of the Central European Palaeozoic sea region (J. Cháb 1975). *Dotted lines* **denote intraplatform rift (on platforms also aulacogen) systems (unlimited) and systems developed into half-opened marine areas (limited). The sea was closing by rotation of Central European plate relative to Fennosarmatian plate in clockwise direction. Modern meridional system is plotted**
B — Berlin, L — London, P — Prague, Pa — Paris, W — Warsaw

7.3.2 The subduction model

Several subduction models have been elaborated for the explanation of the zonal structure of the Hercynian and Cadomian orogens in Central Europe. The subduction zones are placed in different places and different time intervals.

The collision subduction sutures of the Precambrian (Cadomian) development stage can be traced, according to some views, in the Bohemian Massif itself. This idea is based on the fact that several rock masses show a character corresponding to the oceanic crust: for example, the Mariánské Lázně complex (after Cháb 1975), the Proterozoic volcanism of the Barrandian (according to Fiala 1978 and Jakeš 1978), or the Moravo-Silesian ophiolite belt (after Mísař 1974). In this case, the collision suture is identified with the "Perimoldanubian lineament" which, according to Zoubek and Vyskočil, separates the Moldanubian zone from the Brioverian—Barrandian zone in the north.

According to Cháb (1979), the Central European segment of the Upper Proterozoic—Cambrian tectogen may be interpreted in terms of a double belt divided by a crustal block of continental type: the northern belt is incorporated into the central collision zone of the Hercynides, and the southern belt extends along the inner margin of the Moldanubicum towards the NE. The suturation



7.5 Hypothetical collision of three continents in the area of European Hercynides (according to J. P. Bard et al. 1980)
1 — margins of continents; *2* — overthrust; *3* — sutures, presumed; *4* — basic and ultrabasic rocks; *5* — Central European Hercynide continent (*B*); *6* — North European continent (*C*); *A* — South European continent

in the present-day central part of the Bohemian Massif was the most important process.

B e r á n e k et al. (1981) presume the existence of the collision zone of continent/continent type at the boundary between the Bohemian Massif and Brunovistulicum. They explain the so-called Moldanubian overthrust, the character of the Moravicum, the accumulation of metavolcanites and ultrabasites at the eastern margin of the Moldanubicum, and the anomalous supracrustal structure in this area by the collision and subthrusting of the Brunovistulicum beneath the Moldanubicum towards the end of the Precambrian history.

In the Palaeozoic the existence of a North European and a South European continent is assumed. In the intervening subduction zone the belt of European Hercynides originated. According to L a u r e n t (1972) an J o h n s o n (1973) the Saxothuringicum (considered to be Lower Palaeozoic oceanic crust) descended beneath the North European continent in the present Rhenohercynicum, when the hypothetical Devonian—Carboniferous ocean was closed as a result of the collision of the two continental plates. There is of course neither palaeogeographic nor palaeontological evidence available for the existence of this ocean.

B u r r e t - G r i f f i t h s (1977) place the Hercynian suture with subduction in the Lizzard massif in southern England, in the southern part of the Rheinisches Schiefergebirge and the southern part of the Harz. The Bohemian Massif would be in this case a component of the southern European continent and thus a projection of Gondwana (S c a t e s e et al. 1979). The collision zone of continent/continent type is also presumed to have existed south of the Moldanubian zone in the Armorican massif and the Massif Central français, in which subduction may have occurred in the Devonian (L a u r e n t 1972, N i c o l a s 1972). This collision zone cannot be proved in the Bohemian Massif either and the Cambro-Silurian ocean would have been of a very small size (D o r n - s i e p e n - Z w a r t 1980). On an analogous basis B a r d et al. (1980) differentiated two sutures in the European Hercynides, which separated three continents: the Iberian-South European, Meso-European (which includes, among other massifs, the Moldanubicum, Barrandian and the western part of the Lugicum), and the North European (Fig. 7.5). These continents were in the initial phase — from the Ordovician to the Viséan — separated by two oceans. The sutures were closed in the Viséan.

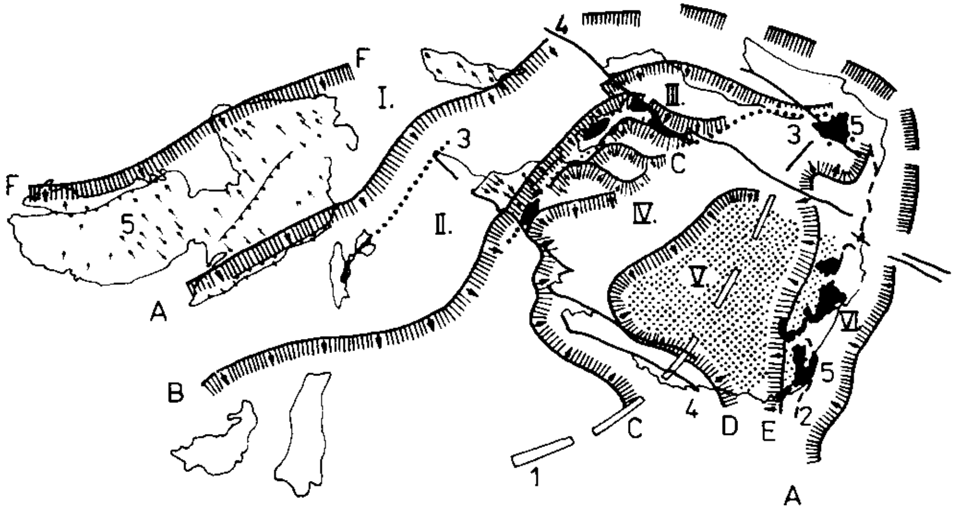
These interpretations, however, do not agree with the distribution of the Hercynian magmatites and with their intracontinental character within the whole range from southern England to the Bohemian Massif (K r e b s - W a - c h e n d o r f 1973), and with the tectonic-metamorphic zoning of the Hercynian orogenic belt.

G r e c u l a and R o t h (1978) presume the existence of a subduction suture at the boundary between the Brunovistulicum and the West Carpathians along the Břeclav—Žilina connecting line. It is thought to have formed by the subduction of the southern margin of the North European Platform beneath the Carpathian—Pannonian microcontinent during the folding of the Outer Carpathians. In the opinion of the above authors, the geophysical pattern of the structure of the upper part of crust and the distribution of andesite volcanism in Slovakia lend support to this hypothesis.

From the global viewpoint, however, the evolution of Central Europe may have been influenced above all by the relationships between the fundamental stable blocks (plates) — the Scandinavian (Scandinavia—North America, Laurasia) and African (Gondwana). They induced the formation of Palaeo-, Meso-, and Neo-Europe, which implies the origin and course of the Cadomian, Caledonian, Hercynian, and Alpine orogenic belts in Central Europe. The global tectonic style of the Cadomides and Hercynides, however, must have differed essentially from that of the Circumpacific belt, which is a model for plate tectonics.

7.3.3 The subfluence model

Since the evidence for the existence of the oceanic crust in Central Europe is not convincing and the tectonics of the Hercynides is characterized rather by vertical movements (e.g. diapiric gneiss cupolas) Krebs - Wachendorf (1973), Weber (1978) and Behr (1978, 1980) have elaborated a subfluence model for the development of the Hercynides. According to these authors, the whole process was caused by the subduction of the lithospheric mantle beneath the continental crust (this is termed A-subduction, Ampferer's subd.). Whereas B-subduction (Benioff's subd.) implies subduction of the oceanic crust, A-subduction provokes at depth an extensive subhorizontal transport of progressively higher and higher layers. In these, regional shear zones develop and are uplifted,



7.6 Arrangement of subfluence zones (A—F) and directions in Central European crystalline system during the Late Proterozoic to Early Carboniferous (H. I. Behr 1978)
I — Rhenohercynicum, II — Saxothuringicum, III — Lugicum, IV — Teplá-Barrandian region, V — Moldanubicum, VI — Moravo-Silesicum; *1* — axis of presumed asthenolith, *2* — Moravicum—Moldanubicum boundary, *3* — mylonite zones, *4* — major deep faults parallel to the margin of European Platform, *5* — granulites and orthogneisses

and folding of supracrustal type occurs in them even at higher levels. According to Behr (1978) there are eight such zones in the Bohemian Massif, distinguished by granulite occurrences. (Zeman J. 1980 and Vrána 1979 also believe the granulite belts in the Bohemian Massif to be indications of deep faults, along which the granulites, regarded as typical products of subfluence supracrustal processes, had been uplifted from depth, Fig. 7.6.)

The subfluence model was applied to the Hercynides by Dvořák (1980). In his opinion, the pressure gradient was caused by the movement of the two Hercynide forelands against each other. In the most mobile sectors at the contact with earlier consolidated core of the developing median mass, external rapidly sinking geosynclines were forming. The subsidence gave rise to an extensive system of heat convection.

In the pre-Flysch stage general subsidence predominated, being accompanied by effusions of the spilite-keratophyre formation and by sedimentation of an up to 1000 m thick reef complex. Once the total compression had attained higher intensity, differentiated movements at the median mass/geosyncline boundary began: the blocks at the periphery of the median mass rose rapidly and the adjacent zone of maximum subsidence was sinking. At this time the flysch formation originated and, in result of a steep thermal gradient (in the median mass up to 250° per 1 km), the Variscan granitoids penetrated into the rising blocks of the median mass. Volcanic-plutonic formations were produced. The products of terrestrial subsequent intermediate to acid volcanism were rapidly destructed by denudation and the fragments and pebbles of this material got together with tuffites into the flysch formation. Its amount increases steadily upwards, being the largest during the deposition of coal-bearing molasse.

The granite layer of the earth's crust beneath the rapidly sinking zones of maximum subsidence of geosynclines was melting due to the steep thermal gradient. The migration of melt beneath the rising blocks of the Hercynian median mass caused in some blocks large intrusions of light granitoids and an increase in the thickness of the crust, especially of the granite layer. The blocks consolidated by granitoid massifs were in their following history always in an elevated position in contrast to blocks which had not been markedly consolidated towards the end of the Proterozoic. Therefore, they do not contain major intrusions of Hercynian granitoids and from the Cambrian to the Tertiary they had rather a sinking tendency (higher mobility, e.g. the Teplá-Barrandian block). According to J. Dvořák the "Ampferer's subduction" need not be postulated.

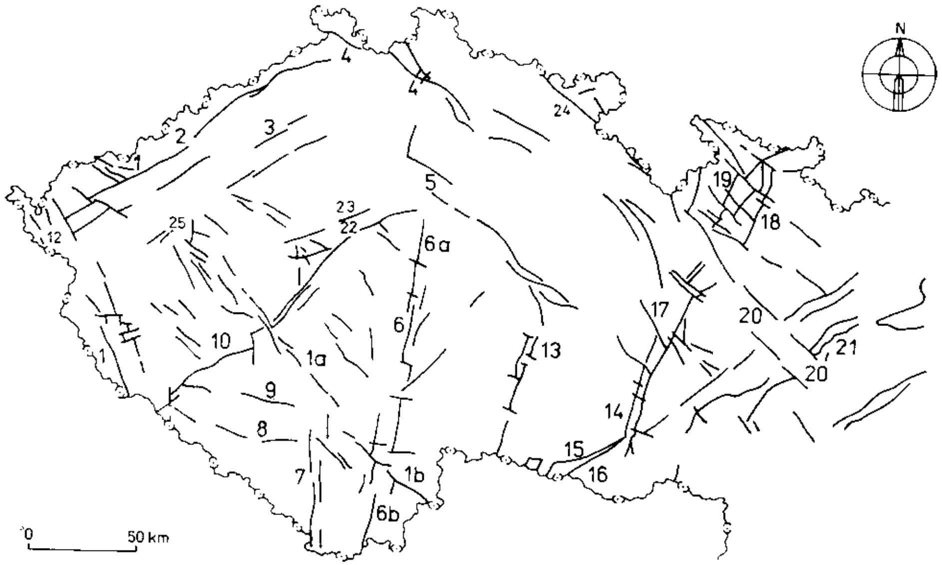
The zones of maximum subsidence, being filled with flysch sediments migrated from the median mass to the foreland at an increasing rate, consistently with accelerated deposition of clastic material (Famennian—Namurian — Dvořák 1975b).

The deformational wave migrated parallel with the zones of maximum subsidence. In the late Viséan the innermost zone of the previous geosyncline was at least deformed and metamorphosed. It was rising and became the main source of clastic material for the youngest zones of maximum subsidence to be filled with flysch sediments (Dvořák 1978a).

7.3.4 The block model

The concept of block structure found favour with many geologists. It assumes the Bohemian Massif to be an independent block of continental crust, which was divided by deep faults ("lineaments") into a mosaic of blocks which have undergone a more or less autonomous development. However, the deep faults, their significance and the characterization of an independent development of the blocks are not easy to interpret. Basically, there exist three concepts of the block structure of the Bohemian Massif, i.e. geophysical, geologico-tectonic and geomorphological.

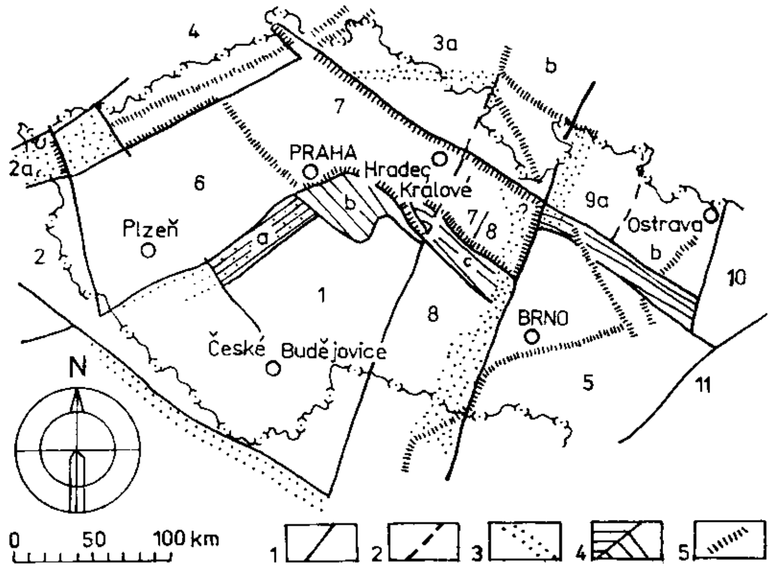
The geophysical model issues from the interpretation of sub-crustal and also superficial anomalies, established by geophysical methods. It reveals mainly the vertical boundaries of deeper (buried) parts of the earth's crust, which are often wrongly connected with inadequate geological boundaries



7.7 Principal fault systems in the territory of the Czech Soc. Republic (M. Suk, with the use of M. Malkovský's map, 1979)
1 — Jáchymov lineament, *1a* — Předbořice zone, *1b* — Stropnice graben; *2* — Krušné hory fault; *3* — Litoměřice fault; *4* — Lusatian fault; *5* — Železné hory fault system; *6* — Blanice Furrow, *6a* — Kouřim fault, *6b* — Kaplice fracture; *7* — Lhenice fault system; *8* — Šumava fault; *9* — Damětice fault; *10* — Klatovy fault; *11* — Bohemian Quartz Lode; *12* — Aš Quartz Lode; *13* — Přibyslav zone; *14* — Boskovice Furrow; *15* — line of Moldanubian overthrust; *16* — Vranov fault; *17* — Blansko fault zone; *18* — Oskava fault zone; *19* — Ramzová fault zone; *20* — Haná fault zone; *21* — fault system of Moravian Gate; *22* — Závist thrust fault; *23* — Prague fault; *24* — Hronov-Poříčí fault; *25* — Žihle graben

at the surface. However, they are of essential importance for the characterization of the earth's crust and its history (Fig. 2.36).

The most significant boundaries in the Bohemian Massif are the limits of positive and negative zones (Fig. 2.36), the boundaries of the Bohemian Massif



7.8 Block structure of the Bohemian Massif (according to A. Zeman 1978)
1 — block boundaries (deep weakened zones); 2 — pre-Neoidic boundaries of blocks affiliated to another block in Hercynian time; 3 — mobile zones affiliated to the blocks in the Palaeozoic; 4 — blocks mobilized in marginal parts, direction of inner structure indicated; 5 — boundary of Neoidic activation. Sialic blocks: 1 — Moldanubian, 2 — block of Český les with the Smrčiny sub-block (2a), 3 — West Sudetic block (a — Krkonoše-Jizerské hory sub-block), b — Orlické hory sub-block); 4 — Krušné hory block. Simatic blocks: 5 — Brunia, 6 — Teplá-Barrandian block, 7 — Labe block (as part of the Labe lineament), 7/8 — part of the Moravian block, which was incorporated into the Labe block in Neoidic time, 8 — Moravian block, 9 — Silesian block (a — Jeseník sub-block, b — Upper Odra sub-block), 10 — Upper Silesian block, 11 — Palaeo-Carpathian block

and the West Carpathians derived from seismic data (the Lednice zone and Peripieninian lineament), the Central Bohemian suture, the Přibyslav zone and Litoměřice fault.

They separate the main crustal blocks of the Bohemian Massif: the Teplá-Barrandian, the Krušné hory-Krkonoše, the Moldanubian, the Moravian and the Silesian blocks.

7.9 Očkov overthrust in Quarry Kobyla near Koněprusy

Photo by J. Svoboda

The mobile Labe zone is an important element of this division but it does not form a separate block.

The geological-tectonic model is based on the geologically evidenced faults which form outstanding boundaries between units of different character in the superficial structure.

In this sense the Bohemian Massif is given as a typical example of "central massif", i.e. an ancient block of continental crust encompassed by geosynclinal basins, whose evolution (e.g. magmatism) also influenced this block (Rozen 1976). In this interpretation the Bohemian Massif consists of the ancient pre-Riphean core (Moldanubicum) surrounded by Riphean (Cadomian) volcano-sedimentary formations, which together with the core created the block structure of the Bohemian Massif in the late Precambrian (Cadomian cycle). The present concept is in many aspects similar to Máška - Zoubek's differentiation (*in* Buday et al. 1960) of a stable block and an area of intensive tectogenesis during the Palaeozoic in the Bohemian Massif.

In consistence with this idea the younger faults are increasingly more prominent and more frequent (Figs. 7.7 to 7.8). The Cadomian (or earlier) age is determinable only for several faults. In the Precambrian units many belts of meta-volcanites indicate ancient fault zones (e.g. the Jílové zone, belt of the Bíteš Gneiss, the "zone of intrusive tectonics" in the mantle of the north-eastern part of the Central Bohemian pluton, the Hlinsko zone and the South Bohemian granulite belt), which acted as their channels of supply (Mísař 1974, Palivcová - Šťovíčková 1968). They usually trend SW–NE to SSW–NNE, which is characteristic of the Precambrian structures of the Bohemian Massif, or perpendicularly to this direction (the Jáchymov zone).

Towards the close of the Hercynian orogeny the NW–SE trending faults (Danube fault, Šumava fault, Odra lineament) originated; they were partly synmetamorphic (Fischer - Troll 1973, Vrána 1963) and partly late tectonic (Thiele 1962). Blocks of a smaller thickness of the crust and lacking major bodies of Hercynian granitoids were sinking on these faults. Later on, (chiefly during the Stephanian–Permian) narrow grabens were formed on ancient faults, especially on those striking NNE–SSW. Whereas Carboniferous and Permian sediments in major bodies within the Teplá-Barrandian block and the Labe block are only slightly altered, metamorphism in narrow furrows attains even the anthracite stage (Dvořák - Skoček 1975).

In the Intra-Sudetic depression a rapid subsidence began as early as the late Viséan (Tásler et al. 1979), being compensated by sedimentation of coarse-grained conglomerates, which attained a thickness of more than 1000 m. Subsidence was so intensive that it enabled a short-time ingression from the north. In the Upper Carboniferous, coal-bearing molassoids predominated, passing upwards into "red beds" (Permian).

The sedimentary area moved within an ancient N–S trending tectonic zone from N to S. In the southern extension of this zone there is a sunken block of Devonian and Carboniferous rocks near Hradec Králové (Nepasice, Chlupáč - Zikmundová 1976, Zukalová 1976). The alteration of organic matter is very low (Dvořák - Wolf 1979). The Krkonoše pluton dated by K-Ar method at 300 Ma adjoins the Intra-Sudetic depression in the west (Stephanian, Bernard - Klomínský 1975). This position suggests a highly intensive thermal convection between the neighbouring rising and sinking blocks during the Carboniferous.

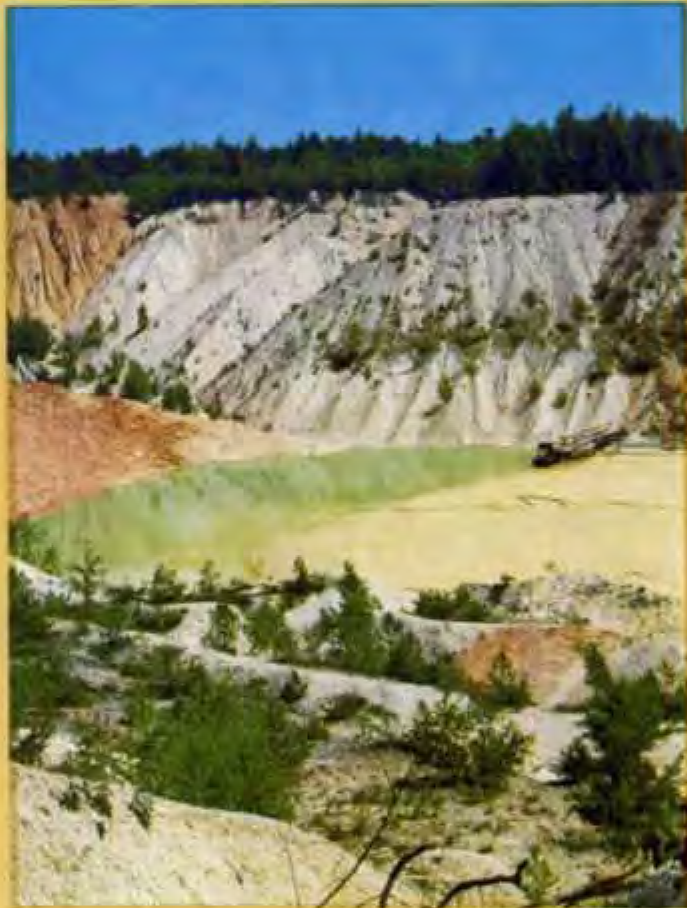
Other fault systems originated and the older ones were rejuvenated during the Saxonic tectonic interval (Malkovský 1979).

The geomorphological model: The Neoidic tectonic structure is reflected in the geomorphological division into blocks (Z. Roth, personal communication); it is presumed that the Bohemian Massif became in the latest Miocene and Quaternary a uniform platform elevation composed of blocks which were affected by autonomous movements.

a) The western part of the Bohemian Massif north-west of the Žatec-Litoměřice fault zone, between the Cheb-Domažlice trough and the Lusatian-Jílovice fault zone, is ranged to the block that can be denoted as the Saxothuringicum block (Malkovský 1979).
b) The north-eastern part of the Bohemian Massif NE of the Lusatian-Jílovice fault zone and the Kyšperk-Zábřeh fault zone belongs to the Sudetic block. It extends south-eastwards up to the Carpathian margin of the platform, far beyond the boundary of the Bohemian Massif.
c) The westernmost part of the Bohemian Massif, W of the Cheb-Domažlice trough is classed with the block of Frankenwald.
d) The central part of the Bohemian Massif belongs to the fundamental Labe-Morava block consisting of the "Bohemicum" and the northern part of the Morava block. It is limited in the W by the Cheb-Domažlice graben, in the N by the Žatec-Litoměřice, Lusatian-Jílovice and Kyšperk-Zábřeh fault zones. The southern boundary is formed by the Klatovy-Závist and Poděbrady-Železné hory fault zones. Is the SE the block extends to the Carpathian margin of the platform, viz beyond the boundary of the Bohemian Massif.
e) The southern part of the Bohemian Massif belongs to the Moldanubicum-Dyje block consisting of the Moldanubicum and the southern part of the Morava block. It is situated S of the Klatovy-Závist and Poděbrady-Železné hory fault zones and extends again to the Alpine-Carpathian margin of the platform in the SE.

Except for the fundamental Labe-Morava block, all fundamental blocks extend beyond the Bohemian Massif boundaries in the territory of the Czech Soc. Republic because they are (in contrast to the Bohemian Massif as a whole) limited by fault zones along their whole periphery.

8. Neoidic geomorphological development



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8.1 Intensive kaolinitic weathering of the Carboniferous arkoses. Open pit at Horní Bříza in the Plzeň area
Photo by J. Svoboda

The Neoidic phase of the geomorphological history of the Bohemian Massif began in fact already after the close of Hercynian orogeny by extensive denudation and peneplanation. The character of Permo-Carboniferous sediments indicates that denudation processes occurred in medium-humid and semiarid climate. The central part of the Bohemian Massif even during the early Mesozoic was a dry land affected by long-lasting denudation so that already in Jurassic time a flat relief was created in the area of the Bohemian Upland (in the sense of Demek et al. 1965). Only in Dogger the sea invaded the region of Moravia from the NW through a shallow broad depression and connected thus the Boreal region with the Mediterranean one. The Jurassic at the south-eastern margin of the Bohemian Massif was developing on the Tethydian shelf (Eliáš 1979); the character of its basal sediments shows that they filled depressions in a fairly levelled relief. The same conclusion may be derived from a lack of psephitic sediments, which provides evidence for advanced peneplanation of the surrounding mainland (Kodym *in* Buday et al. 1960). The sea flooded a well levelled earth's surface also in the limestone areas of the Moravian Karst (Koutek 1927). The beginning of the Mesozoic—Palaeogene global peneplain is also placed in this time interval. The climate was warm with humid and dry oscillations (Störr et al. 1978); at the transitions to the Upper Jurassic the landmass became drier and the climate arid.

8.1.1 Cretaceous

The Bohemian Upland together with incorporated Jurassic sediments remained dry land even in the Early Cretaceous and peneplanation and lowering of the relief continued in the whole region. Jurassic sediments of rather small thickness for the most part succumbed to intensive kaolinite-lateritic weathering and denudation (Dvořák 1956) in a hot and humid climate. Diversified relief reflected practically the differences in resistance of the rocks only; depressions developed especially in the sedimentary fillings of the Permo-Carboniferous basins.

At the surface of non-carbonate rocks a rather thick weathering mantle had developed. It was removed by denudation or washed away by the transgression of the Cretaceous sea so that only the basal parts of profiles have been preserved. The bare carbonates were exposed to intense surficial karstification, which was supported by high temperature and precipitation of above 800—1200 mm/year. The existence of karst depressions, sinkholes and pockets filled with Cenomanian sediments was proved at the surface of the Barrandian Palaeozoic limestones (Kunský 1968, Turnovec 1980) as well as of the carbonates in the Moravian Karst (Krystek 1959, Kettner 1960, Bosák 1978, etc.). At Rudice (Moravian Karst) the karstification reaches to a depth of 140 m.

Ancient pre-Miocene valleys in the same area (Lažánky valley and the lower part of the Punkva system — S c h ü t z n e r o v á - H a v e l k o v á 1958) exceed a depth of 100 m. The summit level of karst relief with the overlying Cenomanian occurs e.g. in both the Berounka-river valley and the Rudice area at altitudes of 480—500 m a.s.l. M e i b u r g (1979) ascribes the same age to the fossil weathering of Devonian limestones near Warstein in Westphalia, whose surface lies at similar elevations. A simple comparison would indicate that at many places in Central Europe no major Neoidic movements occurred since the Late Cretaceous.

Fossil karstification is not exceptional, as evidenced by the occurrences of fossil forms in the Jurassic of Poland (T y c z y ń s k a 1958) or karst features accompanying bauxite deposits in Upper Jurassic limestones in southern Hungary, dated again as Early Cretaceous (S z a b ó 1958). Preservation of karst forms proves that no climamorphogenetic change, which would lead to their destruction, had occurred before their burial (T y r á č e k 1962).

The continuation of the peneplain beneath the sedimentary cover of the Carpathian foredeep and flysch nappes was demonstrated at the SE margin of the Bohemian Massif between Ostrava, Brno and Znojmo (Z e m a n A. 1980). Intensive chemical weathering produces two types of relief. Kaolinitic residues or their root zones have been preserved predominantly on granite and gneiss plateaus and flat elevations. On the Devonian and Jurassic carbonates SE of Brno the existence of cone karst is assumed (B e z v o d o v á - Z e m a n A. 1983), which is probably an analogue of the fossil forms originated by karstification of Devonian limestones near Hranice (T y r á č e k 1962), at Supíkovice (C z u d e k - D e m e k 1970) or Přerov.

In addition to the products of chemical weathering also a system of ancient valleys has been preserved at the buried surface. They probably began to develop at the onset of the Cretaceous, as evidenced by Lower Cretaceous sediments of the "Carpathian type" found at the margin of the Nesvačilka trough near Kuřim (K r y s t e k 1972). These valleys incised into the Mesozoic—Palaeogene peneplain show the character of troughs on the sunken platform, whereas in the upper courses they are usually linked to ancient "pre-Miocene" valleys exhumed at the SE margin of the Bohemian Massif (Z e m a n A. 1980). In the Ostrava area this ancient system was obviously a precursor of deep "channels" cut into the Carboniferous underlying the Neogene filling of the Carpathian foredeep. Genesis of the valleys, more than 1000 m deep, remains inconclusive particularly as the disparity between the postulated absolute altitude of the surface and the depth of incision and the position of the base level of erosion are concerned. In the top parts of the buried relief variegated weathering residues exist attaining a thickness of up to 150 m (J u r k o v á 1959); they are also known from other parts of the Bohemian Massif.

8.2 Denuded basal weathering surface (etchplain) in the Central Bohemian Pluton in the Sedlčany area
Photo by J. Rubín

At the beginning of the Upper Cretaceous the Bohemian Upland underwent a substantial change. The area of the landmass of the Bohemian Massif existing over the greater part of the Mesozoic was decreasing in the Cenomanian and fluviatile and lacustrine deposits began to sediment in the depressions. Their distribution indicates a distinct dependence of sedimentation on the palaeorelief (M a l k o v s k ý et al. 1974). In the remaining part of the Bohemian Massif intensive weathering and denudation continued. In the Late Cenomanian the predominant part of the mainland was being gradually flooded by shallow epicontinental sea extending far into the Bohemian Massif. Higher lying parts of the original peneplain (Bílina crystalline complex, part of the Unhošť-Tursko ridge, lydite tors, the Lužice-Krkonoše and Jesenice islands and Kutná Hora crystalline complex) rose from the sea as islands, around which typical conglomerates and bioclastic limestones were deposited. The initial marine sedimentation of Cenomanian and partly of the Turonian was still dependent more on the palaeotopography than on the tectonic adjustment of the basin. The shoreline was greatly articulated because of the atectonic development of the sedimentary basin, especially in the areas of Čistá-Jesenice massif, Říčany granite, Křivoklát-Rokycany and Jílové zones, etc. (M a l k o v s k ý et al. 1974). The Cretaceous sedimentary basin obtained its definitive form by synsedimentary subsidence along faults during the Middle Turonian, when a partial transgression (M ü l l e r *in* M a l k o v s k ý et al. 1974) flooded even most of the islands mentioned above. Marine sedimentation continued during the later Cretaceous; the sea began to retreat from the eastern part of the basin during the Coniacian and in the early Santonian it left the area of the Bohemian Massif definitively.

The lithology of Cretaceous sediments suggests a levelled surface of the neighbouring landmass, only the facies of coarse-grained very thick-bedded quartz sandstones developed under the influence of tectonic activity in some source areas, in the Lužice island in particular. The uplifts enabled a mass removal of less weathered detritus, which was deposited in the north-western part of the basin (K l e i n - M ü l l e r - V a l e č k a 1980).

Cretaceous transgression is usually explained by the subsidence of blocks or parts of the land below the world-ocean level. This explanation, however, can hardly be applied to the worldwide Cenomanian transgression (supposing a roughly constant amount of water on the planet) which flooded extensive parts of continents that experienced the most varied geological history and occupied various tectonic positions. The predominantly atectonic development of older Upper Cretaceous complexes, controlled rather by pre-Cenomanian relief than by subsidence movements is also in variance with the above interpretation.

The oscillation character of transgression, the nature of basal sediments and the configuration of the sedimentary basin in its initial stage indicate that other causes might have been involved. Recently, there is a tendency to explain the Cretaceous transgression by the rise of the world-ocean level and this, in turn (consistently with an abrupt decline towards the end of Cretaceous), by expansion and following contraction of oceanic ridges. This concept, of course, does not exclude the influence of local tectonic movements or tectonic control of local basins or their parts.

In southern Bohemia drained at that time to the S and SE, a shallow limnic basin developed towards the end of the Cretaceous, in which Senonian freshwater sediments were deposited. The development of the basin provides evidence that the Cretaceous transgression never crossed the Central Bohemian threshold, which even before acted as the main watershed of the Bohemian Massif. The shallow basin was of a through-drainage type and lenient streams of lowland character brought the kaolinitic weathering residues into it at the beginning. The rapid rate of subsidence or the upheaval of the Bohemian Massif indicating the retreat of the Upper Cretaceous sea (or probably acceleration of the lowering of the world-ocean level, or climatic change?) induced a rejuvenation of streams, increase in the transportation capacity and thus a supply and deposition of coarser clasts of kaolinitic sandstones and conglomerates. During the Senonian, presumably a little later than in the Bohemian Cretaceous basin, sedimentation was interrupted in the South Bohemian basins, and since the early Santonian the whole Bohemian Massif has been a landmass again.

8.1.2 Tertiary

In the parts of the Massif non-flooded by the sea, continental development and denudation continued from the Cretaceous to Paleogene, but under somewhat changed conditions. The planation surface originated usually by the conjunction of pediments and of cutting plain with outjutting outliers and knobs of more resistant rocks. It seems more appropriate therefore to characterize the Paleogene planation surface rather as pediplain than as typical peneplain (D e m e k et al. 1965). At the margins of the Cretaceous basin, especially in the SE, the ancient pre-Cenomanian peneplain was partly exhumed and remodelled. Towards the end of the Paleogene the development of the global Mesozoic—Paleogene peneplain culminated, the Bohemian Massif being the constituent part of it. It displayed a very flat relief and did not reach higher altitudes above the sea level (about 200 m — K o d y m , Sen. *in* B u d a y et al. 1960).

Paleogene planation was accompanied, mainly at the beginning by intensive kaolinization. The released SiO_2 formed the silicified layers and crusts (duricrust, silcrete). It is assumed (R o t h - H a n z l í k o v á 1982) that also a part of SiO_2 in menilitic shales was produced by this process. Very typical is the silicification of the upper part of the sedimentary complexes culminating by the formation of a quartzite horizon (Třeboň basin and most of the "dinas quartzite"

8.3 Map of pre-Miocene valleys at the south-eastern margin of the Bohemian Massif (A. Zeman 1980)
1 — crystalline complex and Culm sediments in sandy-shaly development; *2* — sandstones and claystones of the Carpathian Flysch Belt; *3* — Neogene sediments; *4* — Quarry sediments in the Upper Moravian Basin; *5* — Carpathian foredeep with relics of glacigenic sediments; *6* — presumed direction of pre-Miocene valleys on the surface of the autochthonous basement of the Carpathian foredeep and Flysch Carpathians; in NW they link on partly exhumed valleys of the south-eastern margin of the Bohemian Massif; *7* — downwarp of the platform — line of overthrust of nappe fronts on the Carpathian foredeep

8.4 Denudation forms on Upper Cretaceous sandstones, Tiské stěny Photo by J. Rubín

8.5 Earth pillars, called "Pokličky" in the Kokořín valley, Bohemian Cretaceous Basin. Weathered-out upper Turonian sandstones Photo by J. Svoboda

in the North Bohemian basin) in the top part of the profile. In the tropical climate of the Palaeogene (mean temperature 20—30 °C in the warmest summer month — S t ö r r et al. 1978) the karstification of carbonates continued. Under favourable conditions the development of the cone karst (tower karst in places) was nearly accomplished, as evidenced by the forms on Devonian limestones hidden beneath Neogene sediments at Hranice in Moravia (T y r á č e k 1962) and on the Jurassic and Devonian limestones SE of Brno (B e z v o d o v á - Z e m a n A. 1981). The formation of the oldest karst cavities in the Bohemian karst is also placed in this period, before the Miocene tectonic events (L y s e n k o - S l a n č í k 1981).

During the Palaeogene the streams of the drainage pattern in the Bohemian Massif discharged their waters into three basins. Central and south-western Bohemia was drained into the North Bohemian basin and from there farther northwestwards into the Leipzig bay of the Oligocene sea in the German-Polish basin, which encompassed the Bohemian Massif in N and NE. According to K o p e c k ý A. (1972) the predominant part of the Massif belonged to this drainage area. Southern Bohemia was drained into the South Bohemian basins and farther into the flysch sea to the S and SW. The streams of northern and eastern Bohemia and whole Moravia discharged their waters into a vast flysch sea in the E. Part of it was the Nesvačilka-Vranovice estuary, extending to the Subsilesian-Ždánice sedimentary area. Although there are relatively few reliable data available, it is obvious that persisting planation was accompanied by tectonic block disintegration of small intensity.

There is no evidence for major differentiated tectonic movements that would disturb the mature peneplain, on which only the most stable products of intense weathering — quartz and kaolinite — have been preserved. Shallow lacustrine basins developed later between the early and middle Oligocene but their origin had nothing in common with the present-day fault system. Compared with the younger, Miocene basins, the older ones were substantially more extensive. In the Oligocene through-drainage lakes chiefly psammitic sediments were deposited, like the Staré Sedlo Formation in the Cheb and Sokolov Basins, the Lipnice Formation in the Třeboň basin, and their stratigraphic equivalent — the Podbořany Sands. Relics of these sediments also occur beyond the limits of the present-day basins, e.g. along the elevated margins of the Karlovarská vysočina Highland, the Krušné hory Mts., Chlum nad Ohří, beneath the Doupovské hory stratovolcano and in the Podbořany area. Sandy sediments near Abertamy in the Krušné hory Mts. are probably also correlative with them. From the Třeboň basin they extend to the S and SE into Austria. The highly varying lithology indicates that in the basins sedimented on the one hand the washed weathered material transported over short distances from the close neighbourhood, and well-worn deposits of long streams, on the other. A substantial part of the Bohemian Massif was drained into sedimentary basins having the character of shallow through-drainage lakes. One of the Oligocene basins was in the Plzeň area, whose through-drainage lakes were probably connected by streams through the Rakovník area with the environs of Žatec. This initial stage of Tertiary sedimentation was interrupted in the late Oligocene and a greater part of deposits succumbed to denudation.

After the early Savian phase, between the Palaeogene and Neogene, the dynamics of tectonic activity had risen in the Neogene; in contrast to earlier opinions, two phases have been distinguished in it (M a l k o v s k ý et al. 1974): the older (Aquitanian—Burdigalian) is characterized by tectonic disintegration of the Palaeogene peneplain, and the younger (lower Helvetian—lower Badenian) by a progressive subsidence of large parts of the Bohemian Massif below the level of world oceans.

The first phase opens the neotectonic stage in the history of the Bohemian Massif (K o p e c k ý A. 1966); the tectonic movements are accompanied by intensive volcanism and formation of lakes. The Doupovské hory stratovolcano separated the Sokolov basin from the North Bohemian basin and České středohoří Mts. caused the separation of the Žitava basin (M a l k o v s k ý et al. 1974). According to the most recent interpretations, the origin of the North Bohemian basin might be the result of the volcano-tectonic subsidence, viz. gravitational sinking of blocks into spaces in the upper mantle vacated by the ascent of volcanic material to the surface (M a l k o v s k ý 1980).

Typical of the second phase is the sedimentation of lacustrine and marine deposits. This sedimentation was a result of the subsidence of a major part of the Bohemian Massif, which enabled the lower Badenian sea to penetrate through ancient valleys far into the Bohemian Highland and into the South Bohemian basins. The different character of Miocene lacustrine sedimentation in southern Bohemia is accounted for by occasional sea ingressions.

The development of Neogene basins appreciably affected the development of the drainage pattern. The North Bohemian basin was fed by rivers draining large portions of central and south-western Bohemia, as evidenced by relics of Miocene sediments in a belt extending from Klatovy across Plzeň to Rakovník, and from Prague to Rakovník. The basin was drained northwards probably in places of present-day Jirkov. The divide of the South Bohemian threshold separating the drainage area of the Alpine-Carpathian foredeep from the remaining part of the Bohemian Massif still exists, but in the W it extends beyond the borders of the Republic (M a l k o v s k ý et al. 1974). The rivers flowing from S and SE carried their waters into the Žitava basin, and the rivers draining the area S of the South Bohemian threshold emptied themselves into the South Bohemian basins.

At that time the Bohemian Massif was losing its geomorphological monotony and due to continuing tectonic disintegration became divided into structurally and morphologically articulated areas. The diversification of the relief led to the

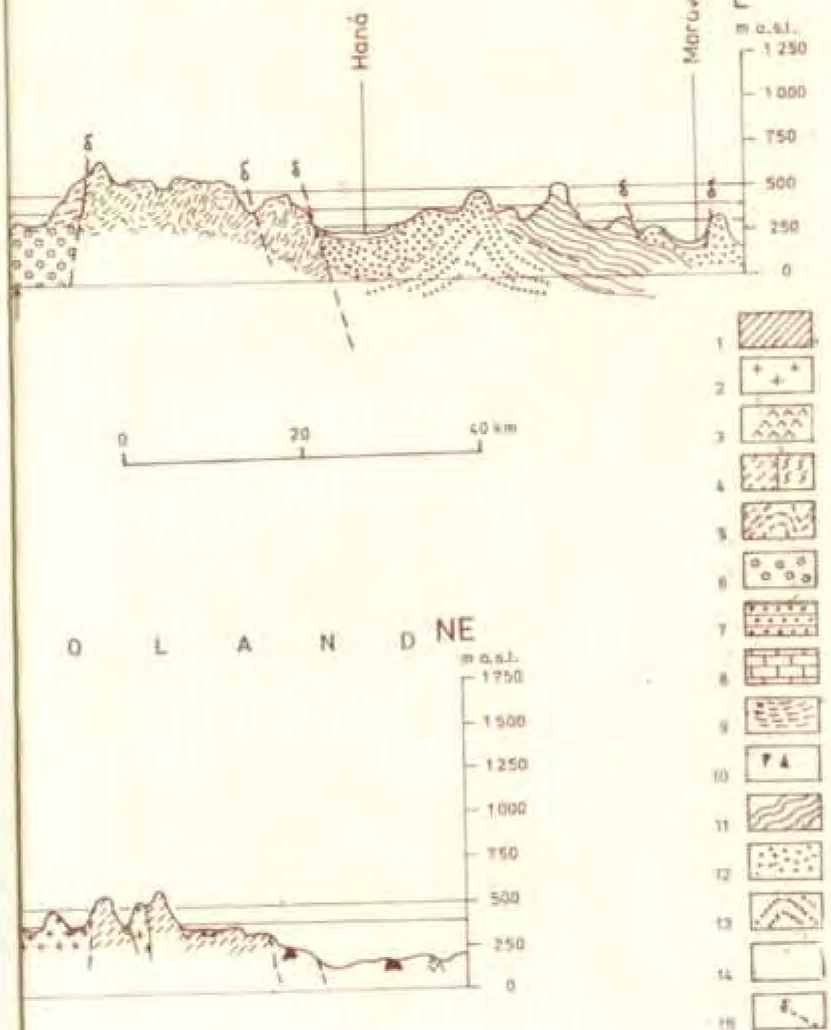
8.6 Quartzite boulders originated by disintegration of silcrete, Rokle near Kadaň
Photo by J. Rubín

destruction of a thick weathering mantle and to its redeposition into the freshwater basins or adjacent seas. The Mesozoic—Palaeogene peneplain assumed the

8.7 Fossil karst forms on the surface of Devonian limestones, Hranice in Moravia
Photo by J. Tyráček

Pl. V

West Carpathians



character of denuded stripped basal weathering plane. In the eastern edge of the Bohemian Highland the weathering residue was also removed by abrasion activity of the Miocene sea, although no typical abrasion platforms had developed there.

In the Carpathians, the early Savian phase provoked large-scale movements and shifting of nappes towards the NW. At the beginning of the Miocene, part of the Outer Carpathians emerged above the sea level and the folded mountain range was gradually levelled down (e.g. the neighbourhood of Hranice — Demek et al. 1965). Kaolinitic products about 12—20 m thick were developing on sandstone complexes. The lower Miocene planation surfaces have also been indentified in the Vizovická Highland (Zeman A. et al. 1977) whereas in the Vienna basin they form the substratum of its Neogene filling. These planation processes were probably synchronous with those occurring in the Bohemian Highland, where they created the so-called post-basalt denudation level (cf. Král 1976).

The eastern margins of the Bohemian Highland facing the Carpathian foredeep, were invaded by the Miocene sea, which left its sediments on platforms and in deep pre-Miocene valleys. Owing to post-sedimentary tectonic movements some sediments were raised to altitudes of up 600 m a.s.l., young uplift being evidenced by their denudation relics found in the Nízký Jeseník Hills.

Sand and gravel deposits cumulated at that time are correlative with abrasive processes that occurred in a narrow belt along the Bohemian Highland (Demek et al. 1965) and at the south-eastern margin of the Carpathian foredeep (surf zone facies around the islands of the Hranice Devonian, traces of marine abrasion in the Pavlovské vrchy Hills).

The south-eastern margin of the Carpathian foredeep was formed by the Pavlovské vrchy and Chřiby Hills, summit parts of the Bílé Karpaty Mts. and to a small extent by the Moravsko-slezské Beskydy Mts. Sedimentation was closed in the Carpathian foredeep in the youngest Styrian phase between the early and late Badenian, when the marginal nappes were moved. The sea receded from the foredeep and practically the entire territory of the Czech Soc. Rep. became dry land. In the Bohemian Massif this movement was responsible for the separation of block mountains at the periphery of the Bohemian Highland (Kunský 1968), although the most intensive uplifts occurred much later (Kopecký A. 1972, Malkovský et al. 1974, Malkovský 1979). In the Carpathians, the Flysch Belt was upheaved and denudation processes were revived. According to Kopecký A. (1972) these movements opened the neotectonic stage there, during which the fundaments to the modern morphostructures were laid. As a result of intra-Badenian movements, the sedimentary area of the Vienna basin originated between the megaanticlines of the Chřiby, Ždánický les, Bílé Karpaty and Malé Karpaty ranges. The lower Miocene does not represent therefore a genetic and tectonic component of the basin filling but,

8.8 Morphology of neovolcanites of the České středohoří Mts. — Porta Bohemica — Labe river valley
Photo by J. Rubín

from this point of view, belongs to its basement. In the Pliocene, sedimentation still continued and movements on faults were revived.

Towards the end of the Badenian, in the dissected relief of the Bohemian Highland tht foundations were laid to the modern drainage pattern, when the ancient pre-Miocene valleys were again employed by many streams. The uplift of mountain ranges, especially in the NE and SW prompted extensive destruction of the Mesozoic-Palaeogene peneplain and its remodelling into the etchplain.

The fall of moldavites in southern Bohemia and in Moravia, which caused the origin of an index horizon, is thought to have occurred in this period. In southern Bohemia terrestrial unsorted sediments characteristic of downwash and flush sedimentation, were deposited (Vrábeč Member, rel. alt. 110 m above the river Malše — Žebera 1967b). The Vrábeč Member was dated with the use of moldavites at 14.7±0.7 million years (Gentner et al. 1967). This member links up with the Domanín Formation, which is younger than lower Badenian and corresponds to relatively little known third Miocene phase (Malkovský et al. 1974). In north-eastern Bohemia sediments of N_1 level, rel. alt. 120—140 m (Prosová 1974) are most probably of the same age. The key locality for the dating of fluvial deposits in the piedmont of the Krkonoše and Orlické hory Mts. lies near Železný Brod in the Jizera river valley. According to Konzalová (1973), those sediments (rel. alt. 130—140 m) are Miocene in age. In general, the gravel relics at the north-eastern margin of the Cretaceous basin between the rivers Jizera and Úpa and the piedmont of Orlické hory Mts. at the altitudes of 120—160 m, show the character of remains of vast proluvial-fluvial sediments.

In central Bohemia the relics of fluvial sediments, particularly in the Berounka river valley between Karlštejn and Sulava (rel. alt. 120—140 m) and at the junction of the Berounka and Vltava rivers (rel. alt. 160—180 m) correspond to the so called Klínec stage and are placed in the upper Miocene.

The Prague depression was at that time an area of confluence of several rivers and streams coming from the NE, SW and S. The rocks from the Barrandian, Mt. Kozákov, the Krkonoše Mts. and their piedmont as well as from the Moldanubicum of southern Bohemia lend support to this contention.

Towards the end of the Miocene in the area of the Bohemian Highland the drainage pattern was established and the range of the Českomoravská vrchovina Highland became a constituent part of the European watershed. Fluviatile sediments of that period were mostly destroyed, and only small relics can be found at rel. altitudes of (110), 120—140 and (160 m). Southern Bohemia was incorporated into the Vltava-Labe drainage basin after the Novohradské hory Hills had been uplifted.

The same situation developed at the south-eastern margin of the Bohemian Massif. Streams flowing down across the Carpathian foredeep deposited their load in depressions and emptied into the sedimentary area of the Vienna basin. In the sectors within the Bohemian Massif they usually followed depressions of ancient pre-Miocene valleys. Their sediments are known from the neighbourhood of Znojmo at rel. altitudes of 100—130 m, where Čtyroký (1980) places them in the Badenian—Pliocene time span. The moldavite-bearing gravels near Dukovany on the Jihlávka river (rel. alt. 110—130 m) are dated by Čtyroký (op. cit.) as late Badenian—Sarmatian. Relics of gravel deposits in the Jihlava river valley and in Brno (Svitava river valley — elevat. Fredam) are at the same relative altitude; they correspond to the late Miocene, too.

The relatively constant altitudes of the relics of Upper Miocene fluviatile and fluviolacustrine sediments in different parts of the Bohemian Massif indicate that only some sectors of the Massif were affected by the post-Miocene tectonics, particularly the peripheral mountain ranges and some basins and depressions like the Cheb basin (Vildštejn Clays) or the Upper Moravian basin (variegated series).

8.1.3 Quaternary

In the Quternary the processes influencing the configuration of the relief changed radically. The climatic fluctuations, which represent the basic factor controlling the geological events in the Quaternary, intensified, being responsible not only for glaciations and oscillations of the sea level (and thus the base level of erosion) but also for erosion, denudation, or sedimentation. In the area of the Bohemian Massif, located in the periglacial zone, the Quaternary period represents a continuous succession of most varied geological events, caused by multiple alternation of erosion, sedimentation and soil-forming cycles (L o ž e k 1973). Their effects, enhanced by the geographical position of the Massif during the cold intervals between the continental ice sheet in the N and mountain glaciers of the Alps, as well as in the transition zone between the oceanic climate in the W and the continental in the E, resulted in intensive modellation of the relief. Although the fundamental features of the region developed in earlier periods, the present relief of the Bohemian Highland and the West Carpathians is for the most part a product of the Quaternary morphogenetic processes.

At the onset of the Quaternary, better to say at the Tertiary—Quaternary boundary interval, which period was until recently considered as latest Pliocene, the climatic fluctuations were not so striking. Even though this assumption is

8.9 Pyroclastics of Quaternary volcanic rocks, Komorní hůrka near Cheb
Photo by J. Rubín

partly based on restricted evidence, it is supported by deviations from the classical Quaternary forms, such as shallower channels of streams meandering and anastomosing freely over flat plains, different lithology of sediments, minimum vertical intervals between individual levels of the upper terrace group, formation of different soil types, and a lack of typical periglacial sediments.

Three principal opinions on the position of the Pliocene-Pleistocene boundary exist. According to the first one the boundary is placed before the Mindelian glaciation of the Alps and the Elster glaciation of the North German Lowland. Palaeomagnetically it would correspond to the inversion between the Brunhes and Matuyama epochs, i.e. to the radiometric age of about 0.69 Ma (recently mostly accepted for the Old—Middle Pleistocene boundary). The second interpretation assumes the Plio-Pleistocene boundary to follow the base of Calabrian, which would be palaeomagnetically coincident with the Gilsa event. The radiometric age of its base (of ca. 1.79 Ma) agrees with the resolution of the 18th International Geological Congress in London. According to the third alternative the boundary is placed at the base of the Villafranchian, i.e. between the Astian and Piacenzian with typical faunas of lower Villafranchian and so-called Sourillon. Palaeomagnetically, it includes the upper half of the reverse Gilbert event or the base of normal Gauss epoch, some 3.4—3.5 million years ago. Towards the Pliocene the fluctuations are less contrasting, and the transition interval shows minor climatic changes. This fact is the main cause of difficulties in precise determination of the Plio-Pleistocene boundary; the previous opinions on a continual cooling of the climate from the Tertiary to the Quaternary is not valid. The oscillatory character does not also permit to regard this boundary as a single episode. The problem concerning the stratigraphic position e.g. of the Vildštejn Formation in the Cheb basin or of the variegated series in the Upper Morava depression are a direct result of this uncertainty. Quaternary volcanism in western Bohemia and northern Moravia falls in this period. The prominent high terraces of the Labe river at Stříbrník near Ústí nad Labem bearing the proboscidian *Archidiskodon meridionalis* are ranged to the earliest Pleistocene, too. However, no relevant stratigraphic conclusions can be deduced from this fact because the conditions of the find are unclear.

Towards the end of the Tertiary, the predominant part of the Bohemian Massif was a relative monotonous peneplain. Nevertheless, the peripheral mountain ranges and the highlands and uplands in the interior were morphologically evidently well defined, although the final uplifts of some blocks convincingly occurred as late as Quaternary (Krušné hory Mts. — M a l k o v s k ý 1980) and the uplift of others is presumed (V y s k o č i l - K o p e c k ý A. 1974). Even if the morphological conditions for more intensive river activity existed there, the supply of coarse clastic material was small on account of weak mechanical weathering and insufficient solifluction. The meandering streams redeposited therefore the older deposits and the weathering residue, thus producing predo-

8.10 Loess and loamified debris (of early Pleistocene age, in two lower thirds with fossil soils) on a Jurassic klippe near Kurovice (Moravia) Photo by P. Havlíček

minantly fine-grained accumulations of the highest terraces of great thickness and areal extent.

At the eastern margin of the Bohemian Massif the braided streams, owing to a higher relief of the Českomoravské vrchovina Highland, carried coarser clastics and deposited them on the flat plains of the Carpathian foredeep in the form of extensive flat gravel cones (older gravel sheet — Zeman A. et al. 1980). Sedimentary areas of some basins and lakes survived to the earliest Pleistocene. The sequences dating from that time include the Vildštejn Formation (up to 100 m thick) in the Cheb basin; upper part of the variegated series in the Upper Morava depression (Macoun - Růžička 1967); sediments of a local basin near Kurovice (Central Moravia — Kovanda et al. 1982); probably equivalent fluviolacustrine sediments in the Zdounky trough, in the Hradiště trough (southern Moravia — Havlíček P. 1980) and in the projections of the Záhorská lowland, and the preglacial sediments (Macoun 1980) preserved at the base of the Quaternary in depressions and tectonically sunken valleys of the ancient stream pattern in the Opava area. At the foot of mountain ranges (Krušné hory, Beskydy and SE margin of the Chřiby) the oldest accumulations of proluvial sediments are deposited grading downstream into the highest terraces.

In Silesia and the Cheb basin the manifestations of the third youngest neovolcanic phase faded out (Kopecký A. *in* Svoboda et al. 1966, Síbrava - Havlíček 1980). The neovolcanites of the České středohoří and Doupovské hory Mts., especially isolated bodies, were succumbing to destruction, slope deposits were accumulating, and platforms with a complex inner structure were forming at their foot (Říp Hill).

In warm periods, the oldest soil types developed being either of illimerized brown-earth type (brownlehm), or ferretto type, and the last terra rossa soils (Ložek - Prošek 1957). At the surface of limestones, karst pockets with complex fillings were forming synchronously.

The hypothesis on the existence of major lakes in central Bohemia (Žebera *in* Svoboda et al. 1966) and in the Říp area (Žebera 1972), which implies a fundamental change of ideas on the history of the interior of Bohemia, must still be verified.

Only later, during the typical Early Pleistocene the rivers began to cut their beds deeper below the level of the planation surface, owing to the increasing

8.11 Exhumed subsurface part of neovolcanic diatreme with a typical foot platform, Říp Hill Photo by J. Rubín

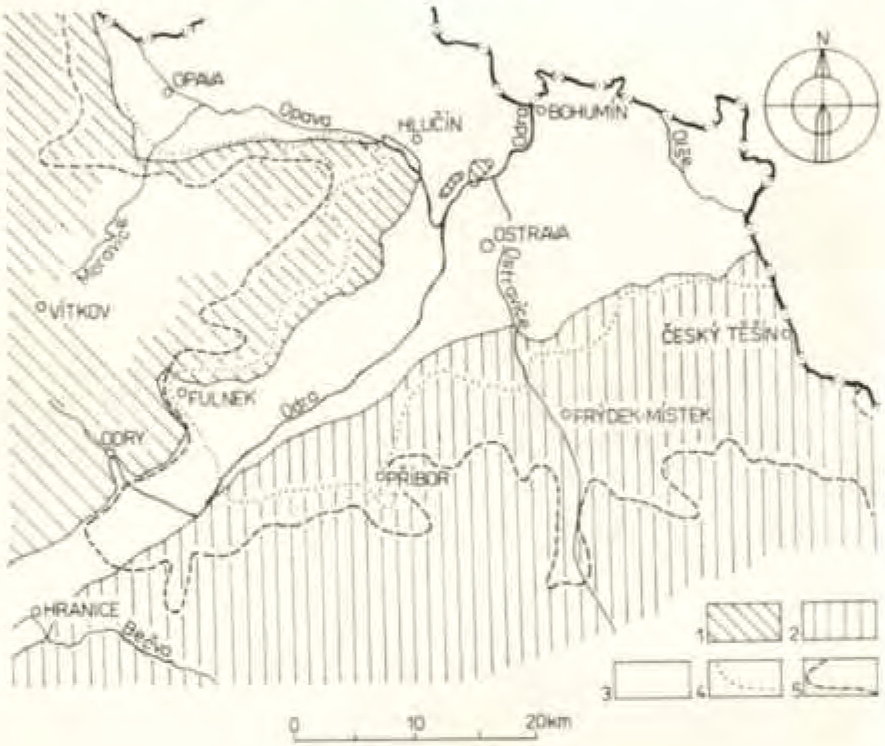
8.12 Exposure in the 100 m terrace of the river Ohře palaeomagnetically dated at 1.7 Ma, with typical Ca-horizon at the base of a relict ancient soil, Vysočany Photo by J. Tyráček

climatic oscillations, fluctuations of the level and probably also to the slow upheaval of the Bohemian Massif, forming thus a typical "Quaternary valley cut". Intensive frost weathering in cold intervals supported the mass wasting of the rock massifs and rock debris was transferred under gravity, mainly by solifluction, into the stream valleys, reworked in the water environment and laid down in the form of terraces. On the platforms of the Carpathian foredeep and in the Vyškov Gate the rivers deposited the younger gravel sheet (Zeman A. et al. 1980) and probably the stratigraphically equivalent high terraces in the Upper Morava depression, in the Moravian Gate and at the foot of the Nízký Jeseník and Beskydy Mts.

The network of streams dissected the flat relief and the landscape topography became more varied. A higher relief energy and a more differentiated character of hilly land was typical of the regional units that originated by intensive selective erosion near the local base levels of erosion, as for example, the marginal parts of the České středohoří Mts., where even subsurface parts of Neoidic volcanoes have been exposed. In the mountainous and hilly areas the first phases of cryoplanation processes set on under the influence of periglacial climate and embryonic forms of frost cliffs appeared on steeper slopes. Solifluxion and sliding phenomena were intensive. In warm periods strongly weathered soils of braunlehm type developed on loess, and terra fusca and/or ferreto formed on carbonate rocks (Smolíková - Zeman A. 1982). Travertines were forming at suitable places (Kokory).

8.13 Cryogenic features at the surface of early Pleistocene fluviatile sediments, Brno-Černovice Photo by A. Zeman

During the G/M interglacial the Drahany neotectonic phase affected the area of the Carpathian foredeep and brought about a change in the stream pattern (Zeman A. 1967, 1971). Šibrava (1981) connects with this phase the



8.14 Map showing the extent of continental glaciation in the Odra area (according to V. Šibrava *in* J. Macoun et al. 1965)
1 — Culm of the Bohemian Massif; *2* — flysch of the West Carpathians; *3* — Neogene of the Carpathian foredeep; *4* — inferred boundary of Elster glaciation; *5* — inferred boundary of Saale glaciation

formation of depressions and overdeepened valleys in the North European Lowland and in Austria, and assumes that these movements preceded the Brunhes/Matuyama inversion.

At the beginning of the Middle Pleistocene, which is at present placed in the Günz—Mindel interglacial, pelitic and psammitic sediments were deposited in floodplains and oxbow lakes (Přezletice) and karst pockets were being filled in (C 712, cave IV in the Bohemian Karst) in the warm humid climate.

8.15 Moravian Karst, Ostrov, sinkhole near Balcarka Cave Photo by J. Rubín

The following Mindel glacial caused changes in the development of some sectors of the Bohemian Highland. The Elster ice-sheet penetrated into northern Bohemia and northern Moravia, leaving behind its glacial deposits. Ice-dammed lakes were formed in front of the continental glacier. At the time of maximum extent of glaciation in northern Bohemia, the melt water flowed through the Jitrava saddle into the Ploučnice-river valley. An extensive through-drainage lake developed in the Upper Moravian depression and a similar one in the Třeboň basin. The formation of river terraces continued both in Moravia and Bohemia; the channel of the river Vltava was transferred to the east of Říp Hill and at its foot a lake probably originated. A minor lake basin was impounded by a landslide in the Bílina river valley near Teplice, and another one on the river Labe near Debrné. At the foot of hill slopes proluvial deposits accumulated at a great thickness; today their relics cover the watersheds in the areas at the foot of the Krušné hory and Beskydy Mts. Rockfalls were frequent on steep slopes

Towards the end of the Mindel the ice sheet retreated, leaving behind relict lakes (Opava—Hlučín, Opava—Oldřichov and Stonava lakes), which were rapidly

8.16 Glaciofluvial sediments of Elster glaciation in the basin of the river Ploučnice, south of Jitrava saddle Photo by A. Zeman

8.17 Rocky outcrops of "tors" type on exfoliation dome, Petrovy kameny in the Krkonoše Mts. Photo by J. Rubín enough filled with clay, sand and organic matter. The lakes in the Upper Moravian and Třeboň basins ceased to exist and a normal system of younger terraces developped in their filling. Gravels of the older accumulation of the Main terrace were laid down by Moravian rivers as well as their stratigraphic equivalents in the Bohemian Massif. Mindel loesses sedimented in the Prague depression (Sedlec, Letky, Žalov) and in Brno depression (Červený kopec).

In the warm Mindel-Riss interglacial strongly weathered soils developed and paludal organic sediments were deposited (Muglinov, Skřečoň, Dolní Lutyně). Some lacustrine sediments and peats (Stonava) and travertines (Tučín, Želatovice) belong obviously to its younger warm phase. Rivers already cut their channels to the level of the modern floodplains.

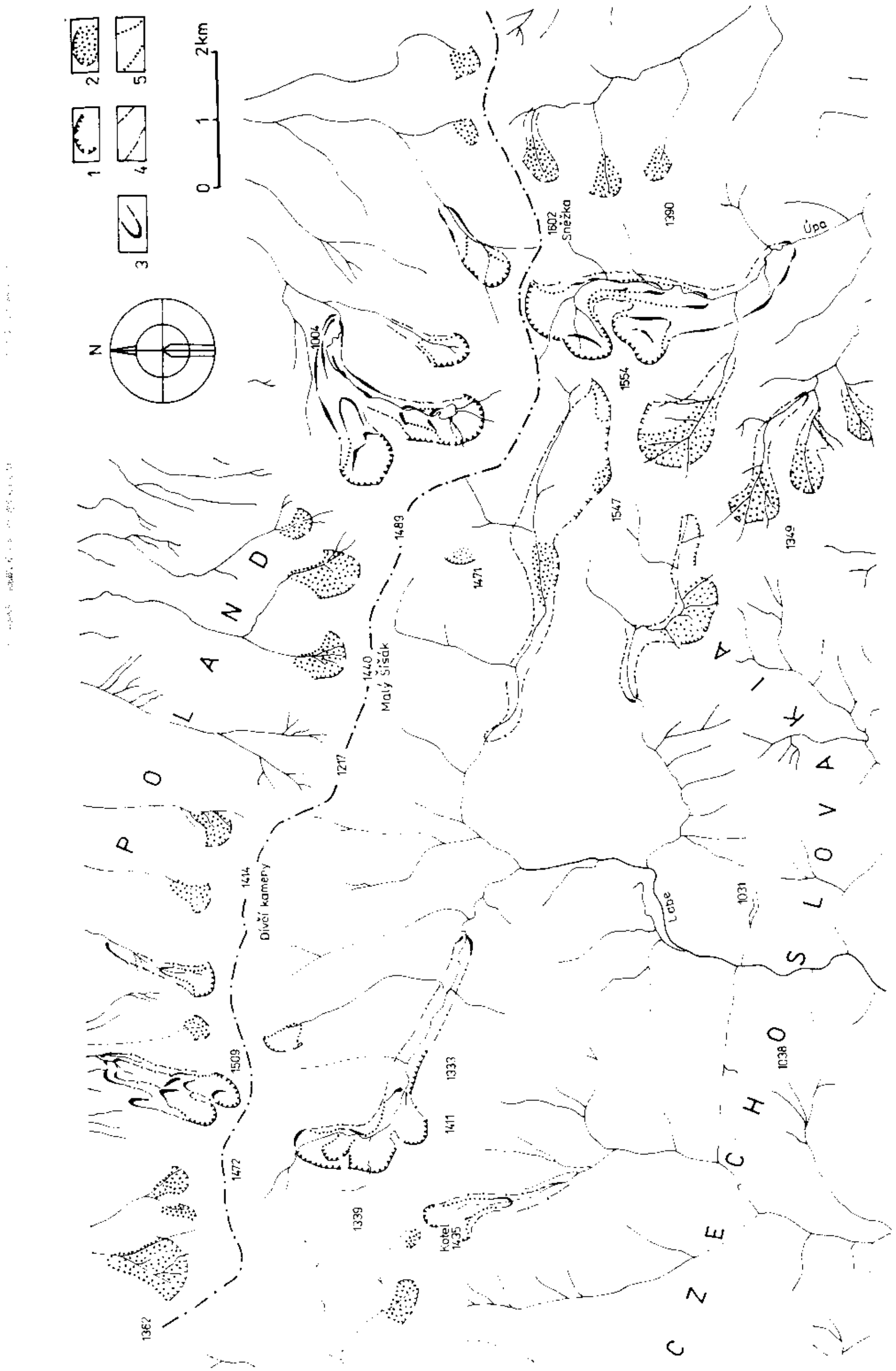
The following cold Riss interval caused reinvasion of the Nordic ice into the Ostrava region. Simultaneously with its approach, the younger accumulation of the Main terrace was deposited.

The ice-dammed lake covered virtually the whole Odra part of the Moravian Gate and its impounded waters flowed through the Poruba Gate into the Danube drainage area. It is the period of drastic hydrographic changes. The river Odra with its tributaries flows southwards into the Black Sea, the Ohře transfers its channel from the Bílina valley to the present course, and the Morava begins to deposit first terraces in the Hradiště trough, (although it had moved from the Vyškov Gate probably earlier). Towards the close of the Riss the Morava migrates from the Senice lowland north-eastwards, and the junctions of the Dyje with the Jihlava and the Svratka also move. At the end of the Riss, wast through-drainage lakes extended in the Dyje-Svratka depression and Lower Morava depression, which communicated through the Dolní Věstonice Gate. Denudation relics of sandy-clayey lacustrine sediments overlie today the Riss terraces (Z e m a n A. et al. 1980).

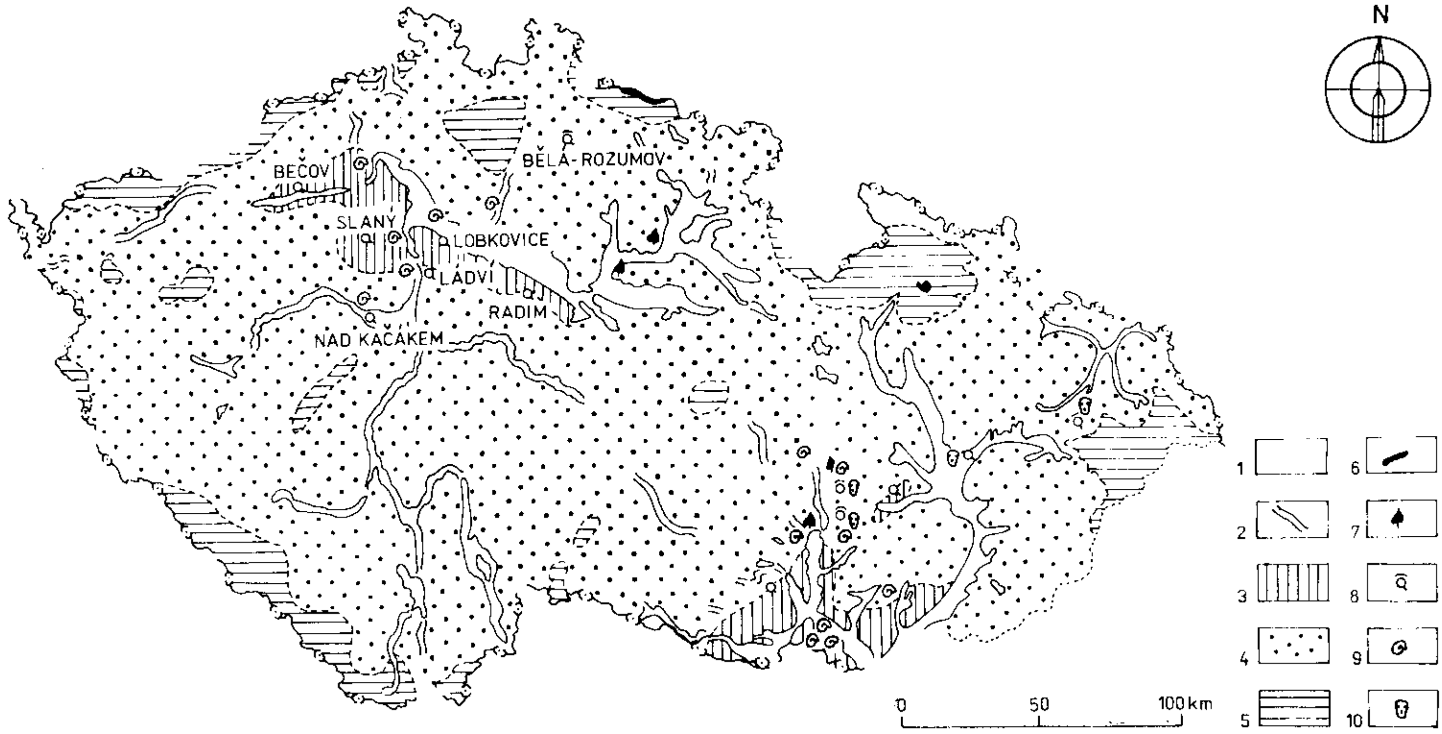
The rivers of the Bohemian Massif deposited the group of lower terraces. The river Labe leaved the Urbanice Gate and moved its channel to the S. At the foot of mountain ranges proluvial sediments cumulated, forming extensive outwash fans and dry deltas. The České středohoří succumbed to intensive destruction; accumulations of slope deposits around the exposed pipes and feeders formed striking volcanic pseudocones. In the hilly areas the cryoplanation process and formation of pediments, frost cliffs, pseudocirques, and boulder fields continued. Loess sheets and drifts in sedimentary areas levelled depressions in the bedrock creating a characteristic slightly undulated loess relief.

The extension of the ice sheet up to the foot of the Krkonoše Mts. caused mountain glaciation of this range.

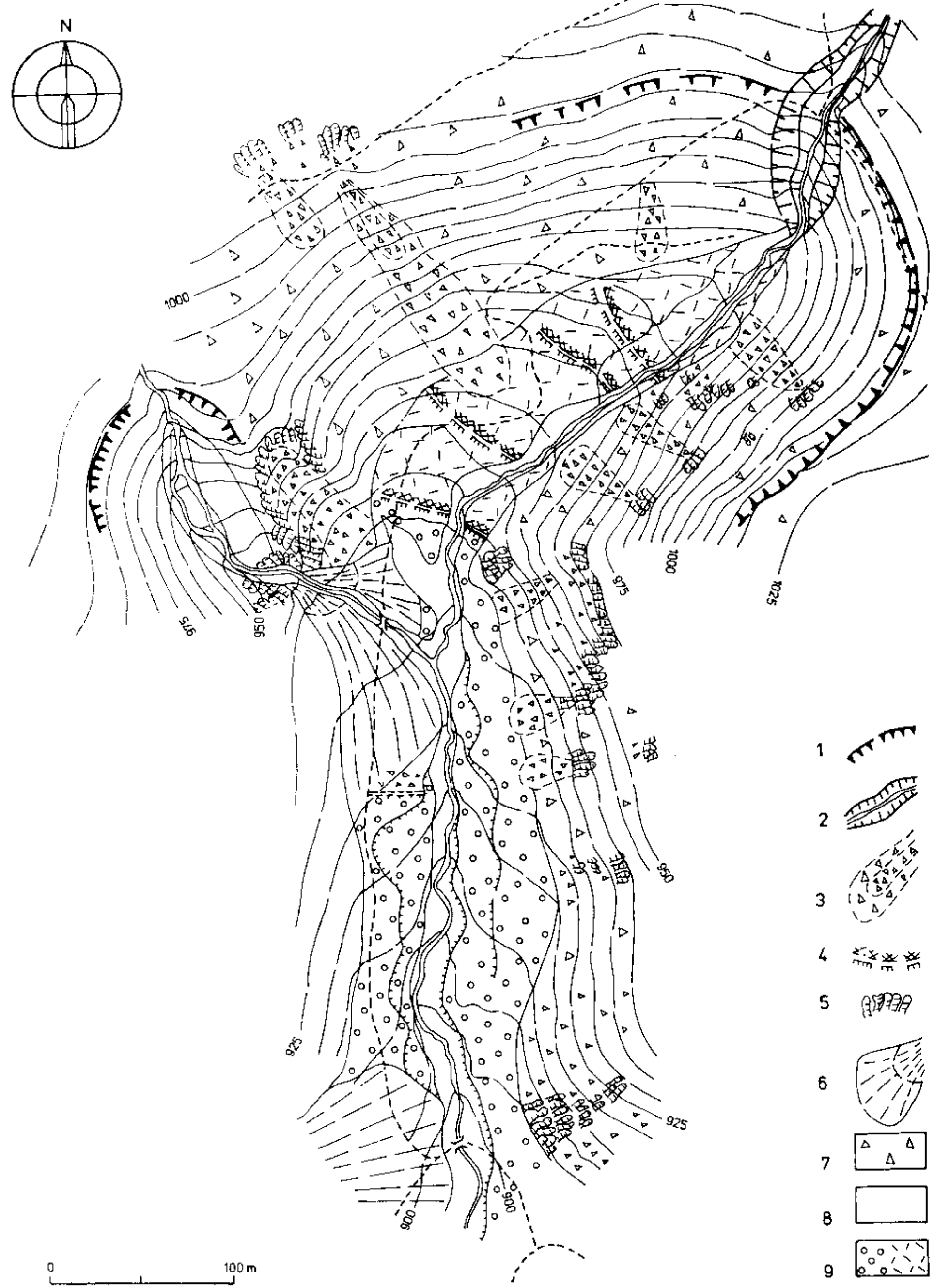
The R/W interglacial with average annual temperature of ca. 13 °C was distinguished by the development of soils of parabrown-earth or chernozem type, and deposition of fresh-water carbonates. In the floodplains the rivers deposited flood loams and abandoned channels and oxbow lakes were filled in. Favourable cli-



8.18 Map of mountain glaciation of the Krkonoše Mts.
1 — Cirque; *2* — nivation depression; *3* — moraine; *4* — extent of Riss glaciation; *5* — extent of Würm glaciation



8.19 Territory of the Czech Soc. Republic in R/W interglacial stage (A. Zeman, orig.)
1 — surface of floodplain and floodplain soils; *2* — floodplains in canyon-like reaches of river valleys; *3* — areas with a predominance of parabrownerde; *4* — brown earths and parabrownerde; *5* — mountain soils and areas with podzols (depending on substrate); *6* — stony syrosem soils; *7* — palynologically evaluated floral finds; *8* — Middle Palaeolithic (R/W interglacial and early Würm, when true Moustérian was developing); cave locality marked by a semicirclet above symbol; *9* — interglacial associations of Banatica fauna; *10* — finds of *Homo sapiens neanderthalensis*



8.20 Cirque below Mt. Klínovec (F. Králík 1969, orig.)
1 — cirque limits; *2* — young erosion gully; *3* — stone and block streams; *4* — rampart of passive moraine; *5* — rocky outcrops; *6* — outwash cone; *7* — loamy-stony debris; *8* — floodplain; *9* — sandy gravel of higher terraces

8.21 Boulder field, Čertova stěna in the Vltava-river valley Photo by J. Rubín

8.22 Cirque lake, Čertovo jezero in the Šumava Mts. Photo by J. Rubín

mate also supported the evoluiton of Man; the river valleys and caves became relatively densely populated.

In the Last Glacial the continental ice extended again southwards and the last intense growth of mountain glaciers took place in the Alps. Mountain glaciers also occurred in the highest parts of the Krkonoše Mts. (snowline at 1200–1500 m), the Šumava Mts. (snowline at 1000–1100 m a.s.l.) and the Jeseníky. Average annual temperature varied about ±3 °C.

In Czechoslovakia the Last Glacial is the most thoroughly investigated part of the Pleistocene, thanks to completely preserved loess covers in the areas of Prague, Litoměřice, Kutná Hora, in southern Moravia and in the Moravian Gate. Their maximum thickness is up to 20 m. In the higher-lying areas the loess loams occur, which formed mostly by decalcification of loesses owing to more humid climate. Wind-blown sands are also joined with the cold climatic phases. In Bohemia and Moravia they follow the eastern margins of valleys of N—S direction, in the form of drifts and dunes. Their relationship to loesses indicates that the youngest accumulations formed towards the end of the Last Glacial.

Slope deposits of 1—15 m thickness accumulated under periglacial climate and partly in warmer phases. Proluvial sediments of this age are known from the area of Znojmo, from the piedmont areas of the Beskydy, Jeseníky and Krušné hory mountain ranges and from the marginal parts of the South Bohemian basins.

Fluvial sediments formed the thalweg terrace and in some areas (e.g. in the Labe valley) constituted two lowest terraces above the floodplain. The thickness of accumulations attains 10—15 m.

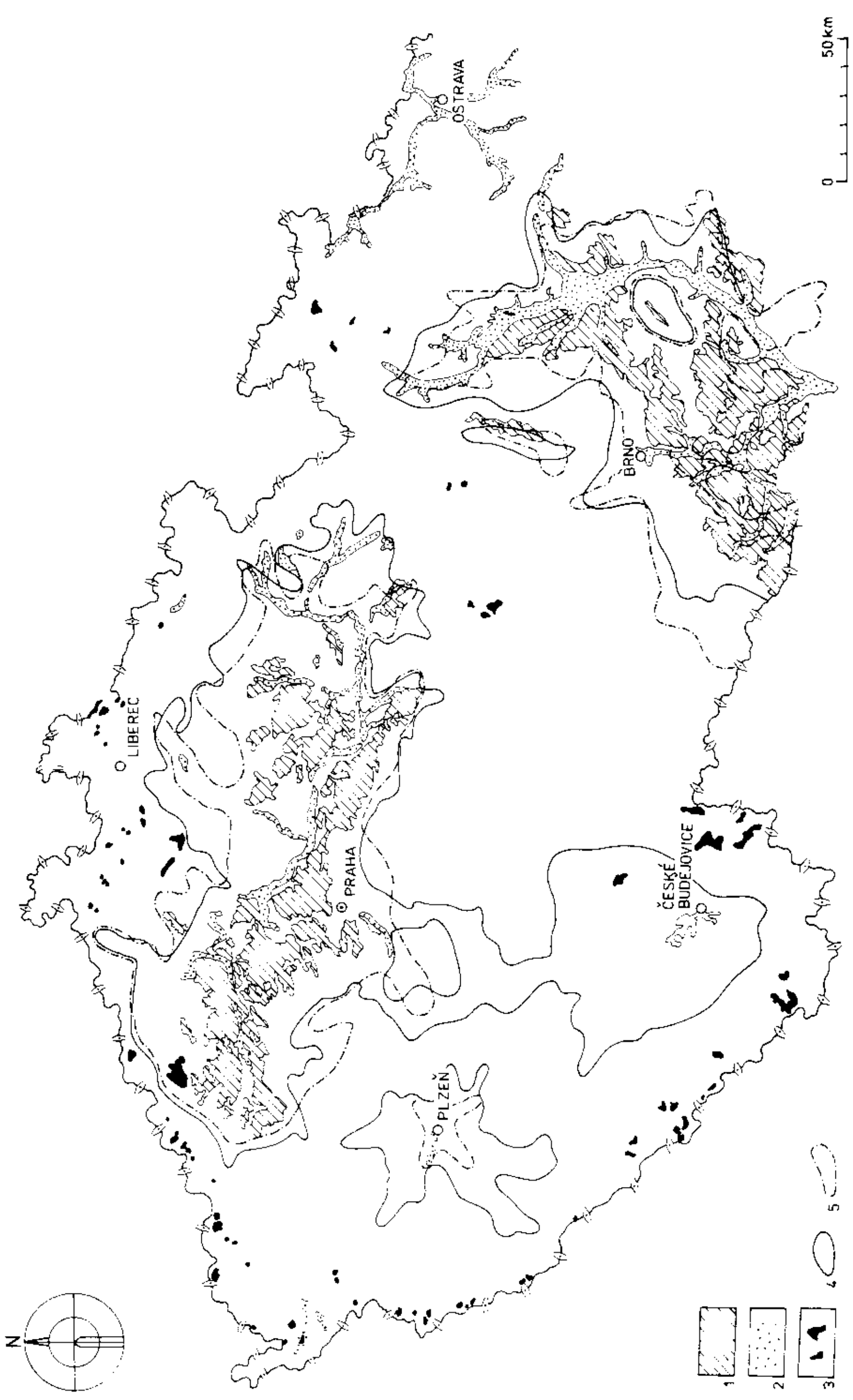
Lacustrine, 2—5 m thick, sandy-clayey sediments are known from the neighbourhood of Znojmo. They fill a shallow basin covering about 10 km^2. Glacigene sediments in the Šumava Mts. dam two cirque lakes. Interrelations between sediments of different genetic types within the accumulation cycle of the Last Glacial are complicated. The formation of fluvial and proluvial sediments probably falls in the middle part of the Glacial, after the deposition of the oldest loess. Towards the end of the glacial period, lacustrine sediments, the youngest loess and eventually blown sands are deposited.

The evolution of vegetation indicates that during the Last Glacial there were both cold and warm oscillations. In warmer interstadials deciduous trees predominated and in cold periods herbaceous vegetation of a continental steppe character prevailed. The development of molluscan fauna presents a similar picture of the palaeoclimate in periglacial regions.

The Late Glacial is a transitional period between the retreating Glacial and beginning Holocene; the greatest accumulations of blown sands were deposited in this time span.

In the territory of our state the presence of Man during the greater part of the Pleistocene is documented mainly by the finds of Palaeolithic implements. Of the oldest age are so-called pebbles industries of the Bohemian and Heidelbergian passing into the classical Clactonian, or Abbevillian, Acheuléan and Moustérian industries. The world-known locality Předmostí near Přerov belongs to the youngest culture. The evolution of Palaeolithic Man continued even during the Last Glacial under severe living conditions (ice cover in the north, mountain glaciation of the Alps, Krkonoše, Šumava, Jeseníky and Tatry regions).

In the Late Glacial, not long before the onset of the Holocene, approximately ten thousand years B.P. a fairly marked warm oscillation — Alleröd interstadial passed in the non-glaciated area into Holocene without a conspicuous cold oscillation. A permanent prominent warming up of the climate began only in the Preboreal. It has been precisely determined in marine sediments that this



8.25 Palaeogeographical map of the Holocene (V. Ložek, orig.)
1 — Distribution of chernozems (after J. Němeček); *2* — peats; *3* — major important flood plains; *4* — settlement in the Old, Middle and Young Bronze Age and at the beginning of the Iron Age (Hallstatt — 1700 to 400 B.P.); *5* — settlement in the Neolithic (5000 to 2000 B.P.)

8.23 Cryoturbated young Pleistocene fossil soil, loess loam section, Polom near Hranice in Moravia Photo by J. Tyráček

8.24 Potholes in the rocky bed of the river Vydra near Srní in the Šumava Mts., Prášily massif of the Moldanubian Pluton Photo by J. Bárta

change took place at about 8300 years B.P. On account of the existence of climatic zones, the evolution of nature in the Postglacial has nowhere been uniform. In Central Europe three such zones have been established. The zone above the present-day timber-line has shown a quiet development. The climatic optimum in the mid-Holocene implied a rise of the timber-line by 200—300 m above the present altitude and thus occupied the greater part of the modern Subalpine stage. The Central European average was represented by the forest zone, which extended from the timber line and descended to lowlands where the climate was sufficiently humid as, for example in the Ostrava area or in northern Bohemia (L o ž e k 1977). Pedologically, it is characterized by a predominance of brown forest soils, which may be more or less podzolized. The characteristic Holocene development of the forest zone was reversed by human interference, caused particularly by deforestation effects. The chernozem areas in the driest and warmest regions, which are distinguished by a predominance chernozemic soils and xerothermal elements, display a quite different picture. On account of the climate and substrate, the steppes survived for the longest time and agricultural settlement appeared there first (Neolithic).

Later on Man gradually occupied additional so far waste areas and penetrated even into mountains. With increasing settlement the effects of human activity intensified. The downwash of soil was increasing so that at elevated tracts the fresh substrate was laid bare, and the soil sediments accumulated in lower-lying parts. Instead of continual virgin forests, the landscape assumed the character of a mosaic composed of woods, meadows and fields, where many animals and plants thrived which would not find there suitable living conditions under the natural state. New ecosystems were developing, such as meadow and floodplain vegetation on valley floors, covered with downwashed mould in the form of flood loam or deluvio-fluvial sediments. Settlement and expansion of agriculture evoked a number of processes which helped to create a new type of landscape. Their effects increased in the late Bronze Age in the dry interval of the Subboreal. The changes in the configuration of landscape became so intensive and of such extent that they can be compared with those resulting from cultivation of new regions in the Middle Ages.

The Holocene is a period of two revolutions in the relations between the human society and nature. In the Neolithic, Man learned to remodel nature by tillage and pasturing, which led to the development of cultural landscape with a high portion of areas where human activity was combined with natural events. Both of them, however, still played their own roles in the development of the environment. The second reverse, called the scientific-technical revolution, occurs nowadays. The nature is being suppressed over steadily increasing areas and the changes of obnoxious character assume a global scale. The question arises what will the environment look like if the present trend will continue. We do not fully realize that the Holocene is a warm period equivalent to Pleistocene interglacials, differing from them only in the effects of human activity. Actuogeological considerations and applications require of us to apprehend how fundamentally the Late Holocene and Recent differ from the earlier epochs. Human activity has afflicted the nature with such intensity that the present conditions are quite unnatural. Vegetation cover and the loosening of the surface by tillage correspond to glacial conditions, whereas climate, especially precipitation and their distribution, correspond to an interglacial. The actuogeological observations can not be therefore applied directly to the geological past.

References

Adam Z. - Beránek B. - Weiss J. (1979): Contribution of deep geophysical investigations to the problem: Solution of the contact between the Carpathians and the Bohemian Massif. — Czechoslovak geology and global tectonics, Proc. of the Conf., Smolenice, May 19—21, 1976, *257—268*. Veda. Bratislava.

Adámek J. - Dvořák J. - Kalvoda J. (1980): Příspěvek ke geologické stavbě a naftově-geologickému hodnocení nikolčicko-kurdějovského hřbetu. — Zem. Plyn Nafta, 25, *441—474*. Hodonín.

Ambrož V. (1935): Studie o krystaliniku mezi Týnem n. Vltavou a Hlubokou. — Spisy přírodověd. Fak. Karl. Univ., 138. *1—44*. Praha.
— (1942): Periglaciální zjevy u Jevan. — Zpr. Geol. Úst. Čechy Mor., 18, *219—230*. Praha.
— (1947): Spraše pahorkatin. — Sbor. St. geol. Úst. Čs. Republ., 14, *225—280*. Praha.

Andrusov (1930): Příspěvky ku geologii severozápadních Karpat. V. Příspěvek k poznání tektoniky a paleogeografie severozápadních Karpat. — Sbor. St. geol. Úst. Čs. Republ. 9, *235—300*. Praha.
— (1958): Geológia československých Karpát, I. — *1—304*, Slov. akad. vied. Bratislava.
— (1959): Geológia československých Karpát, II. — *1—376*, Slov. akad. vied. Bratislava.
— (1968): Grundriß der Tektonik der nördlichen Karpaten. — *1—188*. Bratislava.

Andrusov D. - Čorná O. (1976): Über das Alter des Moldanubikums nach mikrofloristischen Forschungen. — Geol. Práce, Spr., 65, *81—89*. Bratislava.

Angenheister G. (1974): Anomalien der vertikalen Komponente Z des Erdmagnetfeldes im nördlichen Alpen-Vorland und in den Ostalpen, gemessen längs Profilen 1958—1973 (Profilmontage). — Münchener Univ.-Schr., Fak. für Geowiss., Ser. B, 5, 2. *15—36*. München.

Arapov A. et al. (1965): Prognosní mapa Čech a Moravy 1 : 100 000. — MS Geofond. Praha.

Arnold A. et al. (1974): Rb/Sr-Altersbestimmungen an Orthogneisen und Granuliten des südböhmischen Moldanubikums. — MS Ústř. úst. geol. Praha.

Aubouin J. (1965): Geosynclines. 335 pp. Elsevier. Amsterdam.

Augustyniak K. - Grocholski A. (1968): Geological structure and outline of the development of the Intra-Sudetic depression. — Biuletyn (Inst. geol. Warszawa), 227, *87—120*. Warszawa.

Balatka B. - Sládek J. (1962): Terasový systém Vltavy a Labe mezi Kralupy a Českým středohořím. — Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 72, 11, *1—62*. Praha.
— (1976): Terasový systém střední a dolní Ohře. — Acta Univ. Carol., 2, Geogr., *1—26*. Praha.

Bard J. P. - Burg J. P. - Matte Ph. - Ribeiro A. (1980): La chaîne hercynienne d'Europe occidentale en termes de tectonique des plaques. — Mém. BRGM 108, 26 IGC, C. 6., *233—246*. Paris.

Barth V. (1963): Variský geosynklinální vulkanismus v Hrubém a Nízkém Jeseníku a jeho vztahy k tektonice. — Sbor. Prací Univ. Palackého (Olomouc), Geogr. Geol., 14, *5—117*. Praha.

— (1964): Faciální vývoj vulkanického komplexu v jižní části konicko-mladečského devonu na Drahanské vrchovině. — Sbor. Prací Univ. Palackého (Olomouc), Geogr. Geolo., 17, 6. *13—67*. Praha.

— (1966): The initial volcanism in the Devonian of Moravia. *In:* Paleovolcanites of the Bohemian Massif, *115—125*. — Přír. fak. Univ. Kralovy. Praha.

Batík P. - Skoček V. (1981): Litologický vývoj paleozoika na východním okraji dyjského masívu. — Věst. Ústř. Úst. geol., 56, 6, *337—347*. Praha.

Behr H. J. (1978): Subfluenzprozesse im Grundgebirgsstockwerk Mitteleuropas. — Z. Dtsch. geol. Gesell., 129, *283—318*. Hannover.

— (1980): Subduktion oder Subfluenz im mitteleuropäischen Varistikum? — Berl. geowiss. Abh., R. A, 19, A. Wegener-Symposium, *22—23*. Berlin.

Behr H. J. - Fritsch E. - Mansfeld L. (1965): Die Granulite von Zöblitz im Erzgebirge als Beispiel für Granulitbildung in tiefreichenden Scherhorizonten. — Krystalinikum 3, *7—29*. Praha.

Beneš K. (1964): Structural analysis of Moldanubian—Assyntian boundary area at the NE margin of the Moldanubian core. — Rozpravy Čs. Akad. Věd, Ř. mat. přír. Věd, 74, 2, *1—80*. Praha.

— (1971): Flow and fracture fabrics and their relationship in some granitic bodies of the Bohemian Massif. — Krystalinikum, 8, *149—166*. Praha.

Beránek B. (1971): Hlubinné seizmické sondování v ČSSR. — Geol. Průzk., 13, 10, *289—293*. Praha.

Beránek B. et al. (1972): The crustal structure of Central and Southeastern Europe based on the results of explosion seismology. *In:* Czechoslovakia.. Geophysical trans., spec. ed. *87—98*. Budapest.

Beránek B. - Dudek A. (1972): Results of deep seismic sounding in Czechoslovakia. — Z. angew. Geophys., 38, *415—427*. Würzburg.

— (1980): Osnovnye zakonomernosti stroenija kory zon perechoda v varisskom i aľpijskom orogenach. — Materialy XI Kongressa Karpato-Balkanskoj geologičeskoj associacii, Geofizika. *13—20*. Naukova dumka. Kiev.

— (1981): Geologický výklad tíhových transformovaných polí v Českém masívu a Západních Karpatech. — Sbor. geol. Věd. užitá Geofyz., 17, *47—59*. Praha.

Beránek B. - Dudek A. - Zounková M. (1975): Rychlostní modely stavby zemské kůry v Českém masívu a Západních Karpatech. — Sbor. geol. Věd, užitá Geofyz., 13, *7—20*. Praha.

Beránek B. - Ibrmajer J. (1976): Gravimetrie a výsledky hlubinné seizmické sondáže v ČSSR. *In:* Sbor. referátů z celost. semináře „Problémy současné gravimetrie", Liblice. *5—23*. — Geofyz. úst. ČSAV. Praha.

Beránek B. - Suk M. - Weiss J. (1980): Geological sections through the Variscan orogene in the Bohemian Massif. — Sbor. geol. Věd. Geol., 34, *7—29*. Praha.

Beránek B. - Weiss J. (1979): Geotektonické řešení postavení Českého masívu a Západních Karpat. *In:* Tektonické profily Západných Karpát, Smolenice 1978, *25—29*. — Geol. úst. D. Štúra. Bratislava.

Beránek B. - Zounková M. (1979): Principal results of deep seismic soundings. *In:* Geodynamic investigations in Czechoslovakia, *105—111*. — Veda. Bratislava.

Bernard J. H. (1978): Paragenetic units in relation to the deeper structure of the Bohemian Massif. — Sbor. geol. Věd, Geol., 31, *13—20*. Praha.

Bernard J. et al. (1982): Endogenous mineralization in the Bohemian Massif in relation to global-tectonic concepts: confrontation of geophysics and metallogeny. — Sbor. geol. Věd. užitá Geofyz., 18, *11—52*. Praha.

Bernard J. H. - Dudek A. (1967): Sur le magmatisme et les minéralisations hydrothermales du Massif de Bohême. — Mineralium Depos., 2, 2, *63—79*. Berlin.

Bernard J. - Klomínský J. (1975): Geochronology of the Variscan plutonism and mineralization in the Bohemian Massif. — Věst. Ústř. Úst. geol., 50, 2, *71—82*. Praha.

Bernardová E. (1966): Těžké minerály proterozoika v severozápadním křídle Barrandienu. — Věst. Ústř. Úst. geol., 61, 5, *335—339*. Praha.

Bezvodová B. - Zeman A. (1983): Paleoreliéfy na jižní Moravě a jejich kolektorské vlastnosti. — Sbor. geol. Věd, Geol., 38, *95—140*. Praha.

Blížkovský M. et al. (1981): Odkrytá tíhová mapa Českého masívu na základě revize hustotních dat. — MS Ústř. úst. geol. Praha.

Blížkovský M. - Pokorný L. - Weiss J. (1975): Structural scheme of the Bohemian Massif based on geophysical data. — Věst. Ústř. Úst. geol., 50, 1, *1—8*. Praha.

Blümel P. - Schreyer W. (1977): Phase relations in pelitic and psammitic gneisses of the sillimanite-potash feldspar and cordierite potash feldspar zones in the Moldanubicum of the Lam-Bodenmais area, Bavaria. — J. Petrology, 18, 3, *431—459*. Oxford.

Bosák P. (1978): Rudická plošina v Moravském krasu. Část III. Petrografie a diageneze karbonátů a silicitů jurského reliktu u Olomučan. — Čas. Morav. Muz., Vědy přír., 63, *7—28*. Brno.

Bouček B. (1935): O silurské fauně od Stínavy západně od Plumlova na Drahanské vysočině. — Čas. Vlasten. Spol. mus., 48, *3—4*, *129—138*. Olomouc.

— (1953): Biostratigrafie, vývoj a korelace želkovických a motolských vrstev českého siluru. — Sbor. Ústř. Úst. geol., Odd. paleont., 20, *421—484*. Praha.

Bouček B. - Kodym O. (1958): Geologie, I. — Nakl. Čs. akad. věd. Praha.

Bubeníček J. (1968): Geologický a petrografický vývoj třebíčského masívu. — Sbor. geol. Věd, Geol., 13, *133—164*. Praha.

Bučková M. - Růžičková E. (1967): Proluvial and fluviatile sediments of the south-western margin of the České středohoří Mts. — Sbor. geol. Věd„ Antropozoikum, 4. *39—69*. Praha.

Buday T. et al. (1960): Tectonic development of Czechoslovakia. — *1—232*, Ústř. úst. geol. Praha.

Buday T. et al. (1963): Vysvětlivky k přehledné geologické mapě ČSSR 1 : 200 000 M-33-XXX Gottwaldov. — Ústř. úst. geol. Praha.

Buday T. - Cicha I. - Seneš J. (1965): Miozän der Westkarpaten. — *1—295*, Geol. úst. D. Štúra. Bratislava.

Buday T. - Dudek A. - Ibrmajer J. (1969): Některé výsledky interpretace gravimetrické mapy ČSSR v měřítku 1 : 500 000. — Sbor. geol. Věd, užitá Geofyz., 8, *7—35*. Praha.

Burret C. - Griffiths J. (1977): A case for Mid-European ocean. *In:* La chaîne Varisque d'Europe moyenne et occidentale. — Coll. intern. CNRS, 243, *313—328*. Rennes.

Bůžek Č. - Kvaček Z. - Fejfar O. (1979): Nová paleontologická data o stáří neovulkanismu v severních Čechách. — Čas. Mineral. Geol., 24, 1, *103—104*. Praha.

Čadek J. (1966): K paleogeografii chomutovsko—mostecko—teplické pánve. — Sbor. geol. Věd, Geol., 11, *77—114*. Praha.

Čech S. - Klein V. - Kříž J. - Valečka J. (1980): Revision of the Upper Cretaceous stratigraphy of the Bohemian Basin. — Věst. Ústř. Úst. geol., 55, 6, *277—296*. Praha.

Čermák V. (1980): Mapa tepelného toku v Evropě: Poznámky k její interpretaci, odvozené mapy hlubinných teplot, tepelného toku na rozhraní kůra-plášť a mapa tloušťky litosféry. *In:* 7. celostátní konference geofyziků. Sbor. referátů. — MS Geofyzika. Brno.

Cháb J. (1973): Fosilní oceánská kůra a svrchní plášť na dnešním povrchu souší. — Věst. Ústř. Úst. geol., 48, 5, *303—310*. Praha.

— (1975): Intruzívní horniny strukturního vrtu Bechlín u Roudnice nad Labem. — Sbor. geol. Věd, Geol., 27, *55—82*. Praha.

— (1976): Kadomský vývoj ve střední Evropě z hlediska globální blokové tektoniky: pracovní hypotéza. *In:* Zborník referátov vedeckej konferencie „Československá geológia a globálna tektonika“, Smolenice 1976, *69—72*. — Geol. úst. D. Štúra. Bratislava.

— (1978): Návrh litostratigrafické a litologické terminologie pro svrchní proterozoikum tepelsko-barrandienské oblasti. — Věst. Ústř. Úst. geol., 53, 1, *43—60*. Praha.

— (1979): Svrchní proterozoikum Českého masívu a jeho význam pro vývoj evropského kontinentu. *In:* Seminář k 60. výročí založení ÚÚG. — MS Ústř. úst. geol. Praha.

Cháb J. - Bernardová E. (1968): Präassyntische kristalline Schiefer als klastisches Material in jungproterozoischen Grauwacken im NW Teil des Barrandiums. — Geologie, 17, 6/7, *753—775*. Berlin.

Cháb J. - Bouška V. - Jelínek E. - Pačesová M. - Povondra P. (1980): Petrology and geochemistry of the Upper Proterozoic Fe-Mn deposit Chvaletice, Bohemia, Czechoslovakia. — Sbor. geol. Věd, ložisk. Geol., 23, *9—68*. Praha.

Cháb J. - Fiala F. (1979): Proterozoické paraslepence na Hudlicku (severozápadní křídlo Barrandienu). — Věst. Ústř. Úst. geol., 45, *79—86*. Praha.

Cháb J. - Pelc Z. (1973): Proterozoické droby severozápadní části Barrandienu. — Sbor. Ústř. Úst. geol., Geol., 25, *7—84*. Praha.

Cháb J. - Suk M. (1977): Regionální metamorfóza na území Čech a Moravy. — Knih. Ústř. Úst. geol., 50, *1—156*. Praha.

Cháb J. - Vrána S. (1979): Crossite-actinolite amphiboles of the Krkonoše—Jizera crystalline complex and their geological significance. — Věst. Ústř. Úst. geol., 54, 3, *143—150*. Praha.

Chaloupský J. (1963): Konglomeráty v krkonošském krystaliniku. — Sbor. Ústř. Úst. geol., Odd. geol., 28, *173—190*. Praha.

— (1965): Metamorphic development of the Krkonoše crystalline complex. — Krystalinikum, 3, *31—54*. Praha.

— (1966): Kaledonská a variská orogeneze v ještědském krystaliniku. — Sbor. geol. Věd, Geol., 10, *7—37*. Praha.

— (1967): Problematika kaledonského orogénu v Českém masívu. — Čas. Mineral. Geol., 12, 2, *165—170*. Praha.

— (1973): The basement of the Cretaceous and the Permo-Carboniferous of northern Bohemia. — Geol. Rdsch., 62, *581—594*. Stuttgart.

— (1975): Prekambrická tektogeneze v Českém masívu. *In:* Sborník přednášek k 30. výročí osvobození. — MS Ústř. úst. geol., *26—29*. Praha.

— (1977): Stratigraphie du Precambrien du Massif de Bohême. *In:* La chaine Varisque d'Europe moyenne et occidentale. — Coll. intern. CNRS, 243, *17—32*. Rennes.

— (1978): The Precambrian tectogenesis in the Bohemian Massif. — Geol. Rdsch., 67, 1, *72—90*. Stuttgart.

— (1981): Návrh stratigrafického členění jednotek krkonošského krystalinika. — MS Ústř. úst. geol. Praha.

Chaloupský J. et al. (1968): Geologická mapa Krkonošského národního parku 1 : 50 000. — Ústř. úst. geol. Praha.

Chlupáč I. (1961): Orientační výzkum některých menších výskytů devonu na Drahanské vysočině. — Zpr. geol. Výzk. v Roce 1960, *89—95*. Praha.

— (1962): Zur Biostratigraphie und Faziesentwicklung der Devon/Karbon-Grenzschichten im Mährischen Karst. — Geologie, 11, 9, *1001—1017*. Berlin.

— (1963): Orientační paleontologické výzkumy ve slabě metamorfovaném paleozoiku Ještědského pohoří. — Zpr. geol. Výzk. v Roce 1962, *107—109*. Praha.

— (1964): Nový nález fauny ve slabě metamorfovaném paleozoiku Ještědského pohoří. — Čas. Mineral. Geol., 9, 1, *27—35*. Praha.

— (1965): Fortschritte in der Stratigraphie des mährischen (ostsudetischen) Devons. — Geol. Rdsch., 54, *1003—1025*. Stuttgart.

— (1966): The Upper Devonian and Lower Carboniferous trilobites of the Moravian Karst. — Sbor. geol. Věd, Paleont., 7, *1—143*. Praha.

— (1968): Devonian of Czechoslovakia. *In:* Int. Symp. Devonian system, Calgary 1967, 1, *109—126*. — Alberta Soc. Petrol. Geol. Calgary.

— (1975): Nové nálezy fauny v metamorfovaném devonu Hrubého Jeseníku a jejich význam. — Čas. Mineral. Geol., 20, 3, *259—271*. Praha.

Chlupáč I. (1976): The Bohemian Lower Devonian stages and remarks on the Lower —Middle Devonian boundary. — Newslett. Stratigr., 5, 2—3, *168—169.* Berlin — Stuttgart.

— (1977): The Late Devonian and Early Carboniferous trilobite faunas of Moravia. *In:* Symp. Carbonif. Stratigr., *305—313.* — Ústř. úst. geol. Praha.

— (1981a): K stratigrafii a faciálnímu vývoji metamorfovaného paleozoika sedlčansko-krásnohorského ostrova. — Věst. Ústř. Úst. geol., 56, 4, *225—232.* Praha.

— (1981b): Stratigraphic terminology of the Devonian in central Bohemia (Barrandian area, Czechoslovakia). — Věst. Ústř. Úst. geol., 56, 5, *263—270.* Praha.

— (1982): Preliminary subcommission for Lower/Middle Devonian boundary stratotype in the Barrandian area. — Cour. Forsch.-Inst. Senckenberg, 31, *85—96.* Frankfurt a. Main.

Chlupáč I. et al. (1976): Návrh regionálně geologické klasifikace Českého masívu. — Čas. Mineral. Geol., 21, 1, *1—27.* Praha.

Chlupáč I. - Jaeger H. - Zikmundová J. (1972): The Silurian—Devonian boundary in the Barrandian. — Bull. canad. Petrol. Geol., 20, 1, *104—174.* Calgary.

Chlupáč I. - Kumpera O. (1972): Stratigrafický význam profilu spodním karbonem u Opatovic na Hranicku. — Věst. Ústř. Úst. geol., 47, 3, *147—154.* Praha.

Chlupáč I. - Lukeš P. - Zikmundová J. (1979): The Lower/Middle Devonian boundary beds in the Barrandian area, Czechoslovakia. — Geologica et Palaeont., 13, *125—156.* Marburg.

Chlupáč I. - Svoboda J. (1963): Geologické poměry konicko-mladečského devonu na Drahanské vrchovině. — Sbor. Ústř. Úst. geol., Odd. geol., 28, *347—386.* Praha.

Chlupáč I. - Zikmundová J. - Zukalová V. (1968): Relationships of Devonian and early Lower Carboniferous faunas from Moravia. — Rep. Sess. 23, Int. Geol. Congr. Czechosl. 1968, Proc. Sect. 9, *63—71,* Ústř. úst. geol. Praha.

Chmelík F. et al. (1969): Vysvětlující text k základní geologické mapě 1 : 25 000 M-33-107-B-a Zborovice, M-33-107-B-b Kroměříž, M-33-107-B-c Zdounky a M-33-107-B-d Kvasice. — MS Geofond. Praha.

Churkin M. - Carter C. - Johnson B. R. (1977): Subdivision of Ordovician and Silurian time scale using accumulation rates of graptolitic shales. — Geology, 5, *452—456.* Boulder.

Cicha I. (1960): Stratigraphical problems of the Miocene in Europe. — Rozpr. Ústř. Úst. geol., 35, *1—136.* Praha.

Cicha I. et al. (1965): Eine neue tektonische Einheit der äußeren Karpaten in Südmähren. — Geol. Práce, Zpr., 36, *85—104.* Bratislava.

— (1975): Biozonal division of the Upper Tertiary basins of the Eastern Alps and West Carpathians. — Proc. of 6th Congr. RCMNS, Ústř. úst. geol. Praha.

Cicha I. - Čtyroká J. - Jiříček R. - Zapletalová I. (1975): Principal biozones of the Late Tertiary in the East Alps and West Carpathians. *In:* I. Cicha et al.: Biozonal division of the Upper Tertiary basins of the Eastern Alps and West Carpathians. — Proc. of 6th Congr. RCMNS, *19—23,* Ústř. úst. geol. Praha.

Cicha I. - Fejfar O. (1975): Non-marine Neogene of the Bohemian Massif, the West Carpathian Foredeep and the Vienna Basin in Czechoslovakia. — Region. Comm. on Mediterranean Neogene Stratigraphy, 6th Congr., *7—35.* Veda. Bratislava.

Cicha I. - Haga H. - Martini E. - Absolon A. (1974): Das Oligozän und Miozän der Alpen und der Karpaten. Ein Vergleich mit Hilfe planktonischer Organismen. — Vème Congrès du Néogène Méditerranéen, Lyon, septembre, 1971. Mém. Bur. Rech. géol. min., 78, *377—386.* Paris.

Cicha I. - Marinescu F. - Seneš J. et al. (1975): Corrélation du néogène de la Paratethys centrale. — IUGS UNESCO, Project No 25, *5—34.* Ústř. úst. geol. Praha.

Cicha I. - Papp A. - Seneš J. - Steininger F. (1975): Marine Neogene in Austria and Czechoslovakia—Excursion "A". — Region. Comm. on Mediterranean Neogene Stratigraphy, 6th Congr., *6—96,* Veda. Bratislava.

— (1975): Badenian — Stratotypes of Mediterranean Neogene stages, vol. 2, *43—49.* CMNS. — Veda. Bratislava.

Cicha I. - Steininger F. (1975): History of the Neogene nomenclature in the Central Paratethys. *In:* I. Cicha et al: Biozonal division of the Upper Tertiary basins of the Eastern Alps and West Carpathians. — Proc. of 6th Congr. RCMNS, *9—10,* Ústř. úst. geol. Praha.

Cicha I. - Zapletalová I. (1974): Problémy stratigrafie mladšího terciéru ve střední části Karpatské předhlubně. — Zem. Plyn Nafta, 19, 3, *453—460.* Hodonín.

Cogné J. (1972): Le Brioverien et le cycle orogénique cadomien dans le cadre des orogènes fini-précambriens. — Coll. Agadir. Rabat 1970, *193—218.*

Cohee G. H. - Glaessner M. F. - Hedberg H. D. (1978): Contribution to the geologic time scale, A. — Assoc. Petrol. Geol., *1—388.* Tulsa.

Čtyroký P. (1980): Nová biostratigrafická data pro stáří vltavínonosných uloženin u Sukovan a Suchohrdel na Moravě. — Přírodověd. Sbor. Západomorav. muz. v Třebíči, 11, *151—158.* Třebíč.

Čtyroký P. - Fejfar O. - Holý I. (1962): Neue paläontologische Funde im Untermiozän des nordböhmischen Braunkohlenbeckens. — Neu. Jb. Geol. Paläont., Abh., 119, 2, *134—156.* Stuttgart.

— (1964): Nové paleontologické nálezy ve spodním miocénu severočeské hnědouhelné pánve. — Zpr. geol. Výzk. v Roce 1963, *201—203.* Praha.

Čuta J. - Mísař Z. - Válek M. (1964): Interpretace tíhového pole severovýchodního okraje Českého masívu. — Sbor. geol. Věd, užitá Geofyz., 8, *7—35.* Praha.

Czudek T. (1976): Planation surfaces of the Czech highlands. — Sbor. Čs. Společ. zeměp., 81, 1, *16—18.* Praha.

Czudek T. - Demek J. (1979): Pleistocene cryopedimentation in Czechoslovakia. — Acta geogr. lodz., 24, *101—108.* Łódź.

Demek J. (1981): Nauka o krajině. — *1—234,* Univ. J. E. Purkyně v Brně.

Demek J. et al. (1965): Geomorfologie Českých zemí. — Nakl. Čs. akad. věd. Praha.

Dlabač M. - Menčík E. (1964): Geologická stavba autochtonního podkladu západní části vnějších Karpat na území ČSSR. — Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 74, 1, *1—60*. Praha.

Domečka K. - Opletal M. (1974): Granitoidy západní části orlicko-kladské klenby. — Acta Univ. Carol., Geol., 1, *75—109*. Praha.

— (1981): Metamorphosed Upper Proterozoic tholeiites of the NE part of the Bohemian Massif. — Krystalinikum, 15, *55—80*. Praha.

Dornsiepen U. F. (1979): Rb-Sr whole rock ages within the European Hercynian. A review. — Krystalinikum, 14, *33—50*. Praha.

Dudek A. (1960): Krystalické břidlice a devon východně od Znojma. — Sbor. Ústř. Úst. geol., Odd. geol., 26, *101—142*. Praha.

— (1962): Zum Problem der moldanubischen Überschiebung im Nordteil der Thayakuppel. — Geologie, 11, 7, *757—791*. Berlin.

— (1963): Beitrag zum Problem der moldanubischen Überschiebung (Misslitzer Horst). — Sbor. geol. Věd, Geol., 1, *7—20*. Praha.

— (1971): Chemical composition of Moldanubian eclogites and of their garnets. — Krystalinikum, 7, *167—181*. Praha.

— (1980): The crystalline basement block of the Outer Carpathians in Moravia: Bruno-Vistulicum. — Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 90, 8, *1—85*. Praha.

Dudek A. - Fediuk F. (1955): Skalní stěna v údolí Vltavy u Kralup nad Vltavou. — Acta Univ. Carol., Geol., 1, *187—228*. Praha.

Dudek A. - Fediuková E. (1974): Eclogites of the Bohemian Moldanubicum. — Neu. Jb. Mineral., Abh., 121, 2, *127—159*. Stuttgart.

Dudek A. - Matějovská O. - Suk M. (1974): Gföhl orthogneiss in the Moldanubicum of Bohemia and Moravia. — Krystalinikum, 10, *77—78*. Praha.

Dudek A. - Melková J. (1975): Radiometric age determination in the crystalline basement of the Carpathian Foredeep and of the Moravian Flysch. — Věst. Ústř. Úst. geol., 50, 5, *257—264*. Praha.

Dudek A. - Suk M. (1965): The depth relief of the granitoid plutons of the Moldanubicum. — Neu. Jb. Geol. Paläont., Abh., 123, *1—19*. Stuttgart.

— (1971). Metamorphic facies series in the Precambrian of the Bohemian Massif. — Acta Univ. Carol., Geol., 1/2, *67—78*. Praha.

Dudek A. - Weiss J. (1963): Západomoravské krystalinikum. — Sborník referátů 14. sjezdu Společnosti pro mineralogii a geologii, *5—18*. Brno.

Dvořák J. (1956): K rozšíření jurských sedimentů na Českém masívu v okolí Brna. — Věst. Ústř. Úst. geol., 31, 6, *284—285*. Praha.

— (1958a): Vývoj stratigrafie křídového útvaru v oblasti Českého masívu. — Knih. Ústř. Úst. geol., 30. Praha.

— (1958b): Zásady faciálního a litologického vývoje devonu a karbonu na Moravě. — Sbor. Vlastivěd. Muz., Odd. A, 3, *23—46*. Olomouc.

Dvořák J. (1968): Tectogenesis of the Central European Variscides. — Věst. Ústř. Úst. geol., 43, 6, *465—471*. Praha.

— (1969): Geologie des oberen Teiles der Myslejovice-Schichtenfolge am östlichen Rande der Drahaner Höhe. — Čas. Morav. Muz., Vědy přír., 54, *45—60*. Brno.

— (1973a): Problem concerning the north-eastern closure of the Variscan orogeny. — Neu. Jb. Geol. Paläont., Mh., 8, *449—454*. Stuttgart.

— (1973b): Synsedimentary tectonics of the Palaeozoic of the Drahany Upland (Sudeticum, Moravia, Czechoslovakia). — Tectonophysics, 17, *35—39*. Amsterdam.

— (1975a): Interrelations between the sedimentation rate and the subsidence during the flysch and molasse stage of the Variscan geosyncline in Moravia (Sudeticum). — Neu. Jb. Geol. Paläont., Mh., 6, *339—342*. Stuttgart.

— (1975b): Model evropských variscid. — Čas. Mineral. Geol., 20, 1, *25—30*. Praha.

— (1977): Inversion structures of the European Variscan orogeny. — Věst. Ústř. Úst. geol., 52, 1, *55—58*. Praha.

— (1978a): Geologie paleozoika v podloží Karpat jv. od Drahanské vrchoviny. — Zem. Plyn Nafta, 23, *185—203*. Hodonín.

— (1978b): Proterozoischer Untergrund der variszischen Geosynklinale in Mähren (ČSSR) und ihre Entwicklung. — Z. Dtsch. geol. Gesell., 129, *383—390*. Hannover.

— (1980): Geotectonic conditions of the forming and extinction of the reef complex, notably in the Devonian of Moravia. — Věst. Ústř. Úst. geol., 55, 4, *203—208*. Praha.

— (1981): Beziehungen des variszischen Orogens zur Osteuropäischen Tafel in Mitteleuropa. — Z. angew. Geol., 27, *186—188*. Berlin.

— (1982): The Devonian and Lower Carboniferous in the basement of the Carpathians south and southeast of Ostrava (Upper Silesian Coal Basin, Moravia, Czechoslovakia). — Z. Dtsch. geol. Gesell., 133, *551—570*.. Hannover.

Dvořák J. - Freyer G. (1961): Die Devon/Karbon-Grenze im Mährischen Karst (Südteil des mährischen Sedimentationsbeckens) auf der Grundlage von Konodontenfaunen. — Geologie, 10, *881—895*. Berlin.

— (1965): Der heutige Stand der Stratigraphie und Paläogeographie des Devons und Unterkarbons (Dinant) im südlichen Teil der Drahaner Höhe (Mähren). — Geologie, 14, 4, *404—419*. Berlin.

— (1966): Příspěvek k řešení stratigrafie paleozoika na střední Moravě. — Zpr. geol. Výzk. v Roce 1965, *129—130*. Praha.

— (1968): Das Paläozoikum im mittleren Teil der Drahaner Höhe (Mähren). — Geologie, 17, *703—719*. Berlin.

Dvořák J. - Friáková O. - Lang L. (1976): Block structure of the old basement as indicated by the facies development of the Devonian and the Carboniferous in the Moravian Karst (Sudeticum, Moravia, ČSSR). — Geologica et Palaeont., 10, *153—160*. Marburg.

Dvořák J. - Paproth E. (1969): Über die Position und die Tektogenese des Rhenoherzynikums und des Sudetikums in den mitteleuropäischen Varisziden. — Neu. Jb. Geol. Paläont., Mh., 2, *65—88*. Stuttgart.

Dvořák J. - Přichystal A. (1982): Lamprofyry stefanského stáří janovsko-artmanovského antiklinoria ve Slezsku. — Sbor. geol. Věd, Geol. 36, *93—113*. Praha.

Dvořák J. - Pták J. (1963): Geologický vývoj a tektonika devonu a spodního karbonu Moravského krasu. — Sbor. geol. Věd, Geol., 1, *49—84*. Praha.

Dvořák J. - Skoček V. (1795): Reconstruction of the palaeo-heat flow regime in two areas of the Variscan orogeny. — Neu. Jb. Geol., Paläont., Mh., 9, *517—527*. Stuttgart.

Dvořák J. - Wolf M. (1979): Thermal metamorphism in the Moravian Palaeozoic (Sudeticum, ČSSR). — Neu. Jb. Geol. Paläont., Mh., 10, *596—607*. Stuttgart.

McElhinny (1975): Paleomagnetism and continental drift. — *1—343*, J. Wiley. New York.

Eliáš M. (1976): Poznámky k paleogeografickému a paleotektonickému vývoji flyšových Karpat. *In:* Československá geológia a globálna tektonika, Smolenice 1976, *43—53*. — Geol. úst. D. Štúra. Bratislava.

— (1981): Facies and palaeogeography of the Jurassic of the Bohemian Massif. — Sbor. geol. Věd, Geol., 35, *75—155*. Praha.

Eliáš M. - Uhmann J. (1968): Hustoty hornin ČSSR. — Ústř. úst. geol. Praha.

Elznic A. (1966): Lomské souvrství — nejmladší litofaciální jednotka terciérních sedimentů severočeské pánve. — Zprav. Severočes. hnědouhel. Dolů, 4—5, *1—31*. Most.

Fajst M. (1976): Vztah zábřežské a stroňské série v prekambriu Západních Sudet. *In:* Korelace proterozoických a paleozoických stratiformních ložisek, IV., *85—95*. — Úst. geol. věd přírodověd. fak. Univ. Karl. Praha.

Fediuk F. (1958): Staropaleozoické basické vulkanity v Rýchorských horách. — Práce Kraj. Mus., Sér. A, 1, *2—5*. Hradec Králové.

— (1959): Krystalinické valouny ze staropaleozoického slepence od Rožmitálu. — Věst. Ústř. Úst. geol., 34, 6, *436—442*. Praha.

— (1962): Vulkanity železnobrodského krystalinika. — Rozpr. Ústř. Úst. geol., 29, *1—116*. Praha.

— (1967): Permokarbonische Vulkanite unter der Böhmischen Kreidetafel. — Ber. Dtsch. Gesell. geol. Wiss., R. B, 12, *173—179*. Berlin.

— (1971): Cordierite in the Moldanubian gneisses. — Krystalinikum, 7, *183—204*. Praha.

— (1976): The Bechyně "orthogneiss": an anatectic type of Moldanubian orthogneissoids. — Acta Univ. Carol., Geol., 3, *187—207*. Praha.

Fediuk F. - Röhlich P. (1960): Basální vrstvy ordoviku v Praze - Troji. — Acta Univ. Carol., Geol., 1, *75—93*. Praha.

Fediuková E. - Dudek A. (1979): Almandinové eklogity centrální části Českomoravské vrchoviny. *In:* Sborník příspěvků ke geologickému výzkumu jihozápadní části Českomoravské vrchoviny, *20—38*. — Jihočeské muzeum. České Budějovice.

Fediuková E. - Fediuk F. (1971): Moldanubian granulites of the Písek—Týn area. — Acta Univ. Carol., Geol., 1—2, *25—47*. Praha.

Fediuková E. - Suk M. (1979): An example of migmatite origin by dehydrating metamorphism. — Bull. Géol. Soc. Finl., 51, *1—9*. Helsinki.

Fejfar O. (1961): Survey of Czechoslovak Quaternary: Review of Quaternary vertebrata in Czechoslovakia. — Prace Inst. geol., 34, *109—118*. Warszawa.

— (1965): Die unter-mittelpleistozäne Makromammalier-Fauna aus Dobrkovice, Südböhmen. — Ber. Geol. Gesell. Dtsch. Demokr. Republ. geol. Wiss., 10, 1, *57—65*. Berlin.

— (1972): Die Wühlmäuse (Microtidae, Mammalia) der älteren Sammlungen aus Stránská skála bei Brno. — Anthropos, 20, 12, *165—174*. Brno.

— (1976): Plio-Pleistocene mammal sequences. — Proj. 73/1/24 Quaternary Glaciations in the Northern Hemisphere, Rep. No. 3, *351—366*. Bellingham — Prague.

Fejfar O. - Čtyroký P. (1977): Fosilní obratlovci a měkkýši třetihor Chebska a Sokolovska. — Sbor. 8. celostátní paleontologické konference v Sokolově 1977, *17—19*. Sokolov.

Fejfar O. - Heinrich W. D. (1980): Zur biostratigraphischen Abgrenzung und Gliederung des kontinentalen Quartärs in Europa an Hand von Arvicoliden (Mammalia, Rodentia). — Čas. Mineral. Geol., 25, 2, *185—189*. Praha.

Fejfar O. - Horáček I. (1983): Neue Faunen an der Grenze Villányium-Biharium auf dem Gebiet der ČSSR. — Z. geol. Wiss., 19/20, *332—345*. Berlin.

Fencl J. - Záruba Q. (1956): Geologické poměry okolí Lázní Teplic v Čechách. — Sbor. Ústř. Úst. geol., Odd. geol., 22, *427—484*. Praha.

Fiala F. (1948): Algonkické slepence ve středních Čechách. — Sbor. St. geol. Úst. Čs. Republ., 15, *399—612*. Praha.

— (1951): Příspěvek k poznání tzv. algonkických slepenců ze severozápadní části Železných hor. — Sbor. Ústř. Úst. geol., Odd. geol., 18, *117—135*. Praha.

— (1970): Silurské a devonské diabasy Barrandienu. — Sbor. geol. Věd, Geol., 17, *7—89*. Praha.

— (1971a): The Upper Proterozoic and Lower Palaeozoic geosynclinal volcanism of the Barrandian area and the Železné hory Mts. — Krystalinikum, 8, *7—25*. Praha.

— (1971b): Ordovický diabasový vulkanismus a biotitické lamprofyry Barrandienu. — Sbor. geol. Věd, Geol., 19, *7—97*. Praha.

— (1972): Konglomerate jungproterozoischer Flyschfazies im nordwestlichen Flügel des Barrandiums. — Věst. Ústř. Úst. geol., 47, 1, *1—12*. Praha.

— (1976): The Silurian doleritic diabases and ultrabasic rocks of the Barrandian area. — Krystalinikum, 12, *47—77*. Praha.

— (1977): Proterozoický vulkanismus Barrandienu a problematika spilitů. — Sbor. geol. Věd, Geol., 30, *7—247*. Praha.

— (1978): Proterozoic and Early Palaeozoic volcanism of the Barrandian—Železné hory zone. — Sbor. geol. Věd, Geol., 31, *71—90*. Praha.

— (1980): Valouny granitoidů ze spodnokambrických žiteckých slepenců. — Čas. Mineral. Geol., 25, 4, *351—368*. Praha.

Fiala F. - Svoboda J. (1956): Problém subkambria a subkambrického zalednění v Železných horách. — Sbor. Ústř. Úst. geol., Odd. geol., 22, *257—304*. Praha.

— (1957): Geologicko-petrografické poměry algonkia mezi Telčicemi a Týncem n. L. v Železných horách. — Sbor. Ústř. Úst. geol., Odd. geol., 23, 2, *475—532*. Praha.

Fischer G. - Troll G. (1973): Bauplan und Gefügeentwicklung metamorpher und magmatischer Gesteine des Bayerischen Waldes. — Geologica bavar., 68, *7—44*. München.

Fišera M. (1977): Nález safirín-flogopit-pyroxen-pyrop-cordieritové skaliny v moldanubiku. — Čas. Mineral. Geol., 22, 4, *428—429*. Praha.

Frasl G. - Scharbert G. - Wieseneder H. (1968): Crystalline complexes in the southern parts of the Bohemian Massif and in the Eastern Alps. — Int. Geol. Congr., Sess. 23, Prague 1963., Guide to Excursion 32 C, Wien, Austria.

Frič A. (1879—1901): Fauna der Gaskohle und der Kalksteine der Perm-Formation Böhmens, I—IV. — Praha.

— (1912): Studie v oboru českého útvaru křídového. — Arch. přírodověd. Prozk. Čech, 15, 2. Praha.

Fuchs G. (1976): Zur Entwicklung der Böhmischen Masse. — Jb. Gol. Bundesanst., 119, *45—61*. Wien.

Gabriel M. et al. (1982): Miocén ve vrtu Vidnava Z-1. — Sbor. geol. Věd, Geol., 36, *115—137*. Praha.

Galle A. - Chlupáč I. (1976): Finds of corals in the metamorphic Devonian of the Ještědské pohoří Mts. — Věst. Ústř. Úst. geol., 51, 2. *123—127*. Praha.

Gebauer D. - Grünenfelder H. (1974): Vergleichende U/Pb- und Rb/Sr-Altersbestimmungen im bayerischen Teil des Moldanubikums. — Fortschr. Mineral., 50, 3. Stuttgart.

— (1977): U—Pb systematics of detrital zircons from some unmetamorphosed to slightly metamorphosed sediments of Central Europe. — Contr. Mineral. Petrology, 65, *29—37*. Berlin — New York.

Gentner W. - Kleinman B. - Wagner G. A. (1967): New K—Ar and fission—track ages of impact glasses and tectonites. — Earth planet. Sci. Lett., 2, *83—86*. Amsterdam.

Goldbachová Z. - Svoboda J. (1930): Zpráva o nálezu graptolitů v siluru Železných hor u Vápenného Podola. — Věst. St. geol. Úst. Čs. Republ., 6, *4—6*. Praha.

Gorochov I. M. et al. (1977): Rb-Sr vozrast porod kaplickoj gruppy moldanubikuma v južnoj Čechii. *In:* Opyt korreljacii magmatičeskich i metamorfičeskich porod, *73—80*. — Nauka. Moskva.

Grauert B. - Haenny R. - Soptrajanova G. (1973): Age and origin of detrital zircons from the pre-Permian basement of the Bohemian Massif and the Alps. — Contr. Mineral. Petrology, 40, *105—130*. Berlin — New York.

Haake R. (1973): Zur Altersstellung der Granodiorite der westlichen Lausitz und angrenzender Gebiete. — Z. geol. Wiss., 1. *1669—1771*. Berlin.

Hanzlíková E. (1976): Biostratigraphy of the Cretaceous and Palaeogene Flysch in the borehole Jarošov-1. — Věst. Ústř. Úst. geol.. 51, 3. *153—162*. Praha.

Havlena V. (1964): Geologie uhelných ložisek, 2. — Nakl. Čs. akad. věd. Praha.

— (1976): Late Paleozoic paleogeography of Czechoslovakia and the Plzeň Basin. — Folia Mus. Rer. natur. Bohem. occident.. Geol., 7, *1—31*. Plzeň.

Havlena V. - Pešek J. (1980): Stratigrafie, paleogeografie a základní struktury členění limnického permokarbonu Čech a Moravy. — Sbor. Západočes. Muz., Přír., 34, *1—144*. Plzeň.

Havlena V. - Šattran V. (1978): Problémy středoevropských variscid. Úvaha nad sborníkem Franz Kossmat—Symposion 1976. — Čas. Mineral. Geol., 23, 4, *337—348*. Praha.

Havlíček P. (1980): Vývoj terasového systému řeky Moravy v hradišťském příkopu. — Sbor. geol. Věd, Antropozoikum, 13, *93—125*. Praha.

Havlíček P. - Zeman A. (1980): Kvartérní poměry mezi Kobylím, Brumovicemi a Čejčí na jihovýchodní Moravě. — Sbor. geol. Věd, Antropozoikum, 12, *31—55*. Praha.

Havlíček V. (1971): Stratigraphy of the Cambrian of central Bohemia. — Sbor. geol. Věd, Geol., 20, *7—52*. Praha.

— (1977): The Palaeozoic (Cambrian—Devonian) in the Rožmitál area. — Věst. Ústř. Úst. geol., 52, 2, *81—94*. Praha.

— (1980): Vývoj paleozoických pánví v Českém masívu (kambrium—spodní karbon). — Sbor. geol. Věd, Geol., 34, *31—65*. Praha.

— (1981): Development of a linear sedimentary depression exemplified by the Prague Basin (Ordovician—Middle Devonian, Barrandian area — central Bohemia). — Sbor. geol. Věd, Geol., 35, *7—43*. Praha.

— (1982): Ordovician of Bohemia: Development of Prague Basin and its communities. — Sbor. geol. Věd, Geol., 32, *103—136*. Praha.

Havlíček V. - Marek L. (1973): Bohemian Ordovician and its international correlation. — Čas. Mineral Geol., 18, 2, *225—232*. Praha.

Havlíček V. - Šnajdr M. (1951): O střednokambrické a ordovické fauně Železných hor. — Věst. Ústř. Úst. geol., 26, 4, *293—308*. Praha.

— (1955): Některé problémy paleogeografie středočeského ordoviku. — Sbor. Ústř. Úst. geol., Odd. geol., 21, 1, *449—518*. Praha.

Havlíček V. - Vaněk J. (1966): The biostratigraphy of the Ordovician of Bohemia. — Sbor. geol. Věd, Paleont., 8, *7—67*. Praha.

Holub V. (1965): Permokarbon v podloží křídy na Mělnicku. — Sbor. geol. Věd, Geol., 9, *89—98*. Praha.

— (1972): Permian of the Bohemian Massif. *In:* H. Falke: Rotliegend. Essays on European Lower Permian, *137—188*. — E. J. Brill. Leiden.

— (1979): Late Paleozoic deposits underlying the Bohemian Cretaceous Basin in the north-eastern part of the Bohemian Massif. — C. R. 6e Congr. int. Stratigr. Géol. Carbon., Sheffield 1967, *937—948*. Maastricht.

Holub V. - Kozur H. (1981a): Die Korrelation des Rotliegenden Europas. — Geol.-Paläont. Mitt., 11, 5, *195—242*. Innsbruck.

— (1981b): Revision einiger Conchostraceen-Faunen des Rotliegenden und biostratigraphische Auswertung der Conchostraceen des Rotliegenden. — Geol.-Paläont. Mitt., 11, 2, *39—94*. Innsbruck.

Holub V. - Kozur H. (1981c): Revision einiger Tetrapodenfährten des Rotliegenden und biostratigraphische Auswertung der Tetrapodenfährten des obersten Karbons und Perms. — Geol.-Paläont. Mitt., 11, 4, *149—193*. Innsbruck.

Holub V. - Prouza V. - Tásler R. (1965): Neue lithostratigraphische Gliederung des Oberkarbons im böhmischen (SW-) Flügel des Innersudetischen Beckens. — Čas. Mineral. Geol., 10, 3, *331—336*. Praha.

Holub V. - Skoček V. - Tásler R. (1981): Nová litostratigrafická jednotka permského stáří v permokarbonu středočeské oblasti. — Věst. Ústř. Úst. geol., 56, 4, *193—201*. Praha.

Holub V. - Tásler R. (1978): Filling of the Late Palaeozoic continental basins in the Bohemian Massif as a record of their palaeogeographical development. — Geol. Rdsch. 67, *91—109*. Stuttgart.

Holubec J. (1966): Stratigraphy of the Upper Proterozoic in the core of the Bohemian Massif (the Teplá—Barrandian region). — Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 76, 4. Praha.

— (1973): The tectonic units in the core of the Bohemian Massif. — Sbor. geol. Věd, Geol., 26, *105—111*. Praha.

Horný R. (1956): Nové poznatky o biostratigrafii skutečsko-hlinského siluru. — Věst. Ústř. Úst. geol., 31, 2, *128—131*. Praha.

— (1962): Das mittelböhmische Silur. — Geologie, 11, *873—916*. Berlin.

— (1964): Noví graptoliti z metamorfovaného siluru v Podkrkonoší. — Čas. Nár. Muz., Odd. přírodověd., 133, *1—224*. Praha.

Hrdličková D. (1966): Ignimbrite volcanism in the Broumov area in north-eastern Bohemia. *In:* Paleovolcanites of the Bohemian Massif, *191—200*. — Univ. Karlova. Praha.

Hurník S. - Prokš M. (1977): Původ deformací miocenních vrstev u Duchcova v severočeské hnědouhelné pánvi. — Čas. Mineral. Geol., 22, 1, *49—56*. Praha.

Ibrmajer J. (1978): Tíhové mapy ČSSR a jejich geologický výklad. — MS přírodověd. fak. Univ. Karl. Praha.

Ibrmajer J. - Doležal J. (1959): Zhodnocení gravimetrických měření, provedených v československé části Vídeňské pánve. — Geofys. Sbor., 1958, 72—98, *133—145*. Praha.

Jäger E. (1971): The history of central and western Europe. — Ric. Soc. ital. Mineral. Petrologia, 27, 2, *241—247*. Milano.

— (1977): The evaluation of the Central and West-European continent. *In:* La chaîne Varisque d'Europe moyenne et occidentale. — Coll. intern. CNRS, 243, *227—239*. Rennes.

Jahn J. J. (1896): Über die geologischen Verhältnisse des Kambriums von Tejřovice and Skrej in Böhmen. — Jb. K.-Kön. geol. Reichsanst., 45, *641—791*. Wien.

— (1898): O silurském útvaru ve východních Čechách. — Věst. Král. Čes. Společ. Nauk, Tř. mat.-přírodověd., 13, *1—25*. Praha.

Jakeš P. (1973): Ofiolity: tektonicky z oceánického dna nebo netektonicky z ostrovních oblouků. — Věst. Ústř. Úst. geol., 48, 6, *359—364*. Praha.

Jakeš P. (1978): Paleovulkanity Českého masivu a petrometalogeneze. *In:* Teoretické základy prognóz nerostných surovin v ČSSR, *34—39*. — Přírodověd. fak. Univ. Karl. Praha.

Jakeš P. - Zoubek J. - Zoubková J. - Franke W. (1979): Greywackes and metagreywackes of the Teplá—Barrandian Proterozoic area. — Sbor. geol. Věd, Geol., 33, *83—122*. Praha.

Jaroš J. - Mísař Z. (1968): Stratigrafické postavení vápenců na Tišnovsku. — Věst. Ústř. Úst. geol., 43, 1, *9—13*. Praha.

— (1974): Deckenbau der Svratka-Kuppel und seine Bedeutung für das geodynamische Modell der Böhmischen Masse. — Sbor. geol. Věd, Geol., 26, *69—82*. Praha.

— (1976): Nomenclature of the tectonic and lithostratigraphic units in the Moravian Svratka Dome (Czechoslovakia). — Věst. Ústř. Úst. geol., 51, 2, *113—133*. Praha.

Jenček V. - Dudek A. (1971): Beziehungen zwischen dem Moravikum und Moldanubikum am Westrand der Thaya-Kuppel. — Věst. Ústř. Úst. geol., 46, 6, *331—338*. Praha.

Jenček V. - Vajner V. (1968): Stratigraphy and relations of the groups in the Bohemian part of the Moldanubicum. — Krystalinikum, 6, *105—124*. Praha.

Jindřich V. (1960): Příkrovová troska buližníkové jednotky středočeského algonkia na Kladensku, u Žiliny a Lhotky. — Čas. Mineral. Geol., 5, 4, *467—469*. Praha.

Jiříček R. (1979): Diskrepantní vývoj severní větve alpinského orogénu. — Zem. Plyn Nafta, 24, 4, *566—567*. Hodonín.

Johnson G. (1973): Closing of the Carboniferous sea in western Europe. *In:* Implications of continental drifts to the earth sciences., 2, *843—850*. — Academia Press. London.

Jones B. G. - Carr P. F. - Wright A. J. (1980): Silurian and Early Devonian geochronology — a reappraisal with new evidence from the Bungonia Limestone. — Alcherings. 5, *197—207*. Sydney.

Jurková A. (1959): Nové poznatky o morfologii karbonu a miocenních bazálních klastikách v závislosti na tektonickém vývoji Ostravska. — Sbor. prací konference o geologii OKR, *173—178*. Ostrava.

— (1976): Stavba karpatské předhlubně a flyšových příkrovů na sv. Moravě. — Čas. Mineral. Geol., 21, 4, *349—362*. Praha.

— (1981): Strukturně stratigrafický vrt Čeladná SV-6. — Sbor. GPO, 23, *57—83*. Ostrava.

Jurková A. - Novotná E. (1974): Facie a stavba karpatu na sv. Moravě. — Sbor. GPO, 7, *73—88*. Ostrava.

Kadlec E. - Odstrčil J. - Šalanský K. (1978): Souhrnné zpracování geofyzikálních podkladů z oblasti jihočeských pánví. — MS Ústř. úst. geol. Praha.

Kalášek J. et al. (1963): Vysvětlivky k přehledné geologické mapě ČSSR 1 : 200 000 M-33-XXIX Brno. — Ústř. úst. geol. Praha.

Kamarád L. - Malkovský M. (1955): Zpráva o geologickém mapování v okolí Krásného Dvorečka a Rokle. — Zpr. geol. Výzk. v Roce 1954, *70—74*. Praha.

Kapounek J. - Kröll A. - Papp A. - Turnovský K. (1965): Die Verbreitung von Oligozän, Unter- und Mittelmiozän in Niederösterreich. — Erdöl-Erdgas-Z., 81, 4, *109—116*. Wien.

Kettner R. (1960): Morfologický vývoj Moravského krasu a jeho okolí. — Čs. Kras, 12, *47—84*. Praha.

Kettner R. - Dudek A. (1956): Vosnické slepence ve skryjsko-týřovickém kambriu. — Sbor. Ústř. Úst. geol., Odd. geol., 31, *133—157*. Praha.

Kettner R. - Remeš M. (1935): Objev silurských břidlic s graptolitovou faunou na Moravě. — Věst. Král. Čes. Společ. Nauk, Tř. mat.-přírodověd., *1—11*. Praha.

Kheil J. (1965): Pleistocenní ostrakodi z travertinů v Tučíně u Přerova. — Věst. Ústř. Úst. geol., 40, 6, *409—417*. Praha

Klápová H. (1977): Petrochemie a metamorfóza metabazitů strážeckého moldanubika — MS přírodověd. fak. Univ. Karl. Praha.

Klein V. (1978): Stavba a morfologie podloží křídy západně od Hradce Králové. — Věst. Ústř. Úst. geol., 53, 6, *357—372*. Praha.

Klein V. - Müller V. - Valečka J. (1979): Lithofazielle und paläogeographische Entwicklung des Böhmischen Kreidebeckens. — Aspekte der Kreide Europas, IUGS Series A. 6. *435—446*. Stuttgart.

Klomínský J. (1961): Nález alkalicko-syenitických hornin s kankrinitem v čisteckém masívu. — Věst. Ústř. Úst. geol., 36, 6, *355—356*. Praha.
— (1963): Geologie čisteckého masívu. — Sbor. geol. Věd, Geol., 3, *7—29*. Praha.
— (1969): Krkonošsko-jizerský granitoidní masív. — Sbor. geol. Věd, Geol., 15, *1—134*. Praha.

Klomínský J. - Bernard J. H. (1974): Segmentation of the Bohemian Massif in the light of Variscan magmatism and metallogeny. — Věst. Ústř. Úst. geol., 49, 3, *149—158*. Praha.

Klomínský J. - Dudek A. (1978): The plutonic geology of the Bohemian Massif and its problems. — Sbor. geol. Věd, Geol., 31, *47—69*. Praha.

Knobloch E. (1962): Paleogenní flóra z Českého Chloumku u Karlových Var. — Sbor. Ústř. Úst. geol., Odd. paleont., 27, *101—158*. Praha.
— (1965): Hlavní rysy středoevropských pliocenních květen. — Čas. Mineral. Geol., 10, 4, *456—467*. Praha.
— (1971): Neue Pflanzenfunde aus dem böhmischen und mährischen Cenoman. — Neu. Jb. Geol. Paläont., Abh., 139, 1, *43—56*. Stuttgart.

Kodym O., Jun. (1972): Multiphase deformation in the Blanský les granulite massif (South Bohemia). — Krystalinikum, 9, *91—105*. Praha.

Kodym O., Jun. - Suk M. (1961): Příspěvek k poznání migmatitizace moldanubika na Klatovsku. — Věst. Ústř. Úst. geol., 35, 3, *135—140*. Praha.

Kodym O., Sen. (1963): Geologie Československa. *In:* Bouček B. - Kodym O., Sen.: Geologie. II. *299—621*. — Nakl. Čs. akad. věd. Praha.

Kodym O., Sen. - Svoboda J. (1948): Kaledonská příkrovová stavba Krkonoš a Jizerských hor. — Sbor. St. geol. Úst. Čs. Republ., 15, *109—160*. Praha.

Kodymová A. (1977): Occurrence of pink (Archean?) zircon in the pre-Cambrian of central and western Bohemia. — Věst. Ústř. Úst. geol., 52, *121—123*. Praha.

Köhler H. - Müller-Sohnius H. (1979): Rb-Sr systematics on paragneiss series from Bavarian Moldanubicum. — Contr. Mineral. Petrology, 71, *387—392*. Berlin — New York.

Kölbel H. (1954): Große Seitenverschiebungen und Horizontalflexures im deutschen Grundgebirge und ihre lagerstättenkundliche Bedeutung. — Geologie, 3, 4, *445—450*. Berlin.

Koliha J. (1929): Svrchní devon v pohoří Ještědském. — Věst. Stát. geol. Úst. Čs. Republ., 5, 4, *286—292*. Praha.

Konzalová M. (1973): Neogenní rostlinné mikrofosilie z říčních sedimentů v podloží neovulkanitů na Železnobrodsku. — Věst. Ústř. Úst. geol., 48, 1, *17—23*. Praha.
— (1978): Some results of micropaleontological research in the East Sudetic sedimentary sequence. — Čas. Mineral. Geol., 23, 4, *389—394*. Praha.
— (1980): Zu der mikropaläontologischen Erforschung graphitischer Gesteine in Südteil der Böhmischen Masse. — Věst. Ústř. Úst. geol., 55, 4, *233—236*. Praha.

Konzalová M. - Vachtl J. (1976): On the age of the Rychmburk Greywacke. — Věst. Ústř. Úst. geol., 51, 3, *129—138*. Praha.

Kopecký A. (1966): Zpráva o výzkumu mladých tektonických pohybů na území ČSSR za rok 1965. — Zpr. geol. Výzk. v Roce 1965, 1, *298—299*. Praha.
— (1972): Hlavní rysy neotektoniky Československa. — Sbor. geol. Věd, Antropozoikum, 6, *77—155*. Praha.

Kopecký L. (1964): Výzkum neovulkanitů I. a II. sopečné fáze na Teplicku. — Zpr. geol. Výzk. v Roce 1963, 1, *194—197*. Praha.
— (1966): Nález fenitů a hlubinných alkalických hornin v Českém středohoří. — Věst. Ústř. Úst. geol., 41, 2, *121—125*. Praha.
— (1971a): Pyrope-bearing diatremes of the Bohemian Massif. *In:* Upper Mantle project programme in Czechoslovakia 1962—1970, *18—24*. — Academia. Praha.
— (1971b): Relationship between fenitization, alkaline magmatism, barite—fluorite mineralization and deep-fault tectonics in the Bohemian Massif. *In:* Upper Mantle project programme in Czechoslovakia 1962—1970, *73—76*. — Academia. Praha.
— (1978): Neoidic taphrogenic evolution and young alkaline volcanism of the Bohemian Massif. — Sbor. geol. Věd, Geol., 31, *91—107*. Praha.

Kopecký L. - Dobeš M. - Fiala J. - Šťovíčková N. (1970): Fenites of the Bohemian Massif and the relation between fenitization, alkaline volcanism and deep tectonics. — Sbor. geol. Věd, Geol., 16, *51—122*. Praha.

Kopecký L. - Malkovský M. (1958): O nálezech melafyru v kladensko-rakovnickém permokarbonu. — Věst. Ústř. Úst. geol., 33, 4, *198—201*. Praha.

Kopecký L. - Šattran V. (1966): Buried occurrences of pyrope-peridotite and the structure of the crystalline basement in the extreme SW of the České středohoří Mountains. — Krystalinikum 4, *65—86*. Academia. Praha.

Kostelníček P. - Řehánek J. - Holzknecht M. (1979): Mesozoikum v oblasti Uhřice. — Zem. Plyn Nafta, 24, 2, *315—327*. Hodonín.

Koutek J. (1927): K otázce hloubky jurského moře u Brna. — Čas. Vlasten. Spol. mus., 38, *1—5*. Olomouc.
— (1966): Granulity (= leptynity) a „granulity“ v kutnohorském krystaliniku. — Zpr. geol. Výzk. v Roce 1964, 1, *1—36*. Praha.
— (1967): Geologie kutnohorského rudního obvodu. — Sbor. Obl. Muz., Ř. B, 8—9, *1—80*. Kutná Hora.

Kovanda J. (1971): Kvartérní vápence Československa. — Sbor. geol. Věd, Antropozoikum, 7, *1—236*. Praha.

Kovanda J. - Smolíková L. - Fejfar O. (1982): Erforschung des Basalteiles einer pleistozänen Schichtenfolge am Hang der Kurovice-Klippe (Mittelmähren). — Sbor. geol. Věd, Antropozoikum, 14, *29—55*. Praha.

Koverdynský B. - Zikmundová J. (1966): K stratigrafické příslušnosti vrbenské série a andělskohorských vrstev v oblasti Jeseníků. — Věst. Ústř. Úst. geol., 41, 5, *367—373*. Praha.

Král V. (1976): Silcretes and their relationship to planation surface in western Bohemia. — Sbor. Čs. Společ. zeměvěd., 1, 81, *19—21*. Praha.

Králík F. - Sekyra J. (1969): Geomorfologický přehled Krkonoš. *In:* Příroda Krkonošského národního parku, *59—87*. — Stát. zeměd. nakl. Praha.

Krebs W. (1976): Wiederholter Magmenaufstieg und die Entwicklung variszischer und postvariszischer Strukturen in Mitteleuropa. — Nova Acta, leopold., 45, *23—30*. Jena.

Krebs W. - Wachendorf H. (1973): Proterozoic—Palaeozoic geosynclinal and orogenic evolution of Central Europe. — Geol. Soc. Amer. Bull., 84, 8, *2611—2630*. New York.

Kříž J. (1979): Revision of the Lower Silurian stratigraphy in central Bohemia. — Věst. Ústř. Úst. geol., 59, 5, *275—283*. Praha.

Kříž J. et al. (1983): The Přídolí Series as the fourth Series of the Silurian System. — Intern. Subcommission on Silurian Stratigraphy, *1—59*. MS Ústř. Úst. geol. Praha.

Krupička J. (1968): The contact zone in the north of the Moldanubian Pluton. — Krystalinikum, 6, *7—39*. Praha.

Krystek I. (1959): Příspěvek k poznání geneze a stáří rudických vrstev. — Čs. Kras, 1, *22—23*. Praha.
— (1972): Předběžná zpráva o nálezu spodno-střednokřídových vápenců u Kuřimi. — Geol. Práce, Spr., 58, *1—256*. Bratislava.

Krystek I. - Samuel A. (1979): Výskyt křídy karpatského typu severně od Brna (Kuřim). — Geol. Práce, Spr., 71, *93—109*. Bratislava.

Kukal Z. (1962): Petrografický výzkum vrstev šáreckých barrandienského ordoviku. — Sbor. Ústř. Úst. geol., Odd. geol., 27, *175—214*. Praha.
— (1963): Výsledky sedimentologického výzkumu barrandienského ordoviku. — Sbor. geol. Věd, Geol., 1, *103—138*. Praha.
— (1966): Zdroje klastického materiálu sedimentů příbramsko-jineckého kambria. — Sbor. geol. Věd, Geol., 10, *83—116*. Praha.
— (1971a): Sedimentology of Cambrian deposits of the Barrandian area (central Bohemia). — Sbor. geol. Věd, Geol., 20, *53—100*. Praha.
— (1971b): Geology of Recent sediments. — *1—490*, Academic Press. London — Paris — New York.
— (1980): The sedimentology of Devonian and Lower Carboniferous deposits in the western part of the Nízký Jeseník Mountains, Czechoslovakia. — Sbor. geol. Věd, Geol., 34, *131—207*. Praha.
— (in press): Vývoj sedimentů Českého masívu. — Knih. Ústř. Úst. geol., 61. Praha.

Kukla J. - Ložek V. (1961): Survey of Czechoslovak Quaternary: Loesses and related deposits. — Prace Inst. geol., 34, *11—20*. Warszawa.

Kumpera O. (1976): Stratigrafie spodního karbonu jesenického bloku. — Sbor. věd. Prací Vys. Šk. báň. Ř. horn.-geol., 20, 1974, 3, *133—154*. Ostrava.
— (1977): Stratigrafie spodního karbonu jesenického bloku (2. část: Kulmská souvrství a jejich stratigrafické ekvivalenty). — Sbor. věd. Prací Vys. Šk. báň., Ř. horn.-geol., 22, 1, *141—170*. Ostrava.
— (1979a): Faunisticky doložené řezy kulmskými sériemi Nízkého Jeseníku. — Přírodověd. Sbor., *229—244*. Ostrava.
— (1979b): Some features of the paleidic development of the Bohemian Massif. *In:* Czechoslovak geology and global tectonics. *77—88*. — Veda. Bratislava.
— (1981): Některé tektogenetické problémy východního okraje Českého masívu. — Sbor. věd. Prací Vys. Šk. báň., Ř. horn.-geol., 25, 2, *223—234*. Ostrava.

Kumpera O. - Lang V. (1975): Goniatitová fauna v kulmu Drahanské vysočiny (moravskoslezská zóna Českého masívu). — Čas. Slez. Muz., Sér. A, 24, 1, *11—32*. Opava.

Kunský J. (1968): Fyzický zeměpis Československa. — Stát. pedag. nakl. Praha.

Květoň P. (1951): Zpráva o geologickém mapování některých oblastí vnějších fylitů moravské skupiny. — Věst. Ústř. Úst. geol., 26, *59—61*. Praha.

Lang V. - Chlupáč I. (1975): New finds of trilobites in the Culm of the Drahanská vrchovina Upland (Moravia, Czechoslovakia). — Věst. Ústř. Úst. geol., 50, 6, *337—344*. Praha.

Laurent R. (1972): The Hercynides of South Europe, a model. — 24th IGC Toronto, sect. 3, *363—370*. Toronto.

Legierski J. - Vaněček M. (1965): The use of isotopic composition of common lead for the solution of metallogenetic problems of the Czech Massif. — Krystalinikum, 3, *87—98*. Praha.

Liebus A. (1929): Über die Säugetierfauna der Quartärablagerungen aus der Umgebung von Aussig a. d. E. — Lotos, 77, *117—146*. Praha.

Lorenz W. - Hoth K. (1964): Die lithostratigraphische Gliederung des kristallinen Vorsilurs in der fichtelgebirgisch-erzgebirgischen Antiklinalzone. — Akademie-Verlag. Berlin.

Losert J. (1967): Contribution to the problem of the pre-Assyntian tectogenesis and metamorphism in the Moldanubicum of the Bohemian Massif. — Krystalinikum, 5, *61—84*. Praha.

— (1968): On the genesis of nodular sillimanitic rocks. — Int. geol. Congr., Sess. 23, 4, *109—122*. Praha.

— (1971): On the volcanogenous origin of some Moldanubian leptynites. — Krystalinikum, 7, *61—84*. Praha.

Losert J. et al. (1977): Leptinity karelsko-kolskoj časti Baltijskogo ščita i Češskogo massiva. *In:* Opyt korreljacii magmatičeskich i metamorfičeskich porod, *5—72*. — Nauka. Moskva.

Ložek V. (1961): Survey of Czechoslovak Quaternary: Mollusca. — Prace, Inst. geol., 34, Czwart. Eur. środk. i wschod., I, *119—124*. Warszawa.

— (1973): Příroda ve čtvrtohorách. — *372* pp., Academia. Praha.

— (1974): Příroda Českého krasu v nejmladší geologické minulosti. — Bohemia cent., 3, *163—174*. Praha.

— (1977): Holocén — geologická současnost. — Vesmír, 56, 11, *328—335*. Praha.

Ložek V. - Fejfar O. (1957): K otázce staropleistocenní fauny ze Stránské skály u Brna. — Věst. Ústř. Úst. geol., 32, 5, *290—294*. Praha.

Ložek V. - Prošek F. (1957): Krasové zjevy v travertinech a jejich stratigrafický význam. — Čs. Kras, 10, 4, *145—158*. Praha.

Ložek V. - Šibrava V. (1968): Zur Altersstellung der jüngsten Labe-Terrassen. — Sbor. geol. Věd, Antropozoikum, 5, *7—31*. Praha.

Ložek V. - Tyráček J. (1958): Stratigrafický výzkum travertinu v Tučíně u Přerova. — Anthropozoikum, 7, *261—286*. Praha.

Lysenko V. - Slačík J. (1981): Výsledky a závěry výzkumů Českého krasu uskutečněné v letech 1970—1980 skupinou Tarcus. *In:* Sbor. prací ze semináře ke stému výročí narození Jaroslava Petrboka. — Čes. speleol. společ. Praha.

Macák F. - Müller V. (1968): Stratigrafie a paleogeografie křídového útvaru v sz. Čechách. — Čas. Mineral. Geol., 13, 1, *37—46*. Praha.

Machatschek F. (1917): Morphologie der Südabdachung des böhmischen Erzgebirges. — Mitt. Geogr. Gesell., 60, *235—244, 273—316*. Wien.

Macoun J. (1980): Paleogeografický a stratigrafický vývoj Opavské pahorkatiny v pleistocénu, I, 2. — Čas. Slez. Muz., Sér. A, 29, *113—132, 193—222*. Opava.

Macoun J. - Růžička M. (1967): The Quaternary of the Upper Moravian Basin in the relation to the sediments of the continental glaciation. — Sbor. geol. Věd, Antropozoikum, 4, *125—168*. Praha.

Macoun J. - Šibrava V. - Tyráček J. - Kneblová-Vodičková V. (1965). Kvartér Ostravska a Moravské brány. — *1—419*, Academia. Praha.

Mahel M. (1974): Tectonics of the Carpathian—Balkan regions. — Geol. úst. D. Štúra. Bratislava.

Malecha A. et al. (1965): Stavba a podloží jihočeských pánví. — Sbor. geol. Věd, Geol., 4, *97—117*. Praha.

Malkovský M. (1975): Palaeogeography of the Miocene of the Bohemian Massif. — Věst. Ústř. Úst. geol., 50, 1, *27—31*. Praha.

— (1979): Tektogeneze platformního pokryvu Českého masivu. — Knih. Ústř. Úst. geol., 53, *1—176*. Praha.

— (1980): Les bassins sédimentaires post-hercyniens d'Europe Centrale. *In:* Géologie de l'Europe. — Mém. Bur. Rech. géol. min., 108, *289—295*. Orléans.

Malkovský et al. (1974): Geologie české křídové pánve a jejího podloží. — *264* pp., Ústř. úst. geol. Praha.

Mašek J. (1973): Vulkanické produkty středočeského karbonu. — Sbor. geol. Věd. Geol., 24, *73—124*. Praha.

Mašek J. - Zoubek J. (1980): Návrh vymezení a označování hlavních stratigrafických jednotek barrandienského proterozoika. — Věst. Ústř. Úst. geol., 55, 2, *121—123*. Praha.

Mašín J. (1966): The regional magnetic anomalies in Czechoslovakia. — Věst. Ústř. Úst. geol., 41, *55—57*. Praha.

Matějka A. (1949): Geologická studie z okolí Valašského Meziříčí. — Sbor. Stát. geol. Úst. Čs. Republ., 16, *643—693*. Praha.

— (1956): Zpráva o geologických výsledcích sondovacích prací v údolí Bečvy mezi Valašským Meziříčím a Černotínem. — Zpr. geol. Výzk. v Roce 1955, *116—119*, Praha.

Matějka A. - Roth Z. (1956): Geologie magurského flyše v severním povodí Váhu mezi Bytčou a Trenčínem. — Rozpr. Ústř. Úst. geol., 22. Praha.

Matějovská O. (1967): Petrogenesis of he Moldanubian granulites near Náměšť nad Oslavou. — Krystalinikum, 5, *85—103*. Praha.

— (1975): The Moldanubian gneiss series of south-western Moravia and its relation to granulites. — Věst. Ústř. Úst. geol., 50, 6, *345—351*. Praha.

Mazancová M. (1958): Palynologický výzkum hnědouhelného ložiska Uhelná u Javorníka ve Slezsku. — Čas. Mineral. Geol., 3, 4, *417—419*. Praha.

McLaren D. J. (1977): The Silurian—Devonian Boundary Committee. A final report. — Int. Union Geol. Sci. Ser. A, 5, *1—34*. Stuttgart.

Menčík E. (1964): Geologická stavba mezi slezským a magurským příkrovem v oblasti Bílé. — Geol. Práce, Zpr., 38, *99—110*. Bratislava.

— (1973): Problematika předmagurské jednotky v Moravskoslezských Beskydech. — Věst. Ústř. Úst. geol., 48, 2, *73—77*. Praha.

— (1979): Předpříkrovové projevy vrásnění v dílčím godulském příkrovu slezské jednotky v Moravskoslezských Beskydech. *In:* Seminář k 60. výročí založení ÚÚG. — MS Ústř. Úst. geol. Praha.

Mísař Z. (1959): Geologicko-petrologická studie šumperského granodioritového tělesa. — Sbor. Ústř. Úst. geol., Odd. geol., 25, *335—376.* Praha.

— (1963): Metasomatic granitization and its zonation in the Keprník anticline. — Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 73, 9. Praha.

— (1961): Geologické postavení bítešské ortoruly. — Čas. Mineral. Geol., 6, 3, *289—296.* Praha.

— (1963): Geologické postavení a vývoj leukokratních ortorul v okolí Víru. — Sbor. Ústř. Úst. geol., Odd. geol., 28, *31—52.* Praha.

— (1974): Feeding channels of pre-Triassic ultrabasic rocks in the Bohemian Massif. — Krystalinikum, 10, *133—147.* Praha.

Mísař Z. et al. (1972): Interpretace tíhového pole moldanubika a přilehlých jednotek. — Sbor. geol. Věd, užitá Geofyz., 10, *7—34.* Praha.

— (1974): The Ransko gabbro-peridotite massif and its mineralization. — Univ. Karlova. Praha.

— (1982): Regionální geologie Československa I., Geologie Českého masívu. — *1—380,* Stát. pedag. nakl. Praha.

Morel W. - Irving M. (1978): Tentative paleocontinental maps for the Early Phanerozoic and Proterozoic. — J. Geol., 86, *535—561.* Chicago.

Mottlová L. (1969): Model hlubinné stavby Českého masívu na základě gravimetrických anomálií. — Věst. Ústř. Úst. geol., 44, 4, *227—230.* Praha.

Mottlová L. - Suk M. (1970): K rozšíření granitických hornin v hlubší stavbě moldanubika. — Čas. Mineral. Geol., 15, 4, *383—392.* Praha.

Müller V. (1974): Stratigrafie a faciální vývoj české křídové pánve. *In:* M. Malkovský et al.: Geologie české křídové pánve a jejího podloží, *101—115.* — Ústř. úst. geol. Praha.

Musil R. (1966): Holštejn, eine neue altpleistozäne Lokalität in Mähren. — Čas. Morav. Muz., Vědy přír., 51, *133—168.* Brno.

— (1968): Neue Ergebnisse der Forschungen an der Lokalität Stránská skála. — Čas. Morav. Muz., Vědy přír., 53, *139—162.* Brno.

Musil R. et al. (1972): Stránská skála I. 1910—1945. — Anthropos, 20, (N. S. 12), *204* pp. Brno.

Nečaev O. N. (1968): Correlation of the Upper Proterozoic of the complexes Volhyn-Podolia and Bohemian Massif. — Geologija, 28, 5, *91—98.* Kiev.

Němcová J. (1969): Příspěvek k petrografii krystalinika v Hornomoravském úvalu II. — Sbor. Prací Univ. Palackého, Geogr. Geol., 29, *65—76.* Olomouc.

Němec D. (1973): Kvarcity české části Českomoravské vrchoviny. *In:* Sborník příspěvků ke geologickému výzkumu jihozápadní části Českomoravské vrchoviny, *39—56.* — Jihočes. muz. České Budějovice.

Němec D. - Tenčík I. (1976): Regionally metamorphosed greisen at Cetoraz, the Bohemian-Moravian Heights (Českomoravská vrchovina), Czechoslovakia. — Mineralium Depos., 11, 2, *210—217.* Berlin.

Němejc F. (1934): Kounovské čili visuté pásmo středních Čech z hlediska paleobotanického. — Horn. Věst. Horn. hutn. Listy, 16, *449—452.* Praha.

— (1953): Úvod do floristické stratigrafie kamenouhelných oblastí v ČSR. — *1—173,* Nakl. Čs. akad. věd. Praha.

Neužilová M. - Vejnar Z. (1966): Geologie a petrografie hornin kladrubského masívu. — Sbor. geol. Věd, Geol., 11, *7—31.* Praha.

Nicolas A. (1972): Was the Hercynian orogenic Belt of Europe of the Andean type? — Nature 236, 1972, *221—223.* London.

Oberc J. (1979): Der assyntische (bajkalische, kadomische) Bau des nordöstlichen Randgebietes des Böhmischen Massivs. — Neu. Jb. Geol. Paläont., Mh., 4, *237—256.* Stuttgart.

Obrhel J. (1958): Entwurf der eingehenden stratigraphischen Einteilung des oberen grauen Schichtenkomplexes im Kladno-Rakovník-Becken. — Věst. Ústř. Úst. geol., 33, 6, *370—373.* Praha.

Opletal M. et al. (1976): Przegląd wyników nowych badań geologicznych w Górach Orlickich. — Przegl. geol., 7, *414—418.* Warszawa.

Orel P. (1975): Variský tektonický styl paleozoika západní části jesenického bloku Českého masívu. — Výzk. Práce Ústř. Úst. geol., 8, *7—24.* Praha.

Pacltová B. (1962): Několik poznámek ke stratigrafickému zařazení vonšovského a novoveského souvrství v Chebské pánvi. — Čas. Mineral Geol., 7, 3, *283—287.* Praha.

— (1979): Significance of palynology for the biostratigraphic division of the Cretaceous of Bohemia. *In:* Paleontological conference, *93—115.* — Univ. Karl. Praha.

— (1980): Further micropaleontological data for the Paleozoic age of Moldanubian carbonate rocks. — Čas. Mineral. Geol., 25, 3, *275—279.* Praha.

Pacltová B. - Žert B. (1961): Palynologický výzkum v Sokolovské pánvi. — Zpr. geol. Výzk. v Roce 1960, *94—95.* Praha.

Palivcová M. (1965): The Central Bohemian Pluton — a petrographic review and an attempt at a new genetic interpretation. — Krystalinikum, 3, *99—131.* Praha.

Palivcová M. - Beneš K. - Zoubek V. et al. (1968): Genesis of granitoids in the Bohemian Massif. — Int. Geol. Congr., Sess. 23, Prague 1968, Guide to Excursion 29 AC, *1—42.* Praha.

Palivcová M. - Šťovíčková N. (1968): Volcanism and plutonism in the Bohemian Massif from the aspect of is segmented structure. — Krystalinikum, 6, *169—197.* Praha.

Pertold Z. (1961): Nález fylitů s valouny v západočeském proterozoiku. — Čas. Mineral. Geol., 6, 1, *52—59.* Praha.

— (1964): K tektonickému stylu proterozoika barrandiensko-železnohorské zóny. — Čas. Mineral. Geol., 9, 4, *441—451.* Praha.

Pertold Z. - Pouba Z. (1979): Relations between subduction and metallogenesis. *In:* Czechoslovak geology and global tectonics, *215—233.* — Veda. Bratislava.

Pešek J. (1972): Litofaciální výzkum středočeského a západočeského terciéru. — Sbor geol. Věd. Geol., 23, *113—145*. Praha.
— (1975): Volcanogenic rocks in the Carboniferous of central and western Bohemia. — Bull. Soc. belge Géol., 84, *11—121*. Bruxelles.

Pesl V. (1967): Die Vormagura-Einheit auf dem Gebiet der ČSSR. — Věst. Ústř. Úst. geol., 42, 1, *45—48*. Praha.
— (1968): Litofacie paleocénu v magurské jednotce vnějších flyšových Karpat. — Sbor. geol. Vied, Západ. Karpaty, 9, *71—117*. Bratislava.

Pesl V. - Menčík E. - Hanzlíková E. (1964): Předmagurské série jižně od Jablunkova (Moravskoslezské Beskydy). — Věst. Ústř. Úst. geol., 39, 3, *189—199*. Praha.

Petránek J. (1978): Byly variské plutony Českého masívu tak rychle obnaženy, že se staly zdrojem materiálu karbonských arkóz? — Čas. Mineral. Geol., 23, 4, *381—387*. Praha.

Petrascheck W. (1921—1923): Kohlengeologie der österreichischen Teilstaaten, I. Die kohlenführenden Formationen, III. Die mittel- und westböhmischen Steinkohlenbecken, IV. Das Rossitzer Revier und kleine Steinkohlenvorkommen in Böhmen und Mähren. — Berg- u. hüttenmänn. Jb. Montan. Hochsch. Leoben, 1. 69—70/2, *1—20*, 3. 69—70/4, *1—54*, 4. 71/2 *1—28*, 5. 71/3 *1—12*. Wien.
— (1922): Zur Entstehungsgeschichte der sudetischen Karbon- und Rotliegendablagerungen. — Z. Dtsch. geol. Gesell., *8—12*. Berlin.
— (1928): Deckentektonik und Tektonik des autochthonen Untergrundes in den Nordkarpaten. — Z. Dtsch. geol. Gesell., 80, *8—10*. Berlin.
— (1934): Der böhmische Anteil der Mittelsudeten und sein Vorland. — Mitt. Geol. Gesell., 26, *1—136*. Wien.

Pícha F. (1968): Paleogeographic reconstruction of the Carpathian flysch and molasse sedimentation basins in southern Moravia. — Čas. Mineral. Geol., 13, 2, *141—148*. Praha.

Pícha F. - Hanzlíková E. - Cahelová J. (1978): Fosil submarine Canyons of the Tethyan margins of the Bohemian Massif in southern Moravia. — Věst. Ústř. Úst. geol., 53, 5, *257—272*. Praha.

Pletánek J. - Suk M. (1976): Poznámky ke stratigrafii a stavbě jihočeského moldanubika. — Výzk. Práce Ústř. Úst. geol., 9. Praha.

Pokorný L. - Šťovíčková N. (1980): Hlubinné zlomy v centrální části Českého masívu a jejich geofyzikální indikace. — Stud. geogr., 70, *57—64*. Brno.

Polanský J. (1977): Strukturně tektonická pozice smrčinského masívu. — Geol. Průzk., 19, 8, *227—229*. Praha.

Pouba Z. (1962): Vysvětlivky k přehledné geologické mapě ČSSR 1 : 200 000 Jeseník. — MS Geofond. Praha.
— (1970): Precambrian banded magnetite ores of the Desná Dome. — Sbor. geol. Věd, ložisk. Geol., 12, *7—64*. Praha.
— (1971): Acid rocks at the contact of basic and ultrabasic intrusions with biotite gneisses (Vysoký Jeseník Mts., Czechoslovakia). — Acta Univ. Carol., Geol., 1—2, *123—139*. Praha.

Pouba Z. (1973): Korelace stratiformních ložisek v českém prekambriu. *In:* Korelace prekambrických a paleozoických stratiformních ložisek I., *36—41*. — Univ. Karl. Praha.

Poubová M. (1963): Krystalinikum Oparenského údolí a České brány. — Sbor. geol. Věd, Geol., 2, *79—99*. Praha.

Prantl F. - Růžička R. (1941): Fauna spodního tremadoku Železných hor. — Rozpr. Čes. Akad. Věd Umění, Tř. II, 51, 13, *1—36*. Praha.

Prosová M. (1974): Geneze reliktního terciéru (sv. část Českého masívu). — Přírodověd. fak. Karl. univ. Praha.

Rast N. - Grant R. (1973): Transatlantic correlation of the Variscan—Appalachian orogeny. — Amer. J. Sci., 273, *572—579*. New Haven.

von Raumer J. F. (1976): Le massif du Mont Blanc, socle prépermien dans un cadre alpin. — Bull. Soc. Frib. Sc. Nat. 65, 2, *123—155*. Fribourg.

Reading H. G. (1978): Sedimentary environments and facies. — *1—557*, Blackwell. Oxford.

Řeháková Z. (1965): Fossile Diatomeen der Südböhmischen Beckenablagerungen. — Rozpr. Ústř. Úst. geol., 32. Praha.
— (1967): Výsledky mikropaleontologického výzkumu diatomitů v oblasti Ústí nad Labem. *In:* O. Shrbený et al.: Základní geologická mapa 1 : 25 000 list Ústí nad Labem, Velké Březno, Lovosice a Litoměřice. — MS Ústř. úst. geol. Praha.
— (1969): Beitrag zur stratigraphischen Gliederung des Neogens der südböhmischen Becken. — Věst. Ústř. Úst. geol., 44, 5, *307—309*. Praha.

Řehánek J. (1978): Mikrofacie a mikrofauna (incertae sedu) písčito-glaukonitové série svrchní křídy z podloží karpatské předhlubně a vnějšího flyšového pásma na jižní Moravě. — Zem. Plyn Nafta, 23, 4, *327—340*. Hodonín.

Remy W. - Havlena V. (1962): Zur floristischen Abgrenzung von Devon, Karbon und Perm im terrestrisch-limnisch entwickelten Raum des euramerisch entwickelten Florenbereichs in Europa. — Fortsch. Geol. Rheinl. Westf., 3, *735—752*. Krefeld.

Röhlich P. (1966): On the importance of volcanites for the stratigraphy of geosynclinal sediments of the Bohemian Massif. *In:* Paleovolcanites of the Bohemian Massif, *227—236*. — Praha.

Röhlich P. - Chlupáč I. (1950): Zbytky mořského cenomanu nad Sv. Janem. — Čas. Nár. Muz., Odd. přírodověd., 118—119. *110*. Praha.

Röhlich P. - Šťovíčková N. (1968): Die Tiefenstörungstektonik und deren Entwicklung im zentralen Teil der Böhmischen Masse. — Geologie, 17, *670—694*. Berlin.

Ronov A. B. - Chain V. Ju. - Baluchovskij A. N. - Seslavinskij K. B. (1976): Izmenenija rasprostranennosti, ob"emov i skorosti nakoplenija osadočnych i vulkanogennych otloženij v fanerozoe (v predelach sovremennych materikov). — Izv. Akad. Nauk SSSR, Ser. geol., *5—12*. Moskva.

Roth Z. (1944): Skalní proudy, ledovcové kary a ledovce. — Rozpr. Čes. Akad. Věd Umění, Tř. II, 54, 30. Praha.

Roth Z. (1957): L'état actuel de nos connaissances de l'édifice de la zone du flysch des Carpates tchécoslovaques. — Int. geol. Congr., Sess. 20, *253—265*. México.

— (1960): Vztah sedimentační oblasti flyšového pásma čs. Západních Karpat k Českému masívu. — Věst. Ústř. Úst. geol., 35, 6, *383—386*. Praha.

— (1964): Das geologische Profil des Karpatenrandes zwischen den Mährisch-Schlesischen Beskiden und der Mährischen Pforte. — Mitt. Geol. Ges., 56, *503—513*. Wien.

— (1964): K strukturnímu rozdělení ČSSR. — Věst. Ústř. Úst. geol., 39, 5, *285—288*. Praha.

— (1977): Structure of the North European platform below the Carpathian Foredeep and the Carpathians in the CSR. — Věst. Ústř. Úst. geol., 52, *129—135*. Praha.

— (1978): Geology of the Moravian margin of the platform and its relations to the structure of the Carpathian Mts. — Čas. Mineral. Geol., 23, 4, *349—356*. Praha.

— (1980): Západní Karpaty — terciérní struktura střední Evropy. — Knih. Ústř. Úst. geol., 55, *1—128*. Praha.

Roth Z. et al. (1962): Vysvětlivky k přehledné geologické mapě 1 : 200 000 list Ostrava M-34-XIX. — Ústř. úst. geol. Praha.

Roth Z. - Hanzlíková E. (1982): Palaeotectonic and palaeoecological position of the Menilitic Formation in the Carpathian Mts. — Čas. Mineral. Geol., 27, 2, *113—126*. Praha.

Roth Z. - Leško M. (1974): The Outer Carpathian Flysch Belt in Czechoslovakia. *In:* M. Mahel' (ed.): Tectonics of the Carpathian—Balkan regions, *158—175*. — Geol. úst. D. Štúra. Bratislava.

Rozen O. M. (1976): Osobennosti vnutrennego stroenija nekotorych dokembrijskich massivov paleozoid. *In:* Tektonika sredinnych massivov, *223—226*. — Nauka. Moskva.

Ryka W. - Znosko J. (1978): The region of Paleozoic consolidation and metamorphism in Poland. *In:* Metamorphic map of Europe 1 : 2 500 000, Explanatory text, Leiden, *139—141*. — University Press. Leiden.

Šalanský K. (1967): Jihočeské krystalinikum v obraze leteckého geofyzikálního mapování. — Čas. Mineral. Geol., 12, 4, *403—410*. Praha.

Šattran V. (1963): Krušnohorské metakonglomeráty a jejich genetický význam. — Sbor. geol. Věd, Geol., 2, *41—62*. Praha.

— (1966): Fluidal structures in the Teplice quartz porphyry. *In:* Palaeovolcanites of the Bohemian Massif, *185—190*. — Univ. Karlova. Praha.

Šattran V. - Gorek A. et al. (1967): Crystalline and magmatic complexes of Czechoslovakia. — Int. Geol. Congr., Sess. 23, Prague 1968, Guide to Excursion 1 AC, *1—50*. Praha.

Šattran V. - Klomínský J. (1970): Petrometallogenic series of igneous rocks and endogenous ore deposits in the Czechoslovak part of the Bohemian Massif. — Sbor. geol. Věd. ložisk. Geol., 12, *65—154*. Praha.

Scharbert H. G. (1962): Die Granulite der südlichen Böhmischen Masse. — Geol. Rdsch., 52, 1, *112—123*. Stuttgart.

Scharbert H. G. (1977): Tiefe Kruste und oberer Mantel in der Moldanubischen Zone Niederösterreichs. *In:* La chaîne Varisque d'Europe moyenne et occidentale. — Coll. intern. CNRS, 243, *193—198*. Rennes.

Scharbert S. (1977): Neue Ergebnisse radiometrischer Altersbestimmungen an Gesteinen des Waldviertels. — Arbeitstagung Geol. Bundesanst., *11—13*. Wien.

Scharbert S. - Batík P. (1980): The age of the Thaya (Dyje) pluton. — Verh. Geol. Bundesanst., 3, *325—331*. Wien.

Scheumann K. (1932): Über die petrogenetische Ableitung des roten Erzgebirgsgneises. — Tschermaks. mineral. petrogr. Mitt., 42, *414—454*. Wien.

Schreyer W. (1965): Metamorpher Übergang Saxothuringikum—Moldanubikum östlich Tischenreuth/Obpf., nachgewiesen durch phasenpetrologische Analyse. — Geol. Rdsch., 55, *491—509*. Stuttgart.

Schütznerová-Havelková V. (1958): Výskyt miocenních sedimentů u Lažánek v Moravském krasu. — Věst. Ústř. Úst. geol., 33, 4, *208—211*. Praha.

Schwab F. L. (1976): Modern and ancient sedimnetary basins: Comparative accumulation rates. — Geology, 4, *723—727*. Boulder.

Scotese C. et al. (1979): Paleozoic base maps. — J. Geol. 87, *217—277*. Chicago.

Sdzuy K. (1972): Das Kambrium der acadobaltischen Faunenprovinz. Gegenwärtiger Kenntnisstand und Probleme. — Zbl. Geol. Paläont., *1—91*. Stuttgart.

Sekyra J. (1961a): Survey of Czechoslovak Quaternary: Wind-blown sands. — Prace Inst. geol., 34, Czwart. Eur. środk. i wschod., I, *29—38*. Warszawa.

— (1961b): Traces of the continental glacier on the territory of northern Bohemia: in the piedmont of West-Sudetic Mountains. — Zesz. Uniw. Wrocł., Ser. B, 8, *71—79*. Wrocław.

— (1967): Kvartérně geologické poměry východního Polabí. — Sbor. geol. Věd, Antropozoikum, 4, *97—124*. Praha.

Selley R. C. (1976): An introduction to sedimentology. — *1—488*, Academic Press. London.

Seneš J. et al. (1975): Regional stages of the Central Paratethys Neogene and the definition of their lower boundaries. — Proc. of 6th Congr. RCMNC, vol. I., *259—266*, Veda. Bratislava.

Šibrava V. (1965): Vysvětlující text ke kvartéru na geologické mapě 1 : 200 000 list M-33-VIII (Chabařovice—Dresden) a M-33-IX (Děčín—Görlitz). — MS Geofond. Praha.

— (1967): Study of the Pleistocene of the glaciated and non-glaciated areas of the Bohemian Massif. — Sbor. geol. Věd, Antropozoikum, 4, *7—38*. Praha.

— (1972): Zur Stellung der Tschechoslowakei im Korrelierungssystem des Pleistozäns in Europa. — Sbor. geol. Věd, Antropozoikum, 8, *1—218*. Praha.

— (1974): K problematice hranice pliocén—pleistocén a její pozici na území Československa. — Sbor. geol. Věd, Antropozoikum, 10, *7—21*. Praha.

Šibrava V. (1981): Neotectonic activity and volcanism in the marginal areas of inland glaciations in the Bohemian Massif. — Rep. 6 Sess. Project 73/1/24 IGCP, Ostrava, Czechosl., August 16—25, 1979, *219—225*. Praha.

Šibrava V. et al. (1979): Erforschung der Pleistozänablagerungen auf dem Hügel Zlatý kopec bei Přezletice (NO-Rand von Prag), I. Teil. — Sbor. geol. Věd, Antropozoikum, 12, *57—146*. Praha.

Šibrava V. - Havlíček P. (1980): Radiometric age of Pliocene—Pleistocene volcanic rocks of the Bohemian Massif. — Věst. Ústř. Úst. geol., 55, 3, *129—139*. Praha.

Šibrava V. - Václ J. (1962): Nové důkazy kontinentálního zalednění severních Čech. — Anthropozoikum, 11, *85—91*. Praha.

Skácel J. (1966): Železnorudná ložiska moravskoslezského devonu. — Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 76, 11, *1—59*. Praha.
— (1970): Geologie předkvartérních útvarů v Osoblažském výběžku. — Sbor. Prací Univ. Palackého, Geogr. Geol., 29, 10, *131—148*. Olomouc.

Skoček V. (1976): Regional and geological interpretation of organic matter coalification in the late Palaeozoic sediments of the Bohemian Massif. — Věst. Ústř. Úst. geol., 1, *13—25*. Praha.
— (1980): Nové poznatky o litologii devonských bazálních klastik na Moravě. — Věst. Ústř. Úst. geol., 55, 1, *27—37*. Praha.

Škvor V. (1970): Metamorphic processes in the Bohemian Massif. — Geol. Soc. Amer. Bull., 81, *955—960*. New York.
— (1975): Geologie české části Krušných hor a Smrčin. — Knih. Ústř. Úst. geol., 48, *1—120*. Praha.

Slavík F. (1930): Prehnit z podloží naftonosného neogénu gbelského. — Příroda, 23. Brno.

Šmejkal V. - Vejnar Z. (1965): Zur Frage der prävariszischen Alters einiger Granitoide des Böhmischen Massivs. *In:* Geochemie v Československu. — Sbor. prací 1. geochem. konf., *123—128*. Ostrava.

Šmíd B. (1962): Přehled geologie a petrografie hornin těšinitické formace na severním úpatí Beskyd. — Geol. Práce, Zoš., 63, *53—60*. Bratislava.

Smolíková L. - Kovanda J. (1979): K vývoji holocénu v Českém krasu. — Sbor. geol. Věd, Antropozoikum, 12, *163—186*. Praha.
— (1983): Die Bedeutung der pleistozänen Sedimente des Fundortes Růženin Dvůr (Brno - Židenice II) für die Stratigraphie des Brno-Beckens. — Sbor. geol. Věd, Antropozoikum, 15, *9—38*. Praha.

Smolíková L. - Zeman A. (1982): Bedeutung der Ferretto-Böden für die Quartärstratigraphie. — Sbor. geol. Věd, Antropozoikum, 14, *57—93*. Praha.

Souček J. (1974): Styk červenského granodioritu s moldanubikem. — Čas. Mineral. Geol., 19, 1, *47—60*. Praha.

Soukup J. (1956): Stratigrafie rozdělení křídy Českého masivu. — Věst. Ústř. Úst. geol., 31, 4, *173—180*. Praha.

Soukup J. (1968): *In:* I. Chlupáč et al.: Lexique stratigraphique international I, Europe, 6b 1, Massif de Bohême. — CNRS Paris.

Spencer E. M. (1974): Mesozoic—Cenozoic orogenic belts. Data for orogenic studies. — *1—120*, Geol. Soc. London, Scot. Acad. Press. Edinburgh.

Steinocher V. (1960): Látkové složení, provinciální charakter a petrogeneze středočeského plutonu. — Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 79, 1. Praha.

Stejskal J. (1925): Geologické poměry v oblasti mezi Bory a Velkým Meziříčím. — Práce Morav. přírodověd. Společ., 2, 9, *223—270*. Brno.

Štelcl J. (1960): Petrografie kulmských slepenců v jižní části Drahanské vysočiny. — Folia. Univ. Purkyn. brun., Geol., 1, *1—103*. Brno.
— (1963): Brněnský masív v geologické literatuře od r. 1801. — Folia Univ. Purkyn. brun., Geol., 4, 5, *43—81*. Brno.
— (1968): Über die Sillimanit-Andalusit-Disthen-Paragenese im Hohen Gesenke. — Freiberg. Forsch.-H., R. C, 231, 2, *135—141*. Freiberg.
— (1969): Petrografie paleozoických slepenců na střední Moravě. — Folia Univ. Purkyn. brun., Geol., 19, *1—90*. Brno.
— (1975): Výsledky geologického a petrografického výzkumu brněnského masívu za léta 1974—1975. — MS Geofond. Praha.

Štelcl J. et al. (1973): Výsledky geologického a petrografického výzkumu brněnského masívu za léta 1971—1973. — MS Geofond. Praha.
— (1976): Souborná zpráva o výzkumu brněnského masívu v letech 1973—1975. — MS Geofond. Praha.

Štelcl J. - Weiss J. (1976): Explanatory text to the Map of metamorphic structure at the contact between the Bohemian Massif and West Carpathians. — Acta Geol. Acad. Sci. hung., 20. Budapest.
— (1978): K problematike korreljacii metamorfičeskogo kontakta Češskogo massiva i Karpat. — Scr. Univ. Purkyn. brun., Geol., 8, *3—9*. Brno.

Stettner F. (1974): Probleme des Bayerischen Präkambriums. *In:* Précambrien des zones mobiles de l'Europe. *109—120*. — Geol. úst. ČSAV. Praha.

Stille H. (1948): Die assyntische Ära und der vor-, mit- und nachassyntische Magmatismus. — Z. Dtsch. geol. Gesell., 98, *152—165*. Berlin.
— (1949): Die kaledonische Faltung Mitteleuropas im Bilde der gesamteuropäischen. — Z. Dtsch. geol. Gesell., 100, *223—266*. Berlin.
— (1951): Das mitteleuropäische variszische Grundgebirge im Bilde des gesamteuropäischen. — Geol. Jb., Beih., 2, 138. Hannover.

Störr M. - Kužvart M. - Neužil J. (1978): Genesis of the weathering crust of the Bohemian Massif. — Schr.-Reihe geol. Wiss., 11, *265—281*. Berlin.

Suk M. (1964): Material characteristics of the metamorphism and migmatization of Moldanubian paragneisses in Central Bohemia. — Krystalinikum, 2, *71—105*. Praha.
— (1969): K problému mapování metamorfních zón v Českém masívu. — Věst. Ústř. Úst. geol., 44, 4, *209—218*. Praha.

Suk M. (1971): Petrochemistry of Moldanubian amphibolites. — Geochemie, 1, *9—57*. Praha.

— (1974): Lithology of Moldanubian metamorphics. — Čas. Mineral. Geol., 19, 4, *374—388*. Praha.

— (1979): Hauptprobleme des tiefen Unterbaues der Böhmischen Masse. — Krystalinikum, 14, *109—118*. Praha.

Suk M. et al. (1975): Vysvětlivky k základní geologické mapě ČSSR 1 : 25 000 list 22-243 Bernartice. — MS Ústř. úst. geol. Praha.

Suk M. - Weiss J. (1976): Problems of interpreting the deep structures of the plutonic bodies in the Moldanubicum. — Věst. Ústř. Úst. geol., 51, *1—11*. Praha.

— (1981): Geological sections through the Variscan orogen in the Bohemian Massif. — Geol. en Mijnb., 60, *161—168*. Amsterdam.

Svoboda J. (1931): Geologicko-petrografické poměry metamorfovaného ostrova sedlčansko-krásnohorského. — Věst. St. geol. Úst. Čs. Republ., 7, *141—152*. Praha.

— (1933): Metamorfovaný ostrov sedlčansko-krásnohorský. — Arch. přírodověd. Prozk. Čech, 18, 4, *1—62*. Praha.

— (1956): Příspěvek k paleogeografii siluru v Českém masívu. — Věst. Ústř. Úst. geol., 31, 2, *120—127*. Praha.

Svoboda J. et al. (1966): Regional geology of Czechoslovakia, Part I, The Bohemian Massif. — Ústř. Úst. geol., Academia. Praha.

Svoboda J. - Fiala F. (1957): Geologicko-petrografické poměry algonkia mezi Telčicemi a Týncem n. L. v Železných horách. — Sbor. Ústř. Úst. geol., Odd. geol., 23, *475—531*. Praha.

Szabó P. Z. (1958): Kras v jižním Maďarsku. — Čs. Kras, 11, *145—156*. Praha.

Tásler R. (1979): Geologie české části vnitrosudetské pánve. — Ústř. úst. geol. Praha.

Tásler R. - Valín F. (1982): Lithofazielle Korrelation des oberen Stefans und Autuns im Innersudetischen Becken und im Krkonoše-Vorlandbecken. — Věst. Ústř. Úst. geol., 57, 1, *81—94*. Praha.

Thiele O. (1962): Neue geologische Ergebnisse aus dem Sauwald (O.-Ö). — Jb. Geol. Bundesanst., 1, *117—129*. Wien.

— (1971): Ein westvergenter kaledonischer Deckenbau im niederösterreichischen Waldviertel? — Jb. Geol. Bundesanst., 119, *75—81*. Wien.

Thurm H. - Bankwitz P. - Bankwitz E. - Harnish G. (1977): Rezente horizontale Deformationen der Erdkruste im Südostteil der Deutschen Demokratischen Republik. — Petermanns geogr. Mitt., 4, *281—304*. Gotha.

Tomek Č. (1978): Are there light granites below the Paleozoic Barrandian basin? — Čas. Mineral. Geol., 23, 3, *283—286*. Praha.

Tomek Č. - Švancara J. - Budík L. (1979): The depth and the origin of the West Carpathian gravity low. — Earth planet. Sci. Lett., 44, 1, *39—42*. Amsterdam.

Tomšík I. (1972): Petrografie a chemické složení metamorfitů z podloží čs. části hornoslezské pánve. — Čas. Mineral. Geol., 17, 2, *147—162*. Praha.

Tonika J. (1978): The Mutěnín ferrodiorite ring intrusion, West Bohemia. — Krystalinikum, 14, *195—208*. Praha.

Tonika J. - Vejnar Z. (1966): Geologie a petrografie stodského masívu. — Čas. Mineral. Geol., 11, 2, *129—137*. Praha.

Turnovec I. (1980): K otázce stáří krasových jevů v Barrandienu. — Čes. Kras, 5. *44—46*. Beroun.

Tyczyńska M. (1958): A Pre-Tortonian karst surface in the vicinity of Cracow. — Bull. Acad. pol. Sci., Sér. Sci. géol. géogr., 6, 6, *399—401*. Warszawa.

Tyráček J. (1961a): Survey of Czechoslovak Quaternary: River terraces in the Carpathian region. — Prace Inst. geol., 34, Czwart. Eur. środk. i wschod., I, *71—76*. Warszawa.

— (1961b): Geologické poměry pleistocenních travertinů v Kokorách u Přerova. — Anthropozoikum, 9, *87—105*. Praha.

— (1961c): Nové názory na rozšíření maximálního zalednění v Moravské bráně. — Přírodověd. Čas. slez., 2, *247—254*. Opava.

— (1962): Fosilní kuželový kras u Hranic na Moravě. — Čas. Mineral. Geol., 2, 2, *176—185*. Praha.

— (1963): On the problem of the parallelization of the continental and the alpine glaciation on the territory of Czechoslovakia. — Rep. of the 6th Int. Congr. Quaternary, Warszaw, Vol. III, Geomorph. sect., *375—384*. Łódź.

Udovkina N. L. - Dudek A. - Lang M. (1977): Eklogity Češskogo Massiva i metamorfičeskich tolšč SSSR. *In:* Opyt korreljacii magmatičeskich i metamorfičeskich porod, *101—117*. — Nauka. Moskva.

Ulrych J. et al. (1976): Petrology of the Petrovice melagabbro. — Rozpr. Čs. Akad. Věd, R. mat. přír. Věd, 86, 9. Praha.

Urban L. (1972): Stratigrafické poměry krystalinika v okolí Licoměřic v Železných horách. — Sbor. geol. Věd, Geol., 23, *75—112*. Praha.

Vachtl J. (1952): K otázce stáří a geneze tzv. oligocenních křemenců v okolí Mostu v severozápadních Čechách. — Sbor. Ústř. Úst. geol., Odd. geol., 19, *213—271*. Praha.

— (1965): Podloží střední části české křídy (vých. od Labe). — Sbor. geol. Věd, Geol., 9. *119—134*. Praha.

— (1971): Acid volcanic rocks of the Vítanov Group (Železné hory Mountains). — Acta Univ. Carol., Geol., 1—2. *139—174*. Praha.

— (1974): Der Übergang von der Geosynklinal- in die Plattformentwicklung. — Sbor. geol. Věd, Geol., 26, *45—55*. Praha.

Václ J. (1964): Hrádecká část žitavské pánve (s relikty terciéru na Liberecku a Frýdlantsku). *In:* J. Svoboda et al.: Regionální geologie ČSSR, I/2, *354—361*. — Ústř. úst. geol. Praha.

— (1977): Chebská pánev — současný stav litostratigrafického a tektonického rozboru třetihorních usazenin. — Sbor. 8. celostátní paleontologické konference v Sokolově 1977. *1—5*. Sokolov.

Václ J. - Čadek J. (1962): Geologická stavba hrádecké části Žitavské pánve. — Sbor. Ústř. Úst. geol., Odd. geol., 27, *331—383*. Praha.

Václ J. - Malkovský M. (1962): Geologie Žatecka. — Sbor. Ústř. Úst. geol., Odd. geol., 27, *201—330*. Praha.

Vajner V. (1963): Geologické poměry metamorfovaného ostrova tehovského. — Sbor. Ústř. Úst. geol., Odd. geol., 28, *231—264*. Praha.

Van Hinte J. E. (1976): A Cretaceous time scale. — Bull. Amer. Assoc. Petrol. Geol., 60, *498—516*. Tulsa.

Vašíček Z. (1977): Zu den Unterkreide-Vertretern der Gattung Inoceramus in der schlesischen Einheit (äußere Karpaten, Tschechoslovakei). — Čas. Slez. Muz., Vědy přír., 26, 1, *55—62*. Opava.

Vejnar Z. (1966a): The petrogenetic interpretation of kyanite, sillimanite and andalusite in the SW Bohemian crystalline complexes. — Neu. Jb. Mineral, Abh., 104, 2, *172—189*. Stuttgart.

— (1966b): Peridotites and serpentinites of the Český les Mountains. — Krystalinikum, 4, *163—169*. Praha.

— (1968): Interrelations between the Monotonous and the Varied Groups of the West Bohemian Moldanubicum. — Věst. Ústř. Úst. geol., 43, *207—211*. Praha.

— (1971): Grundfragen des Moldanubikums und seine Stellung in der Böhmischen Masse. — Geol. Rdsch., 60, *1455—1465*. Stuttgart.

— (1972): Regionally metamorphosed volcanic rocks from the West-Bohemian metabasite belt. — Krystalinikum, 8, *131—156*. Praha.

— (1973): Petrochemistry of the Central Bohemian Pluton. — Geochemie, 2, *1—116*. Praha.

— (1975): Highly ferrous silicates from the Mutěnín ferrodiorite ring intrusion, West Bohemia. — Věst. Ústř. Úst. geol., 50, 5, *265—273*. Praha.

— (1981): Problém izográd v metapelitech domažlické oblasti. — Věst. Ústř. Úst. geol., 56, *245—247*. Praha.

— (1982): Regionální metamorfóza psamiticko-pelitických hornin domažlické oblasti. — Sbor. geol. Věd, Geol., 37, *9—70*. Praha.

Vejnar Z. - Zoubek V. et al. (1962): Vysvětlivky k přehledné geologické mapě ČSSR 1 : 200 000 M-33-XIX Mariánské Lázně a M-33-XXV Švarcava. — Ústř. úst. geol. Praha.

Veselá M. (1976): Jihlavská brázda ve vývoji geologické stavby okolí Jihlavy. — Sbor. geol. Věd, Geol., 28, *200—202*. Praha.

— (1967): On the stratigraphical position of granulites in the Moldanubicum. — Krystalinikum, 5, *137—152*. Praha.

Vidal P. - Auvray B. - Charlot R. - Fediuk F. - Hameurt J. - Waldhausrová J. (1975): Radiometric age of volcanics of the Cambrian "Křivoklát—Rokycany" complex (Bohemian Massif). — Geol. Rdsch., 64, 2, *563—570*. Stuttgart.

Vinogradov A. P. - Tugarinov A. I. - Zykov S. P. - Knorre K. G. - Stenko V. A. - Lebedev V. I. (1962): Über das Alter der kristallinen Gesteine Zentraleuropas. — Freiberg. Forsch.-H., 124, *39—56*. Freiberg.

Vlašímský P. (1973): Pně bazických a tonalitových hornin v exokontaktní zóně středočeského plutonu na Příbramsku. — Acta Univ. Carol., Geol., 3, *179—195*. Praha.

Vrána S. (1963): Anthofylitické horniny okolí Žárovné v jižních Čechách. — Sbor. Ústř. Úst. geol., Odd. geol., 28, *7—30*. Praha.

— (1977): Find of a polymict metaconglomerate on the Moldanubicum of southern Bohemia. — Věst. Ústř. Úst. geol., 52, 2, *65—71*. Praha.

— (1979): Polyphase shear folding and thrusting in the Moldanubicum of southern Bohemia. — Věst. Ústř. Úst. geol., 54, 2, *75—86*. Praha.

— (1982): Petrochemistry and relict textures of quartz keratophyre pebbles from a Moldanubian metaconglomerate in southern Bohemia. — Čas. Mineral. Geol., 27, 1, *11—23*. Praha.

Vrána S. - Cháb J. (1981): Metatonalite-metaconglomerate relation: the problem of the Upper Proterozoic sequence and its basement in the NE part of the Central Bohemian Pluton. — Sbor. geol. Věd, Geol., 35, *145—187*. Praha.

Vyskočil P. (1972): Recentní pohyby zemské kůry na území Českého masívu. — MS Výzk. úst. geod. Praha.

Vyskočil P. - Kopecký A. (1974): Neotectonics and recent crustal movements in the Bohemian Massif. — Výzk. úst. geodet. topogr. kartogr. Praha.

Vyskočil P. - Zeman A. (1980): Problematika a dosavadní výsledky studií recentních pohybů zemského povrchu na styku Českého masívu a Karpat. — Čas. Mineral. Geol., 25, 4, *389—407*. Praha.

Waldhauserová J. (1971): The chemistry of the Cambrian volcanics in the Barrandian area. — Krystalinikum, 8, *45—75*. Praha.

Waldmann L. (1927): Zum geologischen Bau des moldanubischen Grundgebirges auf dem Kartenblatte Gmünd—Litschau, IV. Teil. — Anz. Öster. Akad. Wiss., 64, *153—155*. Wien

Watznauer A. (1968): Das Kristallin am Nordrand der Böhmischen Masse und seine Beziehungen zum Moldanubikum im Süden und skandinavischen Kristallin im Norden. — Geologie, 17, 6/7, *695—702*. Berlin.

Weiss J. (1977): Fundament moravského bloku ve stavbě evropské platformy. — Folia Univ. Purkyn. brun., Geol., 18, 13, *5—64*. Brno.

Weithofer K. A. (1897): Zur stratigraphischen Gliederung der mittelböhmischen Steinkohlenablagerungen. — Verh. K-Kön. geol. Reichsanst., 16, *317—320*. Wien.

— (1902): Geologische Skizze des Kladno-Rakonitzer Kohlenbeckens. — Verh. K-Kön. geol. Reichsanst., 17—18, *399—420*. Wien.

Wieseneder H. - Freilinger G. - Kittler G. - Tsambaurakis G. (1976): Der kristalline Untergrund der Nordalpen in Österreich. — Geol. Rdsch., 65, 2, *512—525*. Stuttgart.

Zahálka B. (1924): Oblasti české křídy. — Čas. Mineral. Geol., 1 (1923—1924), *13—15, 39—45, 99—101, 136—143*. Praha.

Zahálka Č. (1893): Stratigrafie útvaru křídového v okolí Řípu. Pásmo IV - Dřínovské. Pásmo V - Roudnické. — Zpr. stř. hospod. školy v Roudnici za šk. rok 1892—1893.

Žakova H. (1963): Stratygrafia i zasięgi facjalne dolnego karbonu w Sudetach. — Kwart. geol., 7, 1, *73—94*. Warszawa.

Zapletal K. (1926): Geologie středu svratské klenby. — Sbor. St. geol. Úst. Čs. republ., *509—560*. Praha.

— (1933): Vznik a vývoj Tišnovska. — Vlastivěda Tišnovska, *5—44*. Tišnov.

— (1957): Zur Geologie der Sudeten und Umgebung, des oberschlesischen Kohlenbeckens, der Westkarpaten und des Vorlandes. — Spisy přírodověd. Fak. Masaryk. Univ., Ř. G, 7, *1—386*. Brno.

Záruba Q. - Bucha V. - Ložek V. (1977): Significance of the Vltava terrace system for Quaternary chronostratigraphy. — Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 87, 4, *90* pp. Praha.

Zátopek A. (1979): On geodynamical aspects of geophysical synthesis in Central Europe. *In:* Geodynamic investigations in Czechoslovakia, *91—104*. — Veda. Bratislava.

Zázvorka V. (1928): Předběžná zpráva o nálezu křídových hornin v dole Mayrau u Kladna. — Čas. Nár. Muz., Odd. přírodověd., 102, *165—168*. Praha.

Žebera K. (1956): Fluviální štěrkopísky na území speciální mapy list Hradec Králové—Pardubice. — Anthropozoikum, 5, *381—384*. Praha.

— (1958): Československo ve starší době kamenné. — Academia. Praha.

— (1967a): Kvartér Podřipska, I. — Sbor. geol. Věd, Antropozoikum, 4, *71—96*. Praha.

— (1967b): Moldavite-bearing sediments between Koroseky and Holubov in South Bohemia. — Věst. Ústř. Úst. geol., 42, 5, *327—337*. Praha.

— (1972): Kvartér Podřipska, II. — Sbor. geol. Věd, Antropozoikum, 6, *7—34*. Praha.

— (1974): Kvartér Podřipska, III. — Sbor. geol. Věd, Antropozoikum, 10, *23—40*. Praha.

Žebera K. - Puchmajerová M. (1958): Riss-würmská slatina (gyttja) z Královéhradecka ve východních Čechách. — Anthropozoikum, 7, *151—156*. Praha.

Zelenka L. (1925): Geologické studie z Českomoravské vysočiny. — Sbor. St. geol. Úst. Čs. Republ., 5, *561—585*. Praha.

— (1929): Příspěvky k tektonice středních a jihovýchodních Čech, I. — Věst. St. geol. Úst. Čs. Republ., 5, 2—3, *1—23*. Praha.

Zeman A. (1967): Kvartérní neotektonické fáze ve východní části Vyškovského úvalu. — Věst. Ústř. Úst. geol., 42, 2, *105—110*. Praha.

— (1969): Příspěvek k poznání kvartéru a neotektoniky v jz. okolí Prostějova. — Zpr. Geogr. Úst. ČSAV, 6, *1—7*. Brno.

— (1971): Pleistocenní fluviolakustrinní a fluviální sedimenty v jižní části Hornomoravského úvalu. — Věst. Ústř. Úst. geol., 46, 1, *19—30*. Praha.

— (1974): Quaternary of the surroundings of Stránská skála. — Sbor. geol. Věd, Antropozoikum, 10, *41—72*. Praha.

— (1980): Předmiocenní reliéf a zvětraliny v oblasti karpatské předhlubně a moravských Karpat při vyhledávání ložisek nafty a plynu. — Věst. Ústř. Úst. geol., 55, 6, *357—366*. Praha

Zeman A. - Havlíček P. - Minaříková D. - Růžička M. - Fejfar O. (1980): Kvartérní sedimenty střední Moravy. — Sbor. geol. Věd, Antropozoikum, 13, *37—91*. Praha.

Zeman J. (1978): Deep-seated fault structures in the Bohemian Massif. — Sbor. geol. Věd, Geol., 31, *155—185*. Praha.

— (1979): The influence of paleorifts on the development of continental crust in the Bohemian Massif. *In:* Czechosl. geology and global tectonics, *57—75*. — Veda. Bratislava.

Zemánek V. (1967): Interpretace magnetických anomálií v humpolecké a obrataňské oblasti moldanubika. — Sbor. geol. Věd, užitá Geofyz., 6, *125—153*. Praha.

Zikmund J. (1971): Geologie a petrografie pararulových sérií severní části moldanubika — Sbor. geol. Věd, Geol., 21, *7—36*. Praha.

Zikmundová J. (1964): Nálezy konodontů v devonu Ještědského pohoří. — Věst. Ústř. Úst. geol., 39, 6, *455—457*. Praha.

— (1967): Konodontová zóna Scaliognathus anchoralis Branson et Mehl v ponikevských břidlicích Nízkého Jeseníku. — Věst. Ústř. Úst. geol., 42, 6, *449—451*. Praha.

— (1976): Biostratigrafie paleozoika v podkladu a předpolí Karpat východně od Brna. — Čas. Mineral. Geol., 21, 4, *369—385*. Praha.

Zikmundová J. - Holub V. (1965): Valouny silurských a devonských vápenců v permokarbonu na Mladoboleslavsku. — Věst. Ústř. Úst. geol., 40, 3, *185—187*. Praha.

Zoubek V. (1927): Le métamorphisme d'injection et le métamorphisme de contact dans les environs de Pelhřimov. — Sbor. St. geol. Úst. Čs. Republ., 7, *366—412*. Praha.

— (1946): Příspěvky ke stratigrafii krystalinika Českého masívu I., II. — Sbor. St. geol. Úst. Čs. Republ., 13, *463—498*. Praha.

— (1948): Poznámky ke geologii krystalinika Českého masívu. — Sbor. St. geol. Úst. Čs. Republ., 15, *339—398*. Praha.

— (1951): Předběžná zpráva o geologických a petrografických poměrech netolické oblasti. — Věst. Ústř. Úst. geol., 26, *155—162*. Praha.

— (1965): Moldanubikum und seine Stellung im geologischen Bau Europas. — Freiberg. Forsch.-H., 190, *129—148*. Freiberg.

— (1967): Některé kritické problémy krystalinika Českého masívu. — Čas. Mineral. Geol., 12, 2, *151—155*. Praha.

— (1968): Einige Hauptmerkmale und Probleme des Präkambriums der Böhmischen Masse und der Westkarpaten im gegenseitigen Vergleich. — Mitt. Geol. Gesell., 60, *97—108*. Wien.

— (1972): Quelques problèmes et résultats de la corrélation géologique du socle précambrien de l'Europe varisque et alpine. — Notes Mém., Serv. géol. (Rabat), 236, Coll. int. CNRS 192, *177—192*. Rabat.

— (1974): Remarques sur le Précambrien des zones mobiles de l'Europe Centrale et occidentale. *In:* Précambrien des zones de l'Europe, *33—62*. — Geol. úst. ČSAV. Praha.

— (1975): Moldanubikum und seine Stellung im geologischen Bau Europas. — Freiberg. Forsch.-H., R. C, 190, *129—148*.

— (1976): Prekambrium v evropských variscidách. *In:* Korelace proterozoických a paleozoických stratiformních ložisek, 4, *7—25*. — Přírodověd. fak. Univ. Karl. Praha.

Zoubek V. (1977): Remarks to the problem of subdivision of the Precambrian. — Symposium Correlation Precambrian, 1, 62—93. Nauka. Moskva.

— (1980): On the recent state of research of the Precambrian in the European Variscides. — IGCP Proj. 22, Ann. Inst. Geol. Geogr., 5, 57, 57—99. București.

Zoubek V. - Škvor V. et al. (1963): Vysvětlivky k přehledné geologické mapě 1 : 200 000 M-33-XIV Teplice, M-33-VII Chabařovice. — Ústř. úst. geol. Praha.

Zoubek V. - Vyskočil V. (1971): Anomální tíhové pole ve vztahu ke geologickým strukturám v oblasti střední Evropy. *In:* Výzkum hlubinné geologické stavby Československa, 97—133. — MS Geofyzika. Brno.

Zukalová V. (1976): Biostratigrafie paleozoika v podkladu a předpolí Karpat východně od Brna. — Čas. Mineral. Geol., 21, 4, 369—385. Praha.

Zukalová V. - Chlupáč I. (1982): Stratigrafická klasifikace nemetamorfovaného devonu moravskoslezské oblasti. — Čas. Mineral. Geol., 27, 3, 225—241. Praha.

Zukalová V. - Skoček V. (1979): Mass extinction of organisms and lithologic boundaries in the Palaeozoic sediments in Moravia, Czechoslovakia. — Věst. Ústř. Úst. geol., 54, 2, 129—142. Praha.

Zwart H. J. (1969): The duality of orogenic belts. — Geol. en Mijnb., 46, 283—309. Den Haag.

— (1976): Regional metamorphism in the Variscan orogeny of Europe. — Nova Acta leopold., 224, 45. 361—367. Halle.

Zwart H. J. - Dornsiepen U. F. (1980): The Variscan and pre-Variscan tectonic evolution of Central and Western Europe, a tentative model. *In:* Géologie de l'Europe. — Mém. Bur. Rech. géol. min., 108, 226—246. Orléans.

Photographs on cover

Peat moor Hájek near Františkovy Lázně. Nature reserve — Photo by B. Landisch

A mud pot. Hájek near Františkovy Lázně. West Bohemia — Photo by B. Landisch

Small trilobites *Ellipsocephalus hoffi* (Schlotheim) from Middle Cambrian of the Brdy area, Jince Formation, Koníček near Jince — Photo by B. Matoulková

A silicite rock (chert) west of Starý Plzenec. Upper Proterozoic of the Barrandian — Photo by J. Svoboda

Husova kazatelna rock at Bratřejov near Petrovice. Central Bohemian pluton — Photo by J. Svoboda

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Explanation of photographs

page 2 : Stalagmite in Domica cave (Slovakia) — Photo by V. Mlýnek

page 6 : Satellite image of the Czech Socialist Republic — Archive ČHMÚ Praha - Libuš

page 397 : Historical gallery in Jáchymov mining area (West Bohemia) — Photo by V. Mlýnek